Long-term assessment of a multi-unit reservoir system operation: the *ShellDP* programme package manual

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FOREWORD

Population growth, improved standard of living and the inherent requirement of adequate and secure food supply all imply increasing water demands. Deterioration of the quality of water and anticipated climate changes further increase the stress on the limited resources of fresh water. Regions with semi arid climate are among the first to experience prolonged water shortage with unavoidable consequences on socioeconomic activities. Water resources management under these circumstances calls for the mobilization of untapped reserves and for the improvement of the spatial and temporal availability of water.

Through the centuries of human civilization both storage reservoirs and water transfer facilities have proven their viability and sustainability to help resources and demands match. The spatial variability of surface water resources and that of the potential dam sites implies that water reserves of a region can be best captured and stored at multiple sites. Likewise, demand centres (municipalities, industries, irrigated areas) also spread over considerable area, usually far from the potential source of water. Consequently the water resources management problem can be conceived as to find the appropriate linkage of resource and demand centres and to schedule the water deliveries in a "best possible" manner. While for the first glance this seems to be an operational problem, its implications at the planning stage are manyfold. Necessary size and location of reservoirs, as well as the ideal time point to become operational all depend on the anticipated operational performance of the future multiunit water resources system. The physical layout and dimensions of transfer canals and pipelines can be best determined by simulating the operation and water distribution within the system.

This practical problem has several scientifically very challenging aspects. The use of optimization techniques to find the "best possible" solution is seriously hampered by the dimensionality of a multiunit system. Furthermore, the definition of the "best possible", or optimal solution itself deserves particular attention especially in case of multiple conflicting water utilizations and concerning users. Last, but not least the uncertainty inherent in the resource occurrence should be appropriately addressed. Finally even the most convincing scientific solution of a technical problem must surmount the obstacle of acceptance, i.e. will it be applied in the practice or not?

When presenting the Manual of the EAU2000 Shell water resources management model (***ShellDP***), we can claim to have developed a multiunit reservoir operational and water allocation model decomposing a complex system into single unit subsystems. Sequential, iterative solutions of individual reservoir optimizations enable the application for the stochastic dynamic programming with considerable refinement in reservoir state space and inflow discretizations. Thus the resource uncertainty is taken into account while deriving robust, expectation oriented operation rules. The choice of different objective functions and subsequent simulation modes facilitate the assessment of the reservoir system performance for different system configurations and water allocation patterns.

The present model has successfully been applied as planning tool in a national water resources master plan of a semi-arid country where a 14-reservoir-strong interconnected multibasin system is envisaged to form the backbone of the interregional water supply system. While the Manual presented in this report refers to the "planning tool" version, the potential of the EAU2000 Shell model to be used in on-line operation of a complex water resources system is obvious.

The EAU2000 Shell model has been developed at the Department of Water Resources of the Wageningen Agricultural University in collaboration with Agrar-und Hydrotechnik (AHT) GmbH Consulting Engineers, Essen, Germany. This stimulating cooperation helped us to safeguard the practical relevance of the model. The support and professional involvement of Messrs. Dr.-Ing. Günter Keser and Dr.-Ing. Wolfgang Bogacki of AHT was not only a steady source of inspiration but through their suggestions they also contributed to this Manual.

Next to them the authors are also indebted to Mr. Abdel Ghany of Egypt, Miss Emese Horváth, Mr. Tomás Dudás of Hungary and Mrs. H.K. Ampitiya of Sri Lanka who, as graduate students at the Department of Water Resources have used the manuscript of this Manual in their respective thesis work. Their experience and comments as first users have been incorporated in the final version.

Water resources management models are the result of joint efforts as duly reflected in this case by the number of authors. While the term "final version" has been used this could not prevent these models to undergo steady development as new applications emerge, or scientific results and computational refinements become available.

While this Manual presents EAU2000 Shell models as a planning tool, the authors acknowledge their ongoing efforts to develop an operational version along with modified water allocation procedures among competing water users. These developments are expected to result at a later stage in a new, refined release of the planning version itself.

Suggestions of the users of this Manual towards this end will be highly appreciated.

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LP	linear programming
DP	dynamic programming
NLP	nonlinear programming
SDP	stochastic dynamic programming
DDP	deterministic dynamic programming
t	stage
s_t	system state at the stage t
x_t	decision taken at the stage t
C_{s,x_t}	costs or contribution of the decision x_t give state s at the actual stage
$f^*_{t+1}(s_{t+1})$	accumulated sub-optimal costs (or contribution) for the following stages $t+1, t+2, ..., N$, where N stands for the total number of stages to be considered
$f^*_t(s_t)$	accumulated sub-optimal costs (or contribution) for the following stages and including the present one ($t, t+1, ..., N$), where N stands for the total number of stages to be considered
m	number of possible system's state transitions
$p^t_{ij}(k)$	probability of the system transition from state s_i to s_j at stage t, given the decision k is taken
$C(s_i,s_j,k)$	the costs (or contribution) generated during stage t, given the decision k and the system transition from s_i to s_j

$f^*_{t+1}(s_j)$	sub-optimal costs (or contribution) generated and summarized through the following stages $t+1$, $t+2$, ..., N
$f^*_t(s_i)$	sub-optimal costs (or contribution) generated and summarized for the following stages and including the present one (t, $t+1$, ..., N)
p^t_{ij}	probability of occurrence of the streamflow class j in month $t+1$, given the streamflow state i has occurred in month t
NS	number of storage representative discrete values
OF	objective function
SRS	Single reservoir System
MRS	Multi-Unit Reservoir System
SSD	Single Supplied Demands
MSD	Multiple Supplied Demands
DRD	Downstream Reservoir Deficit
INF	inflow
TAD	total annual demand
AMF	annual median (or mean) inflow
DD	distributed demand
UF	useful flow
AUF	average useful flow
RD	reservoir supply deficit

ARD	average reservoir supply deficit
DRS	downstream reservoir supply
DRES	downstream reservoir extra supply
FDF	free downstream flow
WTSC	water transfer structure capacity
BH, BM, KA, ME, SS	reservoir names
TU, BE, JE, MB, NA, MO, SO, SF	municipal water demands
TO	water demands of tourist areas
IBH, INE, IAEA, IBV, IMSC	irrigation water demands
DBH, DBM, DKA, DME, DSS	reservoir supply deficits

1 INTRODUCTION

As a basic component of the hydrological cycle, water can be classified as a renewable resource. Water resources, with respect to actual or foreseen demands, can be defined as the spatial and temporal disposition of available water with a certain potential to be allocated for human consumption, industrial use, irrigation, etc. The continuing growth of human population, together with the rapid industrial development, and the inherent expansion of the demand for more efficient agricultural production necessitate more complex and consistent water resources management. However, both competing demands and uncontrolled use, along with the pollution of water have resulted in the fact that water has become a scarce resource. The increasing scope and complexity of water resources management, a compound of different scientific, engineering, and social disciplines, can be subdivided into several major activities that are vital for a consistent management of water resources [*Bogardi,* 1991]: assessment, planning, design, implementation, operation, and maintenance. The operation stage concerns all the aspects of system performance, including the development and application of systems analysis methods for deriving the operational rules for the chosen system configuration. In fact, a simplified consideration of the operation with the inherent performance assessment must be considered already at the planning stage.

Systems analysis can generally be defined as a group of methods developed for identifying, describing, and screening of a system, its performance and behaviour under different conditions and with different goals to be pursued. It provides the decision maker with a broad information base about the system and gives the opportunity of estimating the system behaviour to compare several feasible alternatives. A variety of initial assumptions, objectives, constraints, and decision variables can be specified and their influence on the system operation evaluated. Hence, systems analysis techniques can be very valuable tools for solving planning and operation tasks in water resources management.

Together with the determination of the physical elements of the system, operation policy of the system is equally important in order to find the best performance of the system to serve its purpose. Operation policy of a water resource system can be defined on a short-term or a long-term time base. This classification implies not only the time base (e.g., hourly or daily for short-term and monthly or seasonal time steps for long-term operation) but the uncertainty of the system and its components. For a short-term operation uncertainty may be neglected, and all the phenomena can be considered as deterministic ones. However, for a long-term case, one must not neglect the stochasticity inherent both in a system itself and in its environment. The complexity of a system itself, together with the uncertainty of all the phenomena involved including the goals to be achieved, raise the need for effective methods for deriving such operational policies that would provide an expected "optimal" response of the system under a number of different conditions. There is a variety of methods in operations research developed for analyzing water resources systems. In general, systems analysis implies two basic strategies in operational assessment: simulation and optimization approaches.

Simulation is used to analyze the effects of the proposed management plans: the achievement regarding the system performance is evaluated on the basis of the selected sets of decisions. By definition, simulation methods do not claim that the particular combination of decisions represents the optimal one. The difficulty inherent in this approach is the large number of feasible operation plans (combinations of decisions) to be checked. If simulation alone were used, the search for the "best" solution might not only be very tedious, but could lead to alternatives far away from the optimal one.

For this reason optimization models are used to narrow down the search for promising combinations of decision variables. Optimization eliminates all the undesirable operation plans and proposes policies which are close to the global optimal solution. However, optimization usually relies on a very simple representation of the water resources system. Therefore optimized alternatives may be further refined by applying simulation techniques.

The most frequently used optimization techniques in water resources management can be classified into three major groups: (1) Linear Programming (LP), (2) Dynamic Programming (DP), and (3) Nonlinear Programming (NLP). This general classification, in addition to simulation models, represents the basic methods used in planning and management of water resource systems [*Yeh,* 1985]. Since most of the water resources systems display considerable nonlinearities, operational assessment - especially in case of reservoirs - is usually based on DP. The more so, since DP lends itself to a relatively easy incorporation of stochasticity [*Loucks et al,* 1981].

The present report describes the development and use of a complex water resources (reservoir) system operational assessment technique based on Stochastic Dynamic programming (SDP). It has been implemented as a computer program package called ***ShellDP***. The package comprises a set of independent routines developed for SDP-based optimization of a multi-unit reservoir system operation. The application of this optimization technique derives optimal long-term operational strategy. The uncertainty is explicitly incorporated into the optimization procedure: in order to describe the stochastic nature of river flows, the inflow to a reservoir is considered as an additional state variable in the SDP-based optimization approach.

The description of the SDP method which is applied in this report is presented in Chapter 2. This chapter also contains information on deterministic dynamic programming (DDP) as an introduction to SDP. This chapter follows closely the descriptions of the SDP algorithm by *Kularathna* [1992]. The main characteristics of optimization of a single and multi-unit reservoir system operation are explained in Chapter 3. This chapter deals with a general description of water resources system elements, decomposition techniques used in the optimization of a complex system operation, and data requirements for the calculations. Chapter 4 presents a five-reservoir water resources system to demonstrate the applicability of the ***ShellDP*** package. Chapter 5 gives detailed information on the ***ShellDP*** package and its software components. Chapters 3 and 5 are generalizing the description of the ***ShellDP*** by *Brorens* [1992], including the description of recently developed features of the package. Finally, the complete example of command, input, and output files for optimization of the presented complex system operation is given in the Appendices A through L. As compiled of a number of titles related to multiple-reservoir operational problems Appendix M should be understood as an initial guideline for those who intend to enrol themselves into research in this field.

2 STOCHASTIC DYNAMIC PROGRAMMING

2.1 Introduction to Dynamic Programming

Dynamic programming [*Bellman*, 1957], is a technique used for optimizing a multistage process. It is a "solution-seeking" concept which replaces a problem of ***n*** decision variables by ***n*** problems having preferably one decision variable each. Such an approach allows the analysts to make decisions stage-by-stage, until the final result is obtained. Hence, the original problem needs to be decomposed into stages. This decomposition could be defined either in space or in time. Each stage is characterized by the different system state expressed by the numerical value of the selected state variable(s). The transition of the state from one stage to another is expressed by a particular course of action (or the decision what to do) which is represented by the decision variable. The changes of the system's state, influenced by the decision taken at the previous stage are described by the state transformation equation. This transition of the state is possible only if certain rules are followed: both system state and decision variable can take values within particular domains. These limits form a set of constraints which must be met at every stage during the optimization process.

The computational routine for deriving the optimal policy follows the Bellman's recursive equation. For every state ***s*** at stage ***t*** the optimal policy is given by (subscripts denote backward computational procedure):

$$f_t^*(s_t) = \underset{x_t}{\overset{\min}{\max}} \left\{ C_{s,x_t} + f_{t+1}^*(s_{t+1}) \right\} \tag{2.1}$$

where

t - stage;

s_t - system state at the stage t;

x_t - decision taken at the stage t;

C_{s,x_t} - costs or contribution of the decision x_t, given state s at the actual stage;

f_{t+1}^* - accumulated sub-optimal costs (or contribution) for the following stages $t+1$, $t+2$, ..., N, where N stands for the total number of stages to be considered.

In other words, Equation 2.1 reflects the well known Bellman's Principle of Optimality [*Bellman*, 1957] which states that *"an optimal policy has the property that whatever the initial decisions are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision"*. Generally, DP procedure starts by initiating the objective function's value (cost or benefit) at the initial stage to zero, or any other arbitrary value. Subsequently, sub-optimal solutions are defined at every stage. Finally, the sub-optimal policy derived at the last computational stage is, actually, the global optimum of the problem. The optimal policy can then be derived as a set of decisions, each of which is taken at a subsequent stage with respect to the corresponding sub-optimal decisions derived at the preceding stage.

Equation 2.1 describes the deterministic dynamic programming algorithm. However, system behaviour and the transition of the system state from one stage to another are seldom deterministic functions. The most general stochastic formulation of the Bellman's recursive equation can be written as follows:

$$f_t^*(s_i) = \underset{k}{\overset{\min}{\max}} \left\{ \sum_{j=1}^{m} p_{ij}^t(k) \cdot [\ C(s_i,s_j,k) + f_{t+1}^*(s_j)\ ] \right\} \tag{2.2}$$

where

m - number of possible system's state transitions starting from s_i;

$p_{ij}^t(k)$ - probability of the system transition from state s_i to s_j at stage t, given the decision k is taken;

$C(s_i,s_j,k)$ - the costs (or contribution) generated during stage t, given the decision k and the system transition from s_i to s_j;

$f_{t+1}^*(s_j)$ - sub-optimal costs (or contribution) generated and summarized through the following stages $t+1$, $t+2$, ..., N.

In deterministic case (Equation 2.1) the optimal operational policy is derived from the space of feasible solutions. However, by introducing stochasticity in the right hand side of the equation, Equation 2.2 brings about the conclusion that we are seeking for the best (minimum or maximum) expectation of the objective function over the time period considered. The distinction between DP and SDP applications is also attributed in the decision whether a backward or forward algorithm should be chosen. In addition to a backward procedure (Equation 2.1), a forward DP algorithm could also be used in the deterministic case i.e., the first stage is considered as the initial one and the procedure continues until the sub-optimal solution at the last stage is derived. However, if the SDP recursive formulation (Equation 2.2) is to be used, the backward stochastic dynamic programming algorithm is required, since the expectation of the objective achievement over the future stages has to be considered. Therefore, the SDP algorithm starts from the last stage of the temporal cycle to be considered. Unlike the deterministic one, the stochastic procedure cannot reach the optimal solution in one pass throughout all stages. The complete computational cycles (iterations) over all stages have to be repeated until a stable decision set and constant expected return are reached for consecutive temporal cycles.

It is essential to point out that DP models require problem-specific formulations. This is due to differences that appear among a variety of problems which can be solved using DP: objective functions can have different forms, some problems have one and some of them can have several state variables, state transformation equations are not the same in all cases, decision variables can vary among different problems, etc.

Due to the inherent discrete nature of the SDP algorithm this method is hampered by the problem of dimensionality. The number of state transformations to be evaluated at any stage show an exponential growth with the increase of the number of state variables. A polynomial growth of the number of state transformations at each stage can be noted with the increase of the number of state discretizations. This is reflected in the excessive computer time and memory requirements to run an SDP model with a comparatively fine discretization of state variables.

2.2 Stochastic Dynamic Programming Algorithm for the Optimization of Reservoir Operation

The SDP based optimization procedure requires discretization of the state variables and their representation by a finite number of characteristic values. In reservoir operation problems sets of characteristic storage volumes and inflows are chosen so that the entire ranges of possible storage volumes and streamflows are represented. In an SDP formulation of a water resources allocation problem, time periods are often considered as stages which are, very frequently, set to monthly time steps. Therefore, each iteration represents one annual cycle and thus consists of 12 stages (months).

The future states or outcomes of any stochastic process cannot be predicted with certainty. However, based on past observations, the probability associated with any particular outcome can be estimated. Hydrologic uncertainty of streamflows is explicitly taken into consideration in the SDP model described in this manual. The model incorporates discrete probability distributions of monthly river flows (or alternatively the transition probabilities between subsequent monthly flows) into the optimization process. They describe the extent of the uncertainty of future occurrences of streamflows and the serial correlation of streamflows within a river basin.

If river flows were considered random processes the uncertainty of the hydrological regime could be described by discrete probability distributions of monthly river flows. After discretizing the entire range of inflow occurrences in a particular month into a set of flow intervals with the respective representative values the corresponding probabilities could be estimated from the available historical record:

p_i^t - probability of occurrence of the streamflow class i in month t.

On the other hand, assuming that the unconditional steady state probability distributions for monthly streamflows are not changing from one year to the next, a Markov chain could be defined for each month's streamflow. First order (lag one) Markov chains are used to estimate the discrete transition probabilities in order to represent the stochastic relationship between subsequent streamflow values. Discrete transition probabilities are evaluated for a number of inflow classes for each month. The class-representative inflow values to be considered are determined according to the available historical streamflow records. Since there are 12 months in a year, there are 12 Markov chains, the elements of which could be denoted as:

p_{ij}^t - probability of occurrence of the streamflow class j in month $t+1$, given the streamflow state i has occurred in month t.

The stored volumes of water in the reservoirs at the beginning of each stage (month) represent the explicit state of the system. To incorporate the uncertainty of inflows into the optimization process (either as a Markovian process or a random one) inflow to the reservoir is also considered as an explicit state variable. Therefore, an SDP formulation of a water resources allocation problem will have a two-dimensional state space consisting of the storage volume and the inflow to the reservoirs as state variables. The decision to be taken at each stage is the quantity of water to be released. This can be implicitly identified by specifying the storage volume at the beginning of the next stage as a decision variable which is, at the same time, the storage volume at the end of the time step considered.

2.2.1 Discretization of Inflows and Storages

Due to a discrete nature of SDP sets of storage and inflow characteristic values have to be selected so that the entire ranges of possible storage volumes and inflows to the reservoirs are considered. The developed model employs a semi-automatic procedure which consists of two steps: (1) the number of discrete storage values is defined by the user; and (2) according to the storage discretization, the model automatically estimates the number of inflow representative values. This is done in order to maintain the influence of the whole range of inflows on the changes of the reservoir storage, i.e to avoid low inflow values while having much higher storage class values.

To obtain discrete values to represent reservoir storage, the following procedure is adopted:

- *NS*, the number of discrete values to represent reservoir storage, can be chosen by the user according to the actual reservoir size. However, *NS* is limited in the model to a maximum of 55.

- The range between the minimum and maximum limits of reservoir live storage is divided into *NS-1* equally spaced intervals.

- Boundary values of these intervals are to be used as discrete representative values of the storage space.

The characteristic streamflows can be found by partitioning the range of streamflows into intervals. The number of these intervals directly depends on the chosen size of the representative storage interval in order to provide "synchronized" discretization of both state variables. It should be noted that the number of discrete flow values cannot exceed 12 in the model. The average of the observed historical inflows that occurred within the limits of an interval is chosen as that interval's characteristic value. This value represents the entire interval in the following computations. Mean and variance of inflows during each month are calculated to check whether they are reproduced by the discretization.

2.2.2 Description of the Optimization Process

The backward stochastic dynamic programming algorithm is used in optimization of reservoir operation. The objective of the SDP based optimization can be chosen among three alternatives offered in the model:

- To minimize the expected value of annual sum of squared supply shortages from the respective demands for water. This, so called 'single-sided squared deviation' objective function (OF) penalizes only deficiency in supply. Possible extra releases of non-consumptive water over demanded volumes or spillage are not penalized.

- To minimize the expected value of annual sum of squared deviations between releases and the corresponding demands. This is the, so called 'double-sided squared deviation' OF because it penalizes both supply shortages and excess releases of water over demanded volumes.

- To minimize the expected value of accumulated annual sum of the 'two-component weighted squared deviation'. This OF comprises two shortage components: (1) the squared deviation of actual reservoir storage from the full capacity of the reservoir, and (2) the squared deficiency in supply. Weight factors are assigned to each of the components according to user's preferences.

The SDP procedure starts by initiating the value of the objective function at the last stage (a month in the future) to zero, or any other arbitrary constant value. Backward algorithm by stages is continued until a stable policy and constant expected annual returns from the operation of the system have been found. One iteration cycle comprises 12 stages (months) of computation. The cumulative expected return grows up by setting the value of all output states (at the last stage) of each iteration to the value of the corresponding input states (at the first stage) of the previous iteration.

After few iterations the increase in OF value for any state over a period of one year becomes constant and independent of the state considered. This increment over a 12-month period is the expected annual return of the system operation. The operation policy designated by the SDP model is a set of rules specifying the storage level at the beginning of the next month for each combination of storage levels at the beginning of the current month and the inflow during the current month.

2.2.3 Test of Convergence of the SDP Procedure

There are two criteria which determine the convergence of the SDP optimization procedure:

- Stabilization of the operational policy.
- Stabilization of the expected annual increment of the OF value.

At each stage (month) during the SDP optimization procedure, an operational policy for that stage is determined. After continuing backward computation for a couple of years, a stable operation policy can be obtained. This implies that the operational policy for a specific month will not change from year to year. When this condition is reached, the convergence criterion of stabilization of the operational policy is achieved.

During the continued backward computation, the optimum expected return for all possible initial states is determined for each stage (month). When the expected return for a period of one year becomes constant for all state transformations at each stage, the convergence criterion of constant expected annual objective achievement is reached [*Loucks et al,* 1981].

3 SINGLE AND MULTI-UNIT RESERVOIR SYSTEM OPERATION

3.1 General Aspects

As conceived during the development of the ***ShellDP*** model, optimization of a multiple-reservoir system operation could roughly be divided into three major steps: (1) preparation of the required input data (inflow sequences; characteristics of reservoirs, water transfer and conveyance structures; demand data; water allocation patterns), (2) optimization of the system's operation, and (3) the assessment of the derived operational policy by simulation and the subsequent allocation of the derived releases. The following sections are giving more detailed descriptions of these steps. Modelling approaches towards optimization of a single and multiple-reservoir systems operation are given in separate sections due to the principal differences between the methods adopted in the ***ShellDP***.

3.2 Optimization of a Single Reservoir System Operation

The basic elements of a Single Reservoir System (SRS) are presented in Figure 3.1. A long-term operational analysis of such a system comprises determination of an operational strategy that would provide, with respect to the reservoirs characteristics, given inflow record, and selected objective function, maximum expected satisfaction of the demand imposed upon the reservoir. For the optimization itself, the ***ShellDP*** package employs a slightly modified SDP-based optimization-simulation computer model developed by Kularathna [1992]. This model consists of two independent routines: (1) the POLICY program determines the reservoir optimal operational policy, and (2) the SIMULATE program is used to assess the derived policy. Both programs, coupled with the adopted decomposition methodology and some additional models, are also used in analyzing multiple-reservoir systems operation. The main input data requirements are:

- **historical inflow data** (preferably for a large number of years);
- **water demand data** (drinking water, irrigation, etc.);

- **reservoir characteristics** (size, 'elevation - capacity' and 'elevation - surface area' curves, estimates of water losses, outlet capacities, etc.).

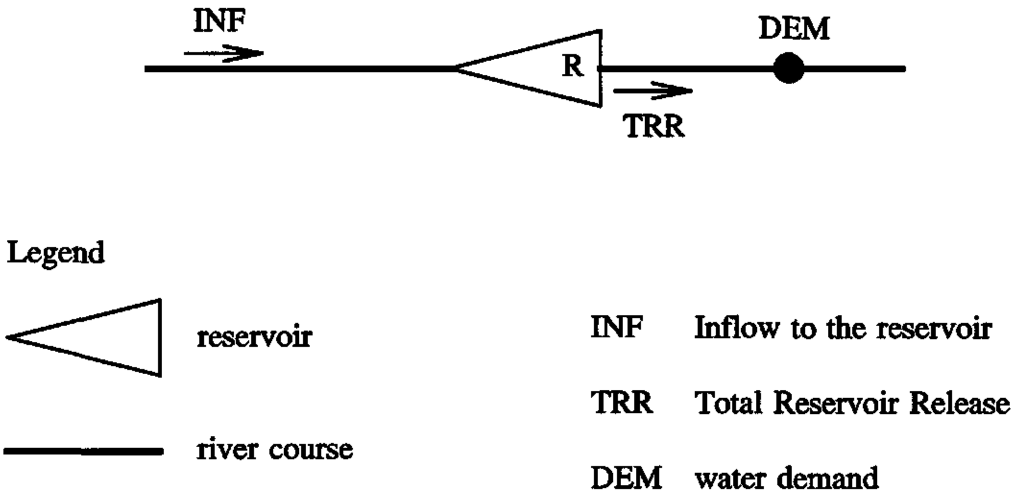


Figure 3.1 Single Reservoir System Elements

Using these data, the POLICY program optimizes the reservoir operation with respect to the selected objective function (see Section 3.4.1). In other words: the inflow time series is modified by the reservoir in order to match the demand curve as much as possible. Due to the stochastic nature of the optimization process, the final result is an expectation-oriented operational policy. Upon determining the policy, the SIMULATE program is activated to evaluate its operational effects. The following steps can be distinguished as basic stages of the optimization process of a SRS operation (for more details see Section 3.4):

- **Preparation of data of the reservoir characteristics and salient features;**
- **Preparation of inflow data;**
- **Preparation of water demand data;**
- **Optimization**: determination of reservoir operation policy;
- **Simulation** of the reservoir operation according to the derived policy;
- **Allocation of the resulting releases** to different demand centres (this can result in reservoir supply deficits during some periods).

3.3 Optimization of a Multi-Unit Reservoir System Operation

A Multi-Unit Reservoir System (MRS) consists of a number of reservoirs interconnected by means of natural streams, artificial transfer canals, or pipelines. A multi-unit system can also be conceived as several independent reservoirs serving the same demand centre(s). Figure 3.2 displays a general scheme of an MRS consisting of 5 reservoirs.

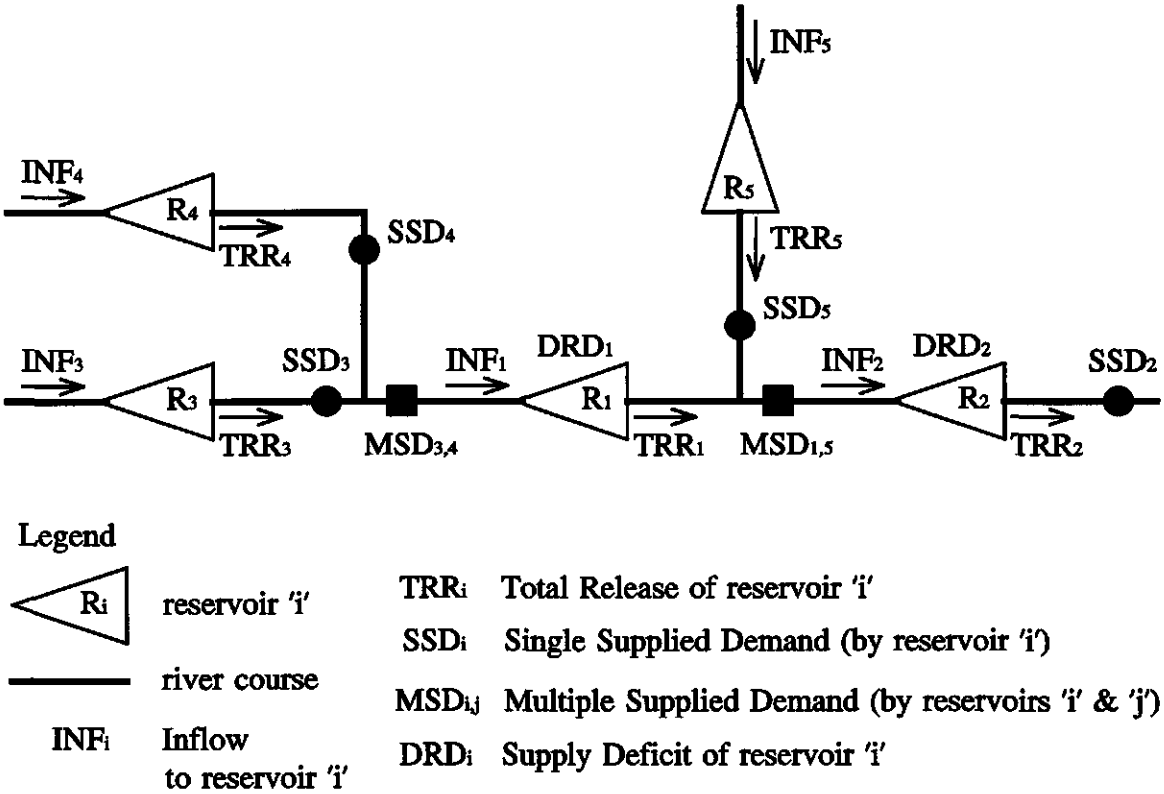


Figure 3.2 Multi-unit Reservoir System Elements

The operation of each reservoir in the system has to be tuned to achieve a "near optimal" performance for the system as a whole. The analysis of the joint operation of a number of reservoirs interconnected into a complex water resources system requires huge computer capacities. If such a task includes stochastic nature of the system's inputs and outputs the problem can sometimes become computationally prohibitive due to its dimensionality. To avoid this, the approach adopted in the ***ShellDP*** model assumes decomposition of a multiple-reservoir system into single-reservoir subsystems. Subsequent analyses concentrate on each reservoir individually thereby deriving local optimal operational strategies of defined subsystems. These policies are refined throughout an iterative process to reach a "near optimal" operation of the system as a whole. Thus, to enable the analyst to derive and to evaluate the system's operation, certain modifications and simplifications of both the system and applied technique had to be adopted in the ***ShellDP***:

- The SDP-based optimization algorithm developed for analysis of complex systems' operation is an iterative procedure. This means that the final solution is obtained by repeated optimization and simulation of the system's performance in several consecutive steps. Iterations are repeated until the expected, "near optimal" system return is obtained.

- The methodology is based on decomposition, i.e. each reservoir's operation is optimized separately, simultaneously considering the inflows from upstream reservoirs and the presence of downstream reservoirs. The order in which the individual reservoirs are optimized is not strictly fixed. It can partly be chosen freely, and partly it depends on the adopted method (going downstream, upstream, or up-and-downstream [*Milutin,* 1992]). The sequence of optimization may reflect existing firm water allocation policies which can be treated as a type of constraint.

Clearly, when considering optimization of an MRS operation as opposed to a situation with a single reservoir (SRS), some differences have to be noticed (Figures 3.1 and 3.2):

- In an SRS the inflow (INF) into the reservoir consists of a set of historical data. In an MRS the inflow volume might be influenced by other reservoirs that are directly upstream of the reservoir in question.

- In an MRS, a demand can be supplied by more than one reservoir, due to the fact that rivers, canals, or pipelines from different reservoirs might lead to the same demand centre. These demands are referred to as 'multiple-supplied demands' (MSD) as opposed to 'single-supplied demands' (SSD).

- The term 'downstream reservoir deficit' (DRD) is considered to be one of the demand components of reservoirs situated upstream, next to SSD's and MSD's. The DRD is the sum of the individual demand components that could not be met by the downstream reservoir. The DRD can be obtained by simulation, following the "optimal" policy derived for the downstream reservoir.

- The solution is obtained through repeated iteration steps. When a reservoir's operation is optimized, either the DRD is not known (the downstream reservoir's operation has not been optimized yet), or the total inflow to the reservoir is not known (the upstream reservoirs' operation have not been optimized yet). Which of the two is missing depends on the adopted decomposition (going downstream, upstream, or up-and-downstream). The lack of either of the data necessitates the use of an iterative computational approach, wherein a particular optimization step relies on the DRD or the additional inflow obtained in the previous iteration.

It has already been pointed out that the dimensionality of an MRS optimization problem requires considerable amounts of computer storage and memory. This phenomenon, so called "curse of dimensionality", can sometimes increase these requirements even beyond capacities of the available computer facilities. Several SDP-based decomposition methods have been developed to cope with this problem. There are three main decomposition orders in which the operation of an MRS can be optimized within the ***ShellDP*** model:

- Going **downstream**: The procedure starts by optimizing the uppermost reservoir of the system, follows the downstream reservoir sequence, and ends up by optimizing the operation of the lowest lying reservoir. The DRD from the previous iteration run are used to modify the actual demand of the reservoir being optimized. In the first iteration these values are assumed to be zero. Figure 3.3 shows the flow chart of the downstream decomposition algorithm of an MRS operation.

- Going **upstream**: Optimization starts at the lowest and ends up at the uppermost reservoir in the system. Inflow to a reservoir is enlarged by unused (free) releases from upstream reservoirs obtained in the previous iteration. In the first iteration these values are unknown, thus reservoirs utilize only their own unregulated inflows.

- Going **up-and-downstream**: This algorithm employs a complex optimization order which not only starts at the lowest reservoir, but also ends up at the lowest reservoir of the system after optimizing each reservoir operation [*Kularathna,* 1992]. This set-up provides the use of DRD and/or additional inflows from upstream reservoirs obtained in the actual iteration rather than those from the previous calculation step. Moreover, every pair of reservoirs in a cascade is considered as a small subsystem which operation is optimized in the same manner as that of the whole system: (1) downstream reservoir operation is optimized on the basis of its own inflow sequence; (2) upstream reservoir operation is optimized according to the demand which is increased by the DRD of the downstream reservoir; and (3) downstream reservoir operation is optimized for the second time, but considering the upstream reservoir free releases in addition to its own inflows. Figure 3.4 shows the flow chart of the up-and-downstream decomposition algorithm of an MRS operation.

Within the ***ShellDP***, the optimization of an MRS operation consists of several computational steps which are executed in the following order:

(1) **Preparation of characteristic data of the reservoirs and determination of the decomposition method (reservoir optimization order);**
(2) **Start the first iteration run;**
(3) **Choose the first reservoir;**
(4) **Optimize the 'current' reservoir operation:**
  - **Preparation of inflow data** including the available free flows from upstream reservoirs, if any;
  - **Preparation of demand data** including DRD, if any;
  - **Optimization**: determination of reservoir operation policy;
  - **Simulation** of the reservoir operation according to the derived policy;
  - **Allocation of the resulting releases** to different demand centres (this can result in reservoir supply deficits during some periods) and determination of free releases (towards the immediate downstream reservoir, if any).

(5) **Choose the next reservoir,** and then **repeat step (4)**. When all the reservoir policies are optimized in this iteration, initialize the next iteration and go to step (3). After several iterations the joint system return should converge to its 'near optimal' value and the computation procedure could be terminated.

The common feature of these three decomposition algorithms is that they all employ a certain sequence of individual optimization and simulation of each reservoir of the system. In other words: (1) the sequence upon which the reservoirs will be taken into consideration is determined in advance; and (2) following the adopted order, the reservoirs are, one by one, introduced for the optimization/simulation process. At this point, a new term needs to be introduced: **'the current reservoir'**. It refers to the reservoir which operation is presently being optimized (or simulated) according to the selected decomposition sequence. The detailed description of all computational steps employed in optimization of both SRS and MRS operation is presented in Section 3.4.

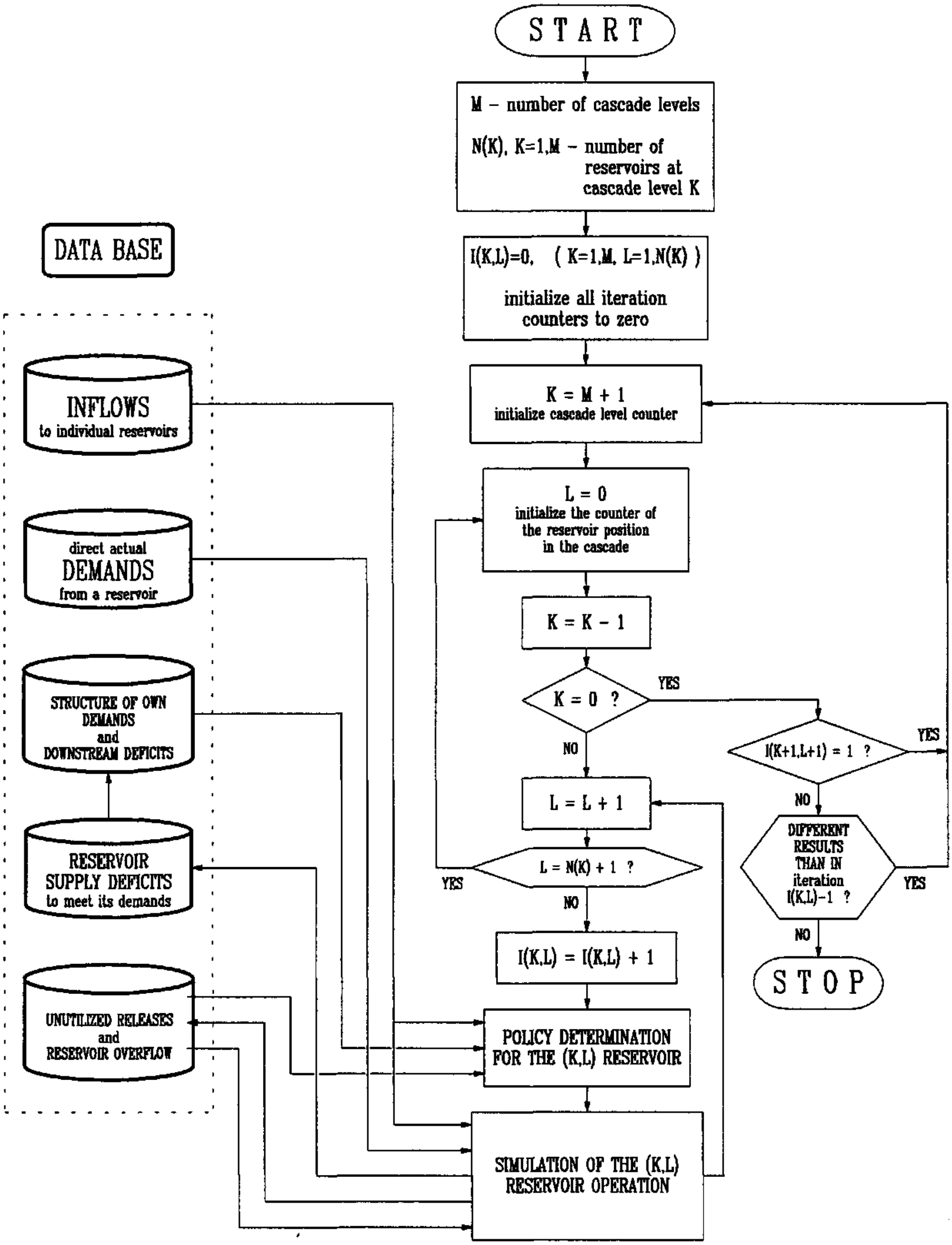
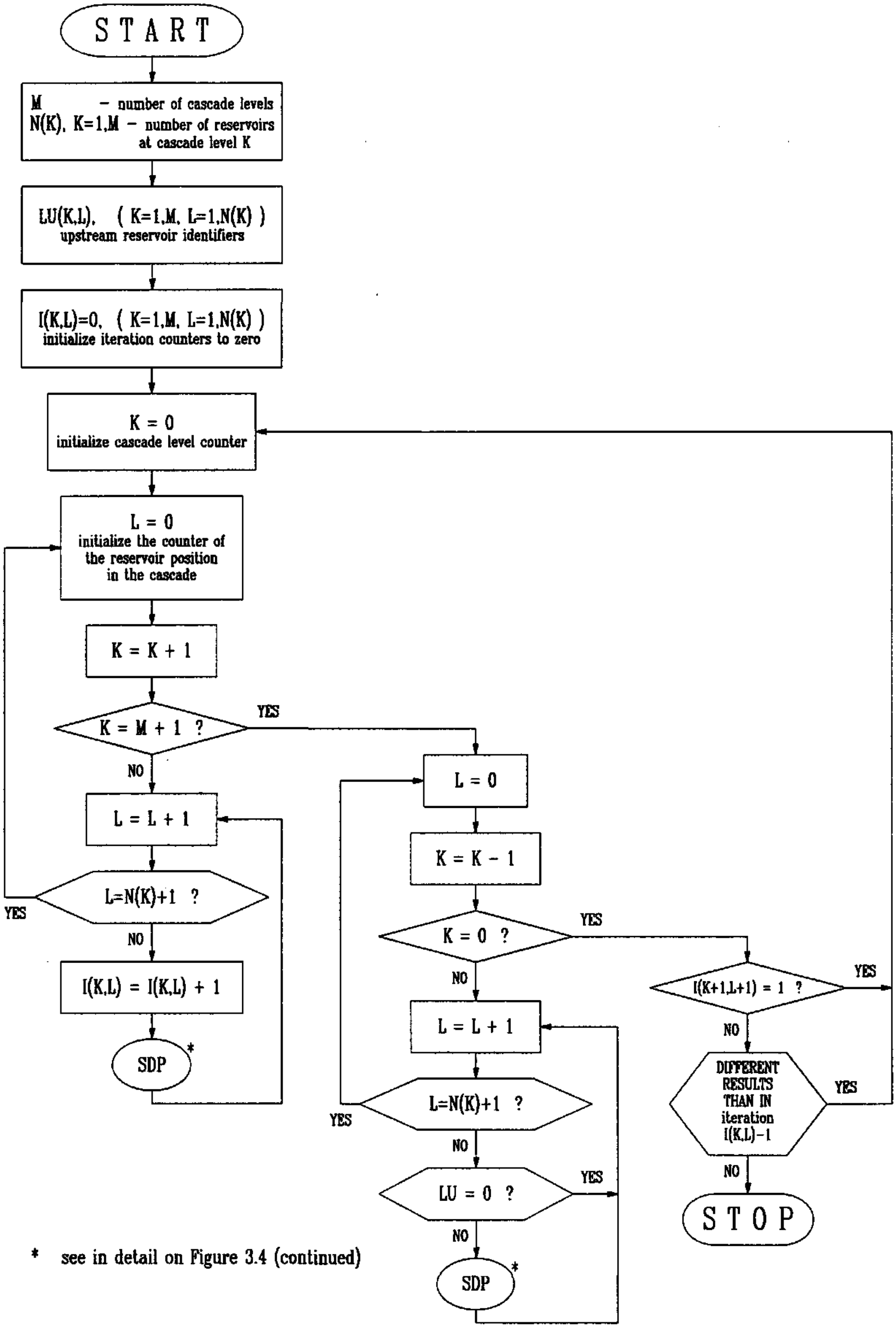


Figure 3.3 Sequential (Downstream) Decomposition in Optimization of an MRS Operation



* see in detail on Figure 3.4 (continued)

Figure 3.4 Iterative (Up-and-Downstream) Decomposition in Optimization of an MRS Operation: DECOMPOSITION

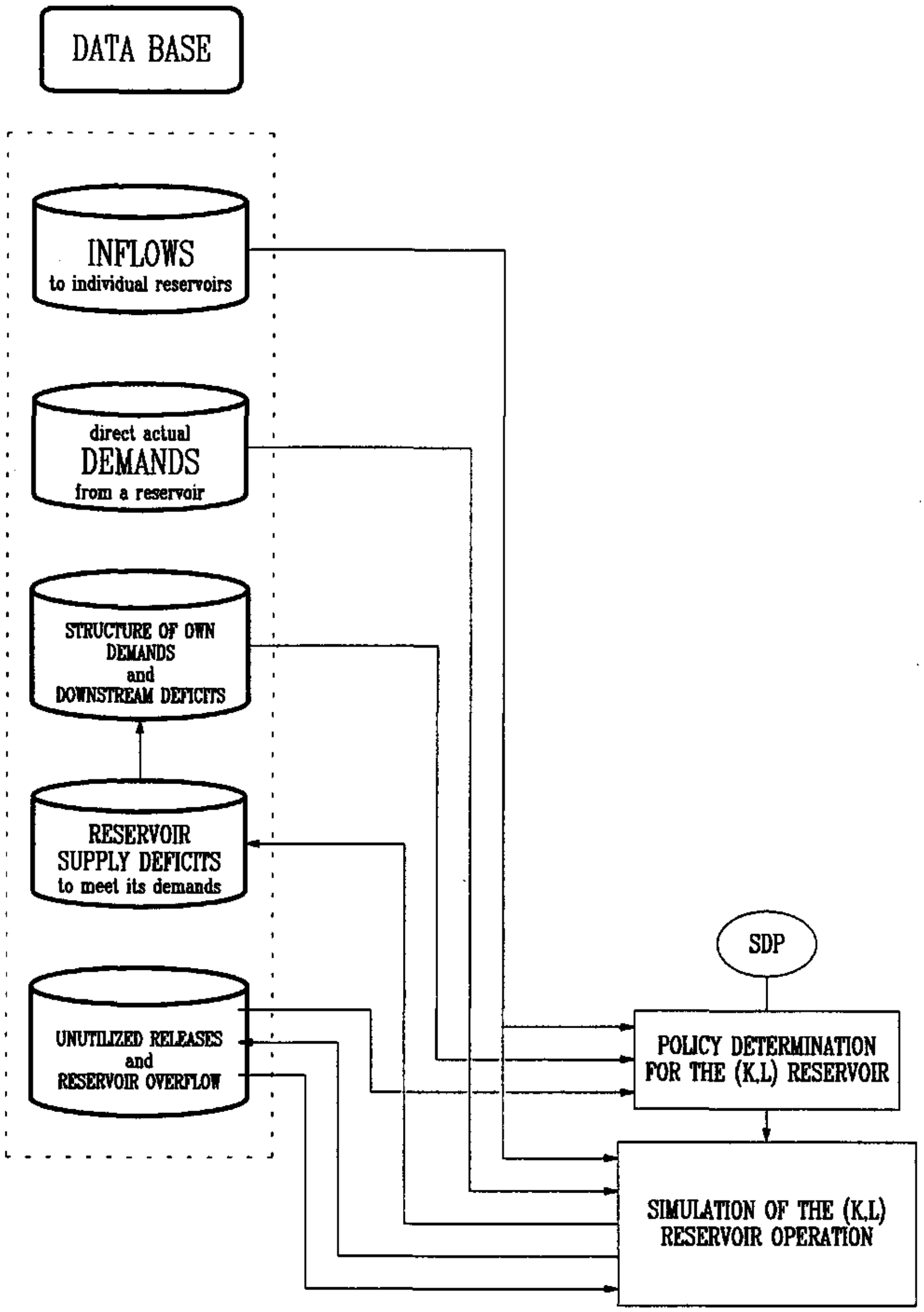
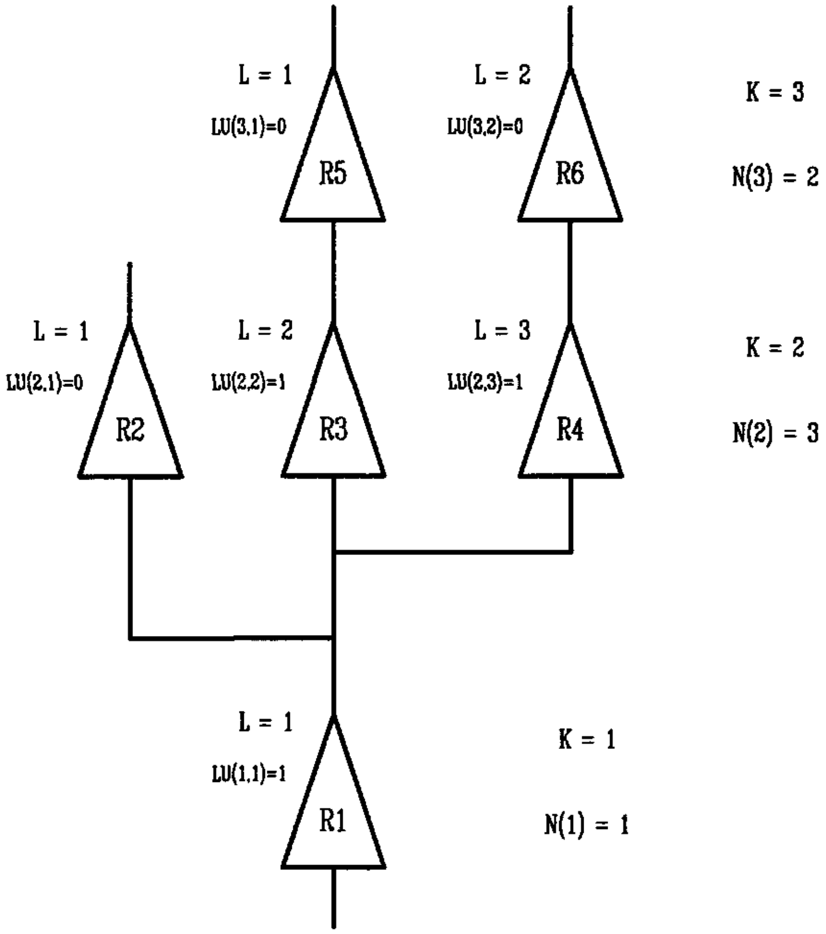


Figure 3.4 (continued) Iterative (Up-and-Downstream) Decomposition in Optimization of an MRS Operation: OPTIMIZATION, SIMULATION and inherent DATA FLOW



LEGEND

R1, R2, R3, R4, R5, & R6 - reservoirs

M - number of cascade levels

K - cascade level counter

N(K), [K=1,M] - number of reservoirs in cascade level K

L - reservoir counter at a cascade level

I(K,L), [K=1,M; L=1,N(K)] - iteration ordinal number of the (K,L) reservoir

LU(K,L), [K=1,M; L=1,N(K)] - upstream reservoir identifier

The Legend of Figures 3.3 and 3.4

3.4 Description of Different Calculation Steps

3.4.1 Preparation of Characteristic Data of the Reservoir(s)

As a part of basic input data requirements, reservoir characteristics are represented by groups of data sets which do not change during the optimization process. The data are stored in an unique file for each reservoir of the system (Tables A.1 through A.5 of Appendix A). This, so called **reservoir characteristics file** contains the following:

- Reservoir name.
- Length (in years) of the inflow record (limited in the model to 100).
- Values of the reservoir's maximum and minimum storage volumes, maximum outlet capacity, and the inflow correlation coefficient threshold. The last parameter determines whether transitional or unconditional inflow probability distributions are used (i.e., if the correlation coefficient between inflows in two consecutive months is higher than the given threshold value then transitional probabilities are to be used to reflect the stochasticity of inflows; otherwise, unconditional monthly inflow probability distributions are used).
- The available inflow record (reservoir **own inflows** - see Section 3.4.2).
- Reservoir characteristics: 'elevation - capacity' and 'elevation - surface area' curves. **Important:** *The model requires that these curves cover a range which exceeds the actual reservoir size and the corresponding maximum surface area, respectively.*
- Estimates of reservoir evaporation losses in terms of characteristic water column (depth) losses in each month.

Another group of reservoir-specific data is compiled into a **demand allocation file** (Tables A.6 through A.10 of Appendix A) describing the selected objective function type to be used in the optimization, the simulation method to be applied, and listing the names of demand centres associated with the reservoir. The contents of a **demand allocation file** also remains unchanged during the entire computational procedure. The **demand allocation file** consists of:

- The value depicting whether a 'real demand' or a 'hypothetical demand' approach is to be applied in optimization (see Section 3.4.3). This parameter is followed by the objective function type code (see Section 2.2.2) that can take values:
    - 1 - 'single-sided squared deviation';
    - 2 - 'double-sided squared deviation';
    - 3 - 'two-component weighted squared deviation'.

  Note that if any value other than 1, 2, or 3 is given, the optimization model assumes objective function type 1. The following input data is a pair of weights associated with the objective function type 3. These two parameters can take values between 0 and 1. The last input parameter is the simulation type code (see Sections 3.4.5 and 3.4.6) which can take values:
    - 0 - 'overrule' simulation approach;
    - 1 - simulation strictly following the derived policy;
    - 2 - 'avoid excess release' simulation approach which, actually, consists of two distinctive simulation methods (see Section 3.4.5).

  Note that if any value other than 0, 1, or 2 is given, the simulation model assumes the simulation type 1.

- The following data include a list of demand centre codes associated with the reservoir. Note that this list not only determines the demand targets of a reservoir but the priority order of release allocation towards them as well.

Important : *There are three model-specific requirements considering the units used:*

- **Volume:** *Reservoir storage, inflows and demands have to be in* $\boldsymbol{10^6 m^3}$.

- **Area:** *Reservoir surface area must be expressed in* ***ha*** $\boldsymbol{(10^4 m^2)}$.

- **Elevation:** *Elevation and evaporation must be expressed in* ***m***.

3.4.2 Preparation of Inflow Data

Optimization procedure requires historical monthly inflow data for as long period as possible (this is limited in the model to a maximum of *100* years). River flows into a reservoir could have two components:

- The so called '**own unregulated inflow**' of a reservoir: the natural inflow to the reservoir which value is not influenced by any other (upstream) reservoir.

- **Inflow from upstream reservoirs** is compound of free downstream releases and spills from reservoirs situated directly upstream from the reservoir in question. These volumes of water are non-consumptive releases from upstream reservoirs (not used to cover consumptive water demands). In addition, this inflow component can also be increased by a contribution from reservoirs situated in neighbouring river basins. Namely, regulated releases from these reservoirs can be transferred via canals and/or pipelines towards the reservoir in question.

The own inflow component to a reservoir, as taken from observed (or generated) time series, does not change during the optimization process. However, free release volumes from upstream reservoirs do change due to modifications in their respective operational policies. Policy adjustments are caused by the different demand structures and might be used in the subsequent iteration cycles. These two inflow components have to be added together in order to serve as input for the optimization of the 'current' reservoir operation.

3.4.3 Preparation of Demand Data

Within the SDP context monthly demand values are considered to be recurring in annual cycles. Actual monthly water demand from a reservoir is calculated by summing up all the individual demands that are supposed to be met by the 'current' reservoir. There are three different demand types considered:

- **Single supplied demands** (SSD): demands that are supplied by only one reservoir.

- **Multiple supplied demands** (MSD): demands supplied by more than one reservoir.

- **Downstream reservoir deficits** (DRD): deficits in demand fulfilment of either the reservoir which is situated on the same river course directly downstream of the 'current' one or the reservoir which receives additional inflow volumes by an interbasin transfer structure from the 'current' reservoir. **NOTE**: *The DRD components are always ranked at the bottom of a demand list.*

A demand is represented by a sequence of average monthly volumes of water. Initially, before starting any calculations, individual demand data for all demand centres (including SSD, MSD, and DRD) are compiled into a, so called, '**general demand file**'.

Important: *Due to some initial assumptions and restrictions imposed during software development it is compulsory to end a 'general demand file' with an additional line containing downstream reservoir deficits of a nonexisting, 'dummy' reservoir. Failing to do so could sometimes unexpectedly interrupt computations with a completely illogical error status. The error occurs under very specific input conditions (fully recognized and demarcated by developers of the software) and it can be safely avoided by the suggested 'dummy' demand remedy. This 'dummy' DRD demand is named 'DXX' in the example provided in this Manual (see Appendix A: Table A.11; Appendix B: Table B.1; Appendix G: Tables G.1 and G.3; Appendix H: Tables H.1, H.2, and H.3; and Appendix I: Table I.1).*

The total annual demand distribution of a particular reservoir is evaluated by summing up all partial demand sets assigned to the reservoir. The aggregated demand distribution can be further used in two different ways in the optimization process:

- Directly, as a 'targeted real demand' (designated in the model by the value '**-999.999**' in the corresponding **demand allocation file**; see Sections 3.4.1 and 5.2). In this case a reservoir operational policy is optimized towards reaching the 'real demand' as close as possible with respect to the best expected achievement of the selected objective function (see Section 2.2.2).

- Indirectly, to be used to form the shape of the demand curve. The final values of the demand, the so called 'hypothetical monthly demands', could be oriented either to the value of the annual median or the annual mean inflow to the reservoir. The choice is based on the hydrological regime of the corresponding basin: (1) in areas with moderate climatic conditions the annual mean inflow is the alternative; whereas (2) the annual median inflow comes up as the decision in sub-humid to semi-arid climates. These alternatives arise from the intention to create an overwhelmingly large demand. The 'hypothetical demand' is assumed to constitute a theoretical maximum demand a reservoir of unrestricted size, while having no losses whatsoever, would be able to fulfil without any shortage to occur. It is obvious that these prerequisites are not met by real-world reservoirs. Thus this hypothetical demand might be approximated, but never achieved. This transformation provides maximum challenge towards the utilization of the reservoir storage capacity, while the demand distribution remains unchanged. The annual median (or mean) inflow is redistributed with respect to the real (monthly) demand distribution within an annual cycle, i.e. the hypothetical demand values are reflecting the monthly distribution of the components of the supply requirements. These fictive monthly demand distributions are obtained according to the following set of equations:

$$\textbf{\textit{if}} \quad \textit{total annual demand} \neq 0 \quad \textbf{\textit{then}}$$

$$\textit{fictive monthly demand} = \textit{actual monthly demand} \cdot \frac{\textit{annual median (or mean) inflow}}{\textit{total annual demand}}$$

$$\textbf{\textit{if}} \quad \textit{total annual demand} = 0 \quad \textbf{\textit{then}}$$

$$\textit{fictive monthly demand} = \frac{\textit{annual median (or mean) inflow}}{12}$$

or

$$\begin{aligned} &\textbf{\textit{if}} \quad TAD \neq 0 \quad \textbf{\textit{then}} \quad DD_m = (\ \Sigma SSD_m + \Sigma MSD_m + \Sigma DRD_m\ ) \cdot \frac{AMF}{TAD} \\ &\textbf{\textit{if}} \quad TAD = 0 \quad \textbf{\textit{then}} \quad DD_m = \frac{AMF}{12} \end{aligned} \tag{3.1}$$

where

- ***TAD*** represents the *total annual demand*;
- ***AMF*** is either the *annual median inflow* or *annual mean inflow*;
- ***DD*** is the, so called, *distributed demand*;
- ***m*** denotes the actual month and takes values from *1* to *12*.

Either of the resulting demand time series as pre-processed for the optimization procedure is called the '**distributed demand**' (DD). Consequently, the DD (either 'real' or 'hypothetical') is used as a target to determine the reservoir operational policy according to the chosen objective function.

3.4.4 Optimization

The maximum potential contribution of each reservoir in the system is evaluated on the basis of their active storage volumes, observed inflows, monthly demand distributions within an annual cycle, estimates of water losses during each month, and the selected objective function. The SDP-based optimization model (see Sections 2.2 and 3.2) is used to derive the optimal long-term, expectation oriented, operational policy of the reservoir.

The optimization procedure starts by selecting the type of the objective function and initiating its value at the last stage to zero, or any other arbitrary value. Each annual cycle consists of 12 stages (months) representing one iteration cycle. The cumulative value of the objective function grows up by setting its value at the beginning of each iteration cycle to the value of the objective function at the last computational stage of the previous iteration. The process goes backwards through these cycles until a stable operational policy and constant annual return of the system are achieved.

After several iterations the increase of the objective function's value over an annual cycle becomes constant and independent from time and state [*Loucks et al.,* 1981]. The operational policy reaches steady state conditions i.e., for every combination of state variables (initial storage volume and inflow during the time interval) the target storage volume remains the same. These two criteria can be used to indicate the convergence of the SDP-based optimization procedure.

The steady state annual increment of the objective function expresses the optimum expected contribution of the reservoir towards the performance criteria as used in the objective function. It is reached for all possible state transformations during each stage within one annual cycle. The steady state condition of the policy implies the fact that for an indefinite long operational period the decision taken during a specific month will not be changed from year to year for the same constellation of the state variables.

Finally, the optimization procedure results in sets of decision tables determined for each month (stage) within an annual cycle (see Table D.2 of Appendix D). These tables specify decisions (final storage volumes of the reservoir) to be taken on the basis of every possible combination of initial storage volume at the beginning and inflows during the month (state variables). The policies are fairly detailed reservoir operational rules that indicate how the reservoir should be operated in order to satisfy the demands as close as possible (actually, the 'distributed demand' DD) in each month on the basis of *the expected inflow pattern.*

NOTE: *Water losses at each stage are estimated as total monthly volumes of water lost by evaporation. The quantities of evaporation losses are expressed as functions of average reservoir volume during the stage (the average of the initial and final reservoir storage).*

3.4.5 Simulation

The assessment of the derived operational policy is performed by simulation. The simulation model uses the operational policy to determine the target storage volume of the reservoir at the end of each month according to the present state of the system (initial storage volume and inflow). Simulation starts by setting up the value of the initial reservoir storage level and it is carried out over a selected sequence of streamflow data. Simulation, as a part of the iterative alternating optimization/simulation (SIMOPT) procedure, always utilizes the same inflow data set which serves as the basis for optimization.

Simulation of reservoir's performance results in a sequence of its storage volumes at the end of each month over the entire simulation time period. Having the values of initial and final storage volumes, inflow volume, and estimates of evaporation, it is possible to define the respective release volume during each month. Total reservoir release is the sum of: (1) reservoir outflow through the service and bottom outlets, and (2) overflow of the reservoir over the spillway. Simulated releases are then used to determine the allocation structure of the released water. Subsequently, sets of allocated release volumes and the respective demands are used to calculate possible shortages in demand fulfilment.

Due to a restrictive discrete nature of SDP-based optimization it can be observed that sometimes strict policy decisions result in significant oversupply. This shortcoming stems from the fact that the decision to be taken in each month is the final storage volume at the end of the period. As the final storage volume can assume a value only from a limited discrete set it is clear that the resulting release will not necessarily match the respective demand for water. In fact, in many months the release would surpass the corresponding demand. To assess the magnitude of such excess withdrawals the simulation model in the ***ShellDP*** package allows use of four different simulation models. These four alternatives are based on the permitted level of policy violation. Alternative policy violations are selected in such a way as to ensure that they will comply with the objective pursued in optimization. That is, a policy decision could be altered only to prevent the portion of a release beyond the corresponding demand to be withdrawn from the reservoir. Dealing with a system with the assumed purpose of only water supply and having no consideration of floods it would be quite logical to store the excess release volume during a particular month so that it could be utilized at a later stage. Bearing in mind the objective pursued in optimization it is fully justified to violate such policy decisions as described above. Additionally, given the fact that water demands are considered deterministic (i.e., the same total and distribution of demands is recurring in annual cycles over the whole time period) the assumption that any reservoir's contribution towards a particular demand could be sufficiently represented by its expected (average) value derived over the whole simulation period inevitably results in two drawbacks that arise when viewing the systems' operation over the entire time period:

- The remaining, unfulfilled demand after one reservoir has allocated water towards a particular demand centre is overestimated in those months in which the actual monthly supply of the reservoir exceeds the respective estimated average monthly supply. This in turn will result in unnecessary withdrawals from other reservoirs towards this demand centre in this particular month.

  A hypothetical example is perhaps the best way to illustrate this. Let two reservoirs R_1 and R_2 provide water for a common demand D. The demand D is represented by a sequence of 12 monthly values d_i , $i = 1, ..., 12$ that are assumed to be recurring in annual cycles over the entire period of n years of inflow data availability. Let the operation of reservoir R_1 be optimized and simulated first. Let us further on concentrate only on simulation results in a single month indicated as i. The resulting releases in month i are $r_{i,j}$, $j = 1, ..., n$. Clearly, the release volumes vary from year to year and, in general, it could be stated that the releases from R_1 in month i could fall short of, be equal to, or exceed the value of the respective demand d_i. By assuming that reservoir R_1 alone cannot fully satisfy the demand D in month i, the average contribution of R_1 to the supply of d_i is $\bar{r}_i$:

  $$\bar{r}_i = \frac{1}{n} \cdot \sum_{j=1}^{n} r_{i,j}^{(d_i)} \quad , \qquad r_{i,j}^{(d_i)} = \begin{cases} r_{i,j} \;, & r_{i,j} < d_i \\ d_i \;, & r_{i,j} \geq d_i \end{cases}$$

  Consequently, the average supply shortage of reservoir R_1 towards the demand D in month i (i.e, the value to be used to optimize and subsequently simulate the operation of reservoir R_2) is $d_i - \bar{r}_i$. Let us further use the asterisk (*) superscript to label those years $j \rightarrow j^*$ in which the release $r_{i,j}$ from reservoir R_1 was higher than the respective average monthly supply $\bar{r}_i$. Ultimately, while simulating the operation of reservoir R_2 with respect to the average remainder of the demand d_i - $\bar{r}_i$ it is realistic to assume that reservoir R_2 would attempt to, and sometimes do manage to release water up to the required volume d_i - $\bar{r}_i$. This means that there is a great possibility that in some of the years $j = j^*$ the aggregate of releases from reservoirs R_1 and R_2 towards the demand D in month i exceeds the demanded value d_i.

- Quite opposite, the information on extreme monthly supply shortages of a reservoir towards a particular demand is lost by relying on the average demand and supply values. By underestimating these extreme events the reservoirs that might contribute to cover these peaks would not do that due to lack of data.

  The clarification of this statement could also be found in the former example. Namely, let $j \rightarrow j^*$ now indicate the years in which the release from reservoir R_1 fell short of the average monthly supply $\bar{r}_i$. As the operating policy of reservoir R_2 targets the remainder of the demand d_i - $\bar{r}_i$ it is unlikely that the supply shortage of reservoir R_1 in month i in years $j = j^*$ would be fully compensated for by releases from reservoir R_2.

Recognizing these restraints four alternative simulation models are incorporated into the ***ShellDP*** package (see also Section 3.4.1). Either of the alternatives could be used both within the iterative SIMOPT procedure of deriving the optimal (expectation oriented) operational strategy of a reservoir system and as a means to appraise the operational policy of a system which has been obtained by combining SDP optimization with a different simulation approach. The available simulation alternatives in ***ShellDP*** are:

- Simulation model 1: Simulation strictly following the derived policy. This simulation type is initiated by entering the code *"1"* into the respective **demand allocation file.**

- Simulation model 2: The policy-based decision is overruled if it cannot provide sufficient release volume to meet the respective demand. A new decision is issued by increasing the release to the level of the demand. This is, to a certain extent, a combination of a standard reservoir operational rule and the derived SDP-based policy. This simulation approach is initiated by entering the code *"0"* into the respective **demand allocation file.**

- Simulation model 3: This model, in fact, consists of two different simulation models based on the same objective named 'avoid excess release'. What differentiates these two models is the criterion used to define the level of excess release:
    - The first, so called 'average demand concept' defines oversupply with respect to the average demand imposed upon the reservoir in a particular month. Thus, the SDP-based policy is violated only to prevent decisions that result in oversupply towards the estimated average demand. That is, if a policy-based decision is to release a volume that is greater than the respective expected demand the decision is overruled by setting the release to the level of the demand. Thereby the excess release volume is stored in the reservoir with a prospect to be utilized at a later stage.
    - The second approach ('monitored demand concept') circumvents the drawbacks of altering a policy with respect to the average demand estimates. Namely, the information on how much water has been allocated towards each individual demand centre in each time step (month) over the entire simulation period is repeatedly updated in every simulation run. Thus, instead of comparing a policy-based release with the respective average monthly demand the model is provided with the estimate of the actual monthly demand to decide whether to violate the policy or not in the month in question. Consequently, decisions on policy violation are no longer prone to factors like overestimated or underestimated (average) demand values, nor is the system allocating more water than needed to each demand target.

Both simulation approaches are represented by the code *"2"* into the respective **demand allocation file**. To distinguish between the two the simulation routine needs some additional information. This can be achieved by simply checking whether all the input data requirements for the 'monitored demand concept' simulation are met or not. Namely, to be able to compare the release with the actual monthly demand, the 'monitored' simulation needs to have a time series of monthly demands recorded (or updated) over the whole simulation period. These demand records are initially created by the DEMGEN program (see Section 5.10) and continuously updated for each reservoir by the AGGRMD program (see Section 5.6) and by the release allocation model DEFICIT (see Sections 3.4.6 and 5.8). The files that contain these time series are named internally by the programs, thereby enabling the SIMULATE routine to distinguish whether to apply the 'average' or 'monitored' demand concept if the code *"2"* is found in the corresponding **demand allocation file**. For instance, if in case of reservoir JO which simulation (code *"2"*) results are to be stored in the file C:\CU\JO.SIM the SIMULATE (or DEFICIT) program finds the file named C:\CU\JODEM.AGG (the output of the AGGRMD program) the 'monitored demand concept' is to be applied. If not, the 'average demand concept' will take place. To summarize, the simulation code *"2"* suboptions are identified by (for details on the actual implementation see Sections 5.6, 5.7, 5.8 and 5.10):

- *"average demand concept":* Given the code *"2"* in the respective **demand allocation file** and provided that neither the DEMGEN (at the beginning of an iteration) nor the AGGRMD (for each reservoir) programs are executed, the SIMULATE program will assume the "average demand concept" of simulation. To be absolutely accurate, the necessary requirement to opt for the "average demand concept" are the code *"2"* and not to run the AGGRMD, whereas the execution of the DEMGEN has no influence on the SIMULATE program's decision which of the two approaches to adopt. The previous description is given because the DEMGEN and AGGRMD programs are meant to be used only in conjunction within the "monitored demand concept".
- *"monitored demand concept":* There are three preconditions to be met if the simulation is to follow the principles of this approach: (1) the code *"2"* has to be specified in the **demand allocation file**; (2) the DEMGEN program has to be executed at the beginning of each iteration; and (3) the AGGRMD program has to be run prior to simulation of each reservoir operation.

3.4.6 Allocation of Reservoir Releases

Optimal reservoir operational policy could be determined according to either real or hypothetical demand distribution over a year (see Section 3.4.3). Furthermore, the real demand is a sum of individual demand components and the simulation results in total reservoir releases without specifying the volumes of water allocated to each demand centre. Thus, it is necessary to perform some further calculation steps:

- **Allocation** of water to direct (consumptive demands) and indirect users (**water transfer**, if any).

- **Reduction** of total reservoir release after allocation of water to all (direct and indirect) demand centres. The remaining unallocated outflow can then be used as inflow from upstream reservoirs to downstream reservoirs (see Section 3.4.2).

- Calculation of monthly '**average reservoir supply deficits**' (ARD_m) of a reservoir by comparing the simulated water allocations to the corresponding *real demands*.

- Calculation of the actual monthly '**reservoir supply deficits**' of a reservoir by comparing the simulated water allocations to the corresponding *real demand* figures in the case of 'monitored demand concept' in simulation.

Except in 'monitored demand' simulation, expected monthly demand data are recurring in annual cycles while the reservoir's release during a particular month is changing from one year to another. The changes of the release are due to the variability of the considered inflow time series. In other words, the decisions based on the initial reservoir storage and the inflow during a particular month bring about different release rates in the same month of different years. Therefore, the approach to solve the problem of water allocation faces a serious obstacle: how to compare the demand (represented as an average monthly value) with the corresponding release which is fluctuating from one year to another. The use of average monthly outflow to overcome this difficulty would be misleading: (1) average flow in the river could be sufficient to cover the demand, but it would also ignore possible deficits in certain years; and conversely, (2) if average monthly flow falls short of the demand then the surplus of water which appears in some years cannot be utilized.

Therefore, the concept and the term of a monthly '**average useful flow**' (AUF_m) is introduced. The AUF_m is a part of the release allocated towards a particular demand in month ***m***. It is the sum of '**useful flows**' ($UF_{y,m}$) available to be supplied in a particular month divided by the number of years involved. The $UF_{y,m}$ for a certain month in a certain year is calculated according to the following relations:

$$\textit{if } \; flow_{y,m} > demand_m \;\; \textbf{then} \;\; UF_{y,m} = demand_m$$

$$\textit{if } \; flow_{y,m} \leq demand_m \;\; \textbf{then} \;\; UF_{y,m} = flow_{y,m}$$

$$\textit{subject to:} \qquad (3.2)$$

$$flow_{y,m} \geq 0$$

$$demand_m \geq 0$$

where

- $flow_{y,m}$ is the total release from a reservoir in the year y during the month m;
- $demand_m$ denotes the *real demand* for the month m.

After calculating the monthly volumes of $UF_{y,m}$ for every year, the value of the AUF_m can be determined:

$$AUF_m = \frac{\sum_y UF_{y,m}}{N} \tag{3.3}$$

where

- *y* denotes a year;
- ***m*** represents a month;
- *N* is the number of years considered.

The "new" (or remaining) demand for a demand centre, which is the part of the demand that could not be satisfied by the 'current' reservoir, is then calculated by:

$$new\,demand_m = demand_m - AUF_m \tag{3.4}$$

This part of unsatisfied demand should be covered by other reservoirs of the system.

The reduction of total reservoir release by the demand is simply done by deducting the demand from the outflow:

$$flow_{y,m} = flow_{y,m} - demand_m \tag{3.5}$$

It is obvious that the release rate can fall short of the demand in some months, thus the Equation 3.5 results in negative flow values for those months. The negative flow values, named as '**reservoir supply deficits**' ($RD_{y,m}$), which are physically impossible, are not converted to zeroes, because they will be used for calculating the '**average reservoir supply deficit**' (ARD_m). After considering all demand centres which are to be supplied by the reservoir, the ARD_m in a certain month is the average value of all the resulting negative flow values. It can be calculated as follows:

$$\begin{aligned} &\textbf{\textit{if}}\ \ flow_{y,m} \le 0\ \ \textbf{\textit{then}}\ \ RD_{y,m} = flow_{y,m} \\ &\textbf{\textit{if}}\ \ flow_{y,m} > 0\ \ \textbf{\textit{then}}\ \ RD_{y,m} = 0 \end{aligned} \tag{3.6}$$

and further

$$ARD_m = \frac{\sum_y RD_{y,m}}{N} \tag{3.7}$$

where

- y denotes a year;
- m represents a month;
- N is the number of years considered.

The remaining positive flow values represent non-consumptive free downstream flows. These flows (release or spill) can originate from different situations: (1) occurrence of floods; (2) considering the 'hypothetical demand distribution' in optimization process while having the value of annual median (or mean) inflow much higher than the total annual real demand (see Section 3.4.3); (3) as a consequence of the operational policy decision; etc.

The former description stands only for consumptive demands for water. However, for reservoirs that are supposed to cover a 'DRD component' (see Section 3.4.3) some modifications of the described algorithm are introduced. The flow left after the allocation of water to all envisaged demand centres to be supplied from the 'current' reservoir should be used to cover a possible DRD, if any. Moreover, the reservoir's operational policy should be created accordingly. This is achieved by considering the DRD as a demand. Although the DRD is not a real existing demand, it is considered to be an additional component of the aggregated demand (see Section 3.4.3). Accordingly, after the release has been allocated for all consumptive water demand components, the remaining part of the release can be allocated to cover the DRD. However, one difficulty appears at this point. As a part of the total demand, the DRD should be deducted from the total release thereby reducing the downstream flow. This would, however, leave space for two potential errors:

- If the DRD was a supply deficit of a reservoir situated on the same river downstream of the 'current' one and if it was treated as a consumptive demand component, the total available volume of water for the downstream reservoir (as a free downstream flow) would be diminished by the deducted amount.

- If the DRD was covered by an interbasin water transfer the allocated volume could exceed the capacity of the transfer structure. Furthermore, actual free flows downstream of the 'current' reservoir cannot contribute as additional inflows to the 'DRD reservoir' situated in another basin.

Due to the aforementioned pitfalls, the allocated water for a DRD-type demand and the final balance of the 'current' reservoir releases are divided into three components:

- **'Downstream reservoir supply'** ($DRS_{y,m}$) is estimated by the Equation 3.8 set. The set is similar to the one in Equation 3.2. Only a constraint that the allocated monthly volume must be less than or equal to the transfer structure capacity is introduced:

$$\begin{aligned} &\textbf{\textit{if}}\ \ flow_{y,m} > DRD_m\ \ \textbf{\textit{then}}\ \ DRS_{y,m} = DRD_m \\ &\textbf{\textit{if}}\ \ flow_{y,m} \le DRD_m\ \ \textbf{\textit{then}}\ \ DRS_{y,m} = flow_{y,m} \\ &\textit{subject to:} \\ &\qquad DRS_{y,m} \le WTSC \\ &\qquad flow_{y,m} \ge 0 \\ &\qquad DRD_m \ge 0 \end{aligned} \tag{3.8}$$

where
- $flow_{y,m}$ is the remainder of the release from the reservoir in the year y during the month m left after all direct demands have been supplied;
- DRD_m denotes the *downstream reservoir deficit* for the month m;
- $DRS_{y,m}$ denotes the *downstream reservoir supply* component in the year y during the month m to cover the DRD_m;
- ***WTSC*** is the designated *water transfer structure capacity.*

Consequently, the 'average useful flow' (AUF_m) to cover the DRD and the new DRD value are calculated by Equations 3.9 and 3.10, respectively:

$$AUF_m = \frac{\sum\limits_y DRS_{y,m}}{N} \tag{3.9}$$

$$new\,DRD_m = DRD_m - AUF_m \tag{3.10}$$

where
- y denotes a year;
- m represents a month;
- N is the number of years considered.

- The following step is to determine additional available monthly volumes of water (up to the transfer structure capacity) which can be conveyed towards the 'DRD reservoir'. These amounts of water are available, if so decided, to be utilized by the 'DRD reservoir'. They are denoted as '**downstream reservoir extra supply**' ($DRES_{y,m}$) and are estimated according to the Equation 3.11:

$$\begin{aligned} &\textit{if } flow_{y,m} > WTSC \textit{ then } DRES_{y,m} = WTSC - DRS_{y,m} \\ &\textit{if } flow_{y,m} \leq WTSC \textit{ then } DRES_{y,m} = flow_{y,m} - DRS_{y,m} \\ &\textit{subject to:} \\ &\qquad flow_{y,m} \geq 0 \end{aligned} \tag{3.11}$$

where

  - $DRES_{y,m}$ denotes the *downstream reservoir extra supply* component in the year y during the month m. It is the additional amount of water available to be transferred to another basin (positive difference between the transfer structure capacity $WTSC$ and the actual allocated water for transfer $DRS_{y,m}$ in month m in a year y).

- The remainder of a monthly release is attributed as a '**free downstream flow**' ($FDF_{y,m}$). These volumes (Equation 3.12) are not accessible to a 'DRD reservoir' which is supplied by an interbasin water transfer system.

$$\begin{aligned} &FDF_{y,m} = flow_{y,m} - (DRS_{y,m} + DRES_{y,m}) \\ &\textit{subject to:} \\ &\qquad flow_{y,m} \geq 0 \end{aligned} \tag{3.12}$$

where

  - $FDF_{y,m}$ denotes the *free downstream flow* component of the reservoir release in the year y during the month m.

This algorithm provides the consistent approach to both "types" of 'DRD reservoirs': (1) the ones situated on the same river course directly downstream of the 'current' one (by setting up the value of the transfer structure capacity to an extremely high value beyond the range of possible release volumes); and (2) the reservoirs supplied by an interbasin transfer.

As mentioned at the beginning of this section, the 'monitored demand concept' of simulation allows the demands to change from year to year. In fact, at the onset of each iteration it is assumed that the estimated annual demand distributions are recurring over the whole simulation period. However, by violating the SDP-based policy during simulation with respect to the actual demand, instead to its average estimate, it is clear that the demand records would not remain even in each year. The DEFICIT program updates the information of the actual monthly supply towards each demand and subsequently calculates the actual unsatisfied demand, if any. This can be described in a mathematical form by simply including an additional index *"y"* depicting a year to certain variables in the set of equations used to describe the release allocation algorithm in this section:

- The term $\boldsymbol{demand}_{m}$ in Equation 3.2 should be replaced by $\boldsymbol{demand}_{y,m}$.
- The variable $\boldsymbol{demand}_{m}$ in Equation 3.4 is the average of the $\boldsymbol{demand}_{y,n}$ estimated over N years of simulation. The variable $\boldsymbol{new\ demand}_{m}$ retains its old definition.
- The term $\boldsymbol{demand}_{m}$ in Equation 3.5 should also be replaced by $\boldsymbol{demand}_{y,m}$.
- The term $\boldsymbol{DRD}_{m}$ in Equation 3.8 should be replaced by $\boldsymbol{DRD}_{y,m}$.
- The variable $\boldsymbol{DRD}_{m}$ in Equation 3.10 represents the average of the $\boldsymbol{DRD}_{y,n}$ estimated over N years of simulation. The variable $\boldsymbol{newDRD}_{m}$ retains its previous definition.

NOTE: *The 'monitored demand concept' is not related to optimization but to simulation only. The estimates average demands are thus necessary to be calculated to provide this information for the optimization procedure.*

The process of total release allocation, subsequent flow reduction, and calculation of reservoir deficits can be summarized as follows:

(1) **Retrieve the total reservoir release records** and determine which **simulation approach** is to be used.
(2) **Retrieve the demand set** of the first demand centre (SSD, MSD, or DRD*).
(3) **Calculate the average useful flow** (AUF) for the current demand.
(4) **Reduce the demand** by the average useful flow.
(5) **Reduce the release values** by the current demand.
(6) **Retrieve the subsequent demand set** (step 2) and continue from **(3)**. The (2)-to-(5) loop is repeated for each demand centre supplied by the reservoir.
(7) Finally, **calculate the aggregated average reservoir supply deficit** (ARD).

* In case of the DRD demand component, the modified three-step procedure described in this section should be applied.

3.5 Simulation With Other Input Data

The main results of the optimization of a complex system operation are:

- Each reservoir's **operational policy** derived according to the respective distributed demand.
- Reservoir **releases** which are obtained by simulation over the historical inflow data and with respect to the optimal operational policy.
- Reservoir **supply deficits** (left after all the available water has been allocated), which are the basis for the evaluation of the system performance over the historical inflow data.

The created sets of operational policies and distributed demands can further be used to estimate the system behaviour and the return if other than the historical inflow data or demand data are employed. For instance, the system operation can be evaluated on **characteristic year inflows** (a standard dry, average or wet year), or sets of **increased or decreased demands.** Note that the result of such simulation might be quite far from being optimal, since no optimization took place. It can, however, serve as an excellent control to estimate the robustness and performance of the expectation oriented optimal reservoir operational policies.

For the simulation with **other reservoir inflow data**, the historical inflow data set has to be replaced by new inflow data time series. The lengths of these new data sets do not have to be identical to the one used to derive the operational policy. Note that the initial reservoir storage can have a major effect on the simulation results, especially if the new data set consists of only few years' records.

If the **demand** is to be changed, the 'original' demand values can simply be replaced by the new ones. The simulation routine includes the preparation of the 'distributed demand', the execution of the simulation itself, and the allocation of the derived reservoir releases. Note that not only the existing individual demands can be modified but completely new demand centres can be introduced. However, in this case, the fact that the operational policies have been derived according to different demand sets should not be forgotten while assessing the simulation results.

Finally, the main phases of the simulation over other input data are presented in the following:

(1) Perform the necessary **modifications in the corresponding input files** (inflow, demand).
(2) **Determine the decomposition sequence of simulation** (downstream, upstream, up-and-downstream).
(3) **Select the first reservoir.**
(4) **Simulation:**
- **Preparation of data of the reservoir characteristics;**
- **Preparation of inflow data;**
- **Preparation of demand data;**
- **Simulation** of the reservoir operation according to the existing policy;
- **Allocation of the resulting releases** to different demand centres.

(5) **Select the next reservoir and repeat stage (4).**

4 A COMPLEX RESERVOIR SYSTEM ILLUSTRATION EXAMPLE

The use of the ***ShellDP*** package is illustrated on an example of a five-reservoir water resources system. The case represents a part of a complex system situated in a river basin. Sub-humid to semi-arid climatic conditions prevail. The subsystem considered in this example consists of 5 large reservoirs (SS, KA, BH, BM, and ME) on the main river and its tributaries, and a diversion barrage EA (Figure 4.1). EA, in this case, having no significant storage space, is assumed to have little influence on the joint system operation and it is excluded from the optimization process.

These 5 multipurpose supply reservoirs form a complex subsystem with the joint objective to manage the available water resources of the basin. They form a network with both serial and parallel connections. They also have joint supply targets.

KA reservoir provides drinking water directly for the city of TU. This is its main purpose, largely due to its good water quality. Its downstream releases of non-consumptive water can be used as additional inflows to SS reservoir.

BM and BH reservoirs are in a cascade. The downstream one, BH, has basically its local irrigation demands to fulfil. The remaining downstream free releases flow towards SS. BM, with its water of high quality, first of all supplies TU with drinking water. The following supply targets are BE, MB, and JE provincial residential areas. If there is any non-consumptive water left, it is released towards BH to cover the shortages of the latter one.

ME supplies its own irrigation demand centre and provides water for irrigation to perimeters downstream of BH that BH reservoir might have failed to supply. It is the third reservoir of the system from which free downstream releases flow directly towards SS to cover its deficits.

SS is not only the downstream but also the largest reservoir of the system. In addition to its own natural inflows, it stores free releases from BH, KA, and ME reservoirs. It allocates water for irrigation purposes, and then supplies urban and tourist centres with drinking water.

This brief description of the case study system, the reservoirs, and their water allocation schemes and priorities shows the complexity of the optimization task. It is, for example, very important to supply TU with drinking water of high quality from KA and BM reservoirs as much as possible. Then, if shortage in this demand still exists, SS releases (with distinctly inferior quality of water) can be used to cover it.

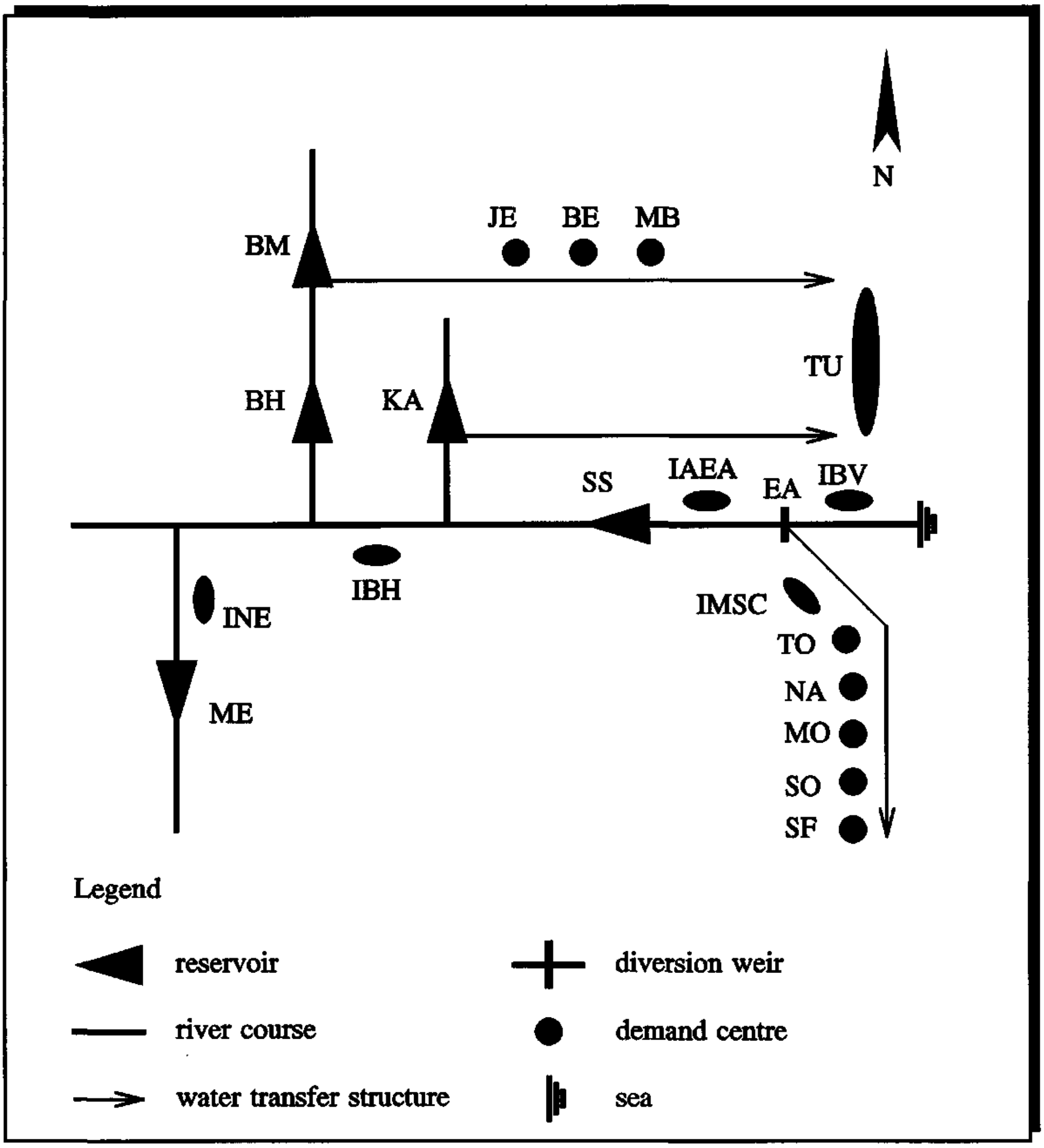
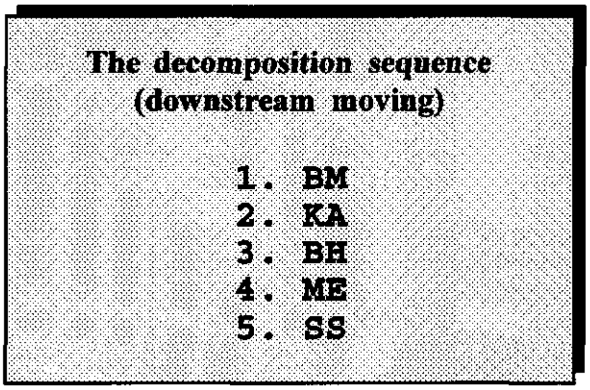


Figure 4.1 Five-Reservoir Water Resources System

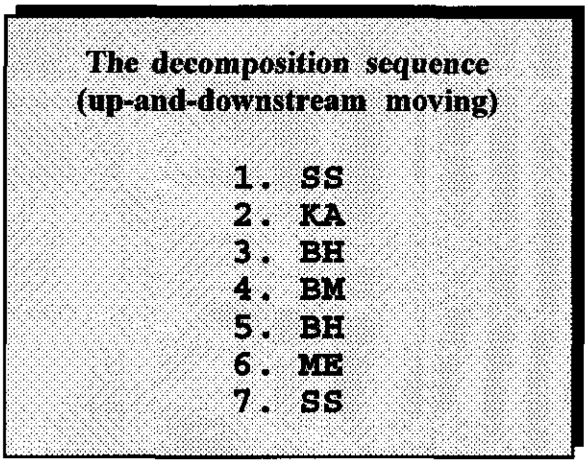
The optimization of such a system operation, due to dimensionality constraints, requires employment of certain decomposition technique (see Section 3.3). Sequential (downstream) and iterative (up-and-downstream) SDP based decomposition methods are used to present the application of the ***ShellDP*** package. Sequential and iterative optimization orders are presented on Figures 4.2 and 4.3, respectively. All examples, tables, and files presented in Appendix A are selected accordingly.



The decomposition sequence
(downstream moving)

1. BM
2. KA
3. BH
4. ME
5. SS

Figure 4.2 The Downstream Moving Decomposition Order



The decomposition sequence
(up-and-downstream moving)

1. SS
2. KA
3. BH
4. BM
5. BH
6. ME
7. SS

Figure 4.3 The Up-and-Downstream Moving Decomposition Order

5 THE *ShellDP* PACKAGE

5.1 General Features

This section provides basic information on the ***ShellDP*** program package, including the necessary hardware and software requirements, the list of executable routines, the elementary description of two possible running modes of the package. It also contains the recommended directory structure of the ***ShellDP***. The chapter proceeds with the detailed description of the individual routines of the package and ends up with the section about the adopted batch processing scheme.

5.1.1 Hardware and Software Components

The ***ShellDP*** package comprises several routines written in MS-FORTRAN 5.0 and TURBO PASCAL 5.5 programming languages for IBM PC compatible computers. The original SDP-based optimization models were programmed by *Nandalal* in 1991 and completed by *Kularathna* [1992]. First set of modifications were introduced by *Brorens* [1992]. Finally, this manual also includes the latest changes and adjustments of the package. The basic hardware requirements are, at least, an IBM PC AT personal computer, with the 80286, 80386, or more advanced main processor. Additional numerical processor unit is optional although it should not be forgotten that its presence provides a considerable reduction of processing time. To execute the largest program, approximately 400 kb of RAM memory is needed. The executable files take roughly 1 Mb of hard disk space while, on average, 0.3 Mb of free space is required for initial data, input, and one set of output files of the optimization and simulation of one reservoir performance. Note that additional 0.25 Mb of storage per optimization/simulation cycle of one reservoir operation are required for temporary results. On the **Tulip Vision Line• dt386**^{SX} (16MHz) computer, the complete computational cycle of optimization and simulation of one reservoir performance (given 25 storage classes) takes, on average, about 4 minutes. Consequently, one iteration cycle (for the case study system presented in Chapter 4) might require about 20 minutes of processing time. However, switching to a **486DX 33** machine reduces time requirements significantly. Namely, a single reservoir analysis (a complete optimization/simulation cycle) takes no more than 30 seconds.

The ***ShellDP*** software package actually consists of a set of programs, one for every major step of the optimization/simulation procedure (see Section 3.4). The main individual routines are listed in the following:

- **DEMAND.EXE:** Preparation of demand data and calculation of the 'distributed demand' (TURBO PASCAL 5.5);
- **INFLOW.EXE:** Preparation of inflow data (TURBO PASCAL 5.5);
- **POLICY.EXE:** Determination of reservoir optimal operational policy based on the SDP principles (MS-FORTRAN 5.0);
- **MODIFPOL.EXE:** This program performs user-defined modifications of operational policies derived by the POLICY program (MS-FORTRAN 5.0);
- **AGGRMD.EXE:** Aggregates individual demand time series into a single demand record in case of a 'monitored demand' simulation (MS-FORTRAN 5.0);
- **SIMULATE.EXE:** Simulation of the reservoir operation according to the optimal (or modified) policy (MS-FORTRAN 5.0);
- **DEFICIT.EXE:** Allocation of reservoir releases to different demand centres and calculation of reservoir deficiency in supply (TURBO PASCAL 5.5);
- **NEWDEM.EXE:** Auxiliary program which carries out the demand data transfer between two consecutive iteration steps (TURBO PASCAL 5.5);
- **DEMGEN.EXE:** Creation of demand time series (see Sections 3.4.1 and 3.4.5) in case of a 'monitored demand' simulation (MS-FORTRAN 5.0);
- **SHELL.EXE:** Menu operated shell which controls executions of all separate programs (TURBO PASCAL 5.5).

Note: *The FILES.EXE is an auxiliary program which is executed as one of the options of the SHELL.EXE program. It is also a menu operated shell and its description is included in the section of the SHELL.EXE. The DIRCHK.EXE is only used jointly with the POLICY.EXE program and its purpose is presented in Section 5.4 (The POLICY program).*

5.1.2 'Manage' and Batch Files

One complete optimization cycle is controlled and executed by the main batch and sets of auxiliary 'manage' and batch files. These files contain the necessary information about the optimization sequence of system elements, the order of program executions, data interchange between different routines, directory specifications of input and output files, etc.

The instructions (mainly input and output filenames) necessary for the execution of each program for the optimization of one reservoir operation (see Section 3.3) are put together in one file. This file, the '**manage file**', can be created either by using the SHELL program or any conventional editor. The 'manage file' has a comment section and seven program sections. The comment section starts with the code word 'COMMENTS', while the program sections start with code words associated with each programme ('INFLOW', 'DEMAND', 'POLICY', 'MODIFY', 'AGGREGATE', 'SIMULATE', and 'DEFICIT').

Important: *If a 'manage file' is created by using a conventional editor rather than SHELL program facilities, code words should be written in uppercase letters to avoid possible run-time errors.*

Each code word is followed by the list of names of the corresponding program input and output files, including some additional input information required by few of the programs. Each program searches through a 'manage file' for the respective code word. On finding the code, it reads the following records until a blank line is encountered. The remaining information in the 'manage file' is ignored. If a particular program execution is not needed during an optimization process, its code word is followed by a blank line which informs the program that no action is required. Consequently, the program ends with the message 'NOTHING TO DO'. The programs, actually, read instructions from a copy of the 'manage file'. The name of the duplicate must always be: MANAGE.TMP; thus indicating its temporary (TMP) nature. It should either be created by the SHELL program or by using the DOS 'COPY' command in the batch file. Appendix A gives examples of 'manage files' (Tables A.12 through A.16 and A.19 through A.28).

Note: *The comment section of a 'manage file' is ignored by the programs. The 'COMMENT' code word marks the beginning of records which contain information for the user only. The comment section length is confined to 20 lines.*

The complete optimization procedure can be performed either interactively or by using batch files. During the interactive run, the preparation of input and output files, and each program execution are directly controlled by the user. The whole interactive scheme is implemented in the SHELL program. Batch processing implies creation of auxiliary batch procedures consisting of operating system commands for carrying out these assignments. This approach enables the user to examine the system thoroughly, create the computational scheme, check the chosen algorithm, and run the procedure avoiding mistakes which might be made in accidental typing errors in an on-line interaction. Tables A.29 to A.33 (Appendix A) present examples of batch files.

Recommendations:

- The names used for 'manage files' could consist of a number indicating the order in which the reservoirs are being optimized and an abbreviation of the reservoir name. For example, for the 'Abcdef' reservoir which comes third in the optimization order, the 'manage file' name could be 3_AB.MAN.
- To avoid accidental mistakes associated with program code words it is advisable to use uppercase letters while creating 'manage files'.

5.1.3 Directory Structure

The entire optimization process of a complex reservoir system operation uses and produces a great number of files. In order to provide a clear overview of obtained results and to prevent files belonging to one iteration step from being overwritten during the next iteration, the use of different directories for storing all the files can be very helpful. The proposed directory structure for sequential (downstream moving) decomposition approach is presented on Figure 5.1 (introducing three iteration steps):

- The **SHELLDP** directory stores all the programs, 'manage', and batch files. This is the directory from which all the programs are executed. Note that all 'manage' and batch input files have to be copied from the **SY** directory (where they are originally stored) to this directory before starting a computational process.

- The **SY** directory: This is a, so called 'system directory' which contains all input files that do not change during iterations. These files are the reservoir data files, permanent additional inflow files, and the demand allocation files.

- The **PR** and the **CU** directories: The files from the previous iteration are stored in the ('previous') **PR** directory, while the ('current') **CU** directory contains the files from the current iteration step. When a new iteration step is initiated, the **PR** directory will be renamed to the **IT_#** directory with the corresponding iteration ordinal number and the **CU** directory will become the **PR**. The new iteration will also create its own **CU** directory. The advantage of such organization structure is that the 'manage', input, and output files in each iteration can have the same names.

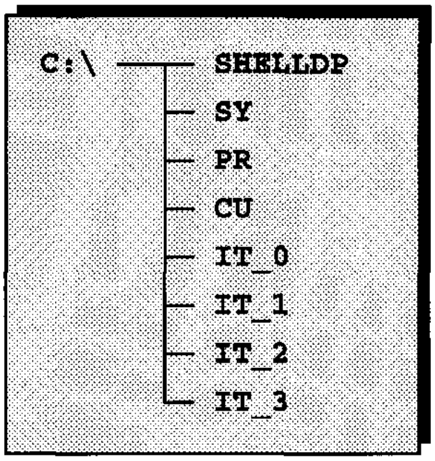


Figure 5.1 The *ShellDP* directory structure (going downstream)

- The **IT_0**, **IT_1**, **IT_2**, and **IT_3** directories: These are the initial demand input data directory, and the directories that contain output files from the first, the second, and the third iteration, respectively.

In the case of iterative (up-and-downstream) decomposition, the directory structure is basically the same. The only difference is that the **PR**, **CU**, **IT_0**, **IT_1**, **IT_2**, and **IT_3** directories are branching into two subdirectories: **UP** and **DO**. This provides the clear distinction between the results obtained when the decomposition is carried out in different directions (upstream and downstream). Examples of such applications can be seen in 'manage' and batch files of iterative decomposition in Appendix A (Tables A.19 through A.28 and A.31 through A.33).

Important: *The proposed directory structure conforms with the presented set of the* ***ShellDP*** *batch files. If any of the* **SHELLDP**, **CU**, **PR**, *or* **SY** *directory names is altered, the corresponding changes must be made in all 'manage' and batch files, and vice versa.*

5.2 The DEMAND Program

The DEMAND program calculates reservoir's 'distributed demand' which is later used in optimization and simulation steps. The 'distributed demand' is either a 'targeted real demand' or a 'hypothetical monthly demand' which could, for instance, be the median or the mean annual inflow to the reservoir distributed according to the 'targeted real demand' distribution (see Section 3.4.3). The program also passes the values of the objective function code and the weight factors for the objective function type 3 (if it is to be used) from the 'demand allocation file' to the POLICY program (see Section 2.2.2). The information is transferred via the 'distributed demand file'. The objective function code takes values of 1, 2, and 3 for the 'single sided squared deviation', the 'double sided squared deviation', and the 'two-component weighted squared deviation' objective function, respectively.

• FILES •

The DEMAND program uses two input files and creates one output file. The input data requirements are:

- The '**general demand file**' contains water demand data for the whole system (Table A.11 of Appendix A). This file has to be created by the user. The format of file records is described in Appendix L.

- The '**demand allocation file**' consists of the value of annual median (or mean) inflow to the reservoir (or the value '**-999.999**' if the 'real' demand is used), the code of the objective function type, weight factors of the objective function type 3, simulation code, and the list of demand centres which are supplied by the reservoir; Tables A.6 to A.10 of Appendix A display the 'demand allocation files' of five reservoirs of the presented system. The format of the file is given in Appendix L.

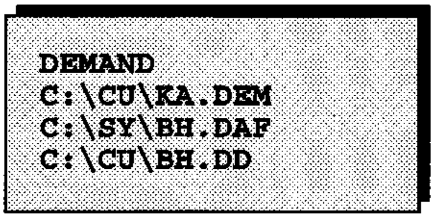
The program creates a '**distributed demand file**' which contains the 'distributed demand' set for the reservoir and the values of the objective function code and weight factors for the objective function type 3. A short description of calculations that are performed by this program is given at the end of this file. Examples of these three file types are presented in Tables B.1 to B.3 (Appendix B). The files originate from the second iteration of the sequential (downstream moving) decomposition algorithm. They are presented according to the corresponding commands in the 'manage file' which is presented in the Table A.14 (Appendix A).

The input and output file names (including full paths) have to be written in the appropriate 'manage file', following the 'DEMAND' code word. The DEMAND program reads those records and considers them, in the following order, as the names of:

- 'general demand file' (input);

- 'demand allocation file' (input);
- 'distributed demand file' (output).

Example: For the BH reservoir (Figure 5.2), the distributed demand is calculated on the basis of data from the KA.DEM ('general demand file') and BH.DAF ('demand allocation file') input files. The results are written to the BH.DD file ('distributed demand file'). Note that full path names have to be entered. If not, the DEMAND program would search for input files and write the output file on the current directory (i.e., the directory where the DEMAND program is) which would cause the termination of the optimization procedure with error status.



```
DEMAND
C:\CU\KA.DEM
C:\SY\BH.DAF
C:\CU\BH.DD
```

Figure 5.2 The DEMAND section of a 'manage' file

• PROGRAM EXECUTION •

The DEMAND program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP and then entering the 'DEMAND' command at the DOS-prompt (or from the SHELL program). The program will then search through the MANAGE.TMP file for the 'DEMAND' section and read the listed file names. If the program run is successfully finished, the corresponding 'READY' message will appear on the screen. In case of errors, error messages are displayed. Execution of the DEMAND program should take no more than a couple of seconds.

5.3 The INFLOW Program

This program has several purposes, but the main one is to calculate cumulative monthly volumes of inflows to the reservoir. This is done by adding up all specified flow records to the own unregulated inflow of the current reservoir (see Section 3.4.2). Shortly, this program enables the use of additional inflows to a reservoir while optimizing (or simulating) its performance. If no additional inflows to a reservoir are expected (like the case of the uppermost reservoir in a cascade), this program's execution can be omitted. Adding the contents of one or more 'flow files' to the observed streamflow section of a 'reservoir data file' is initiated by using the 'ADD-TO' command in the corresponding 'manage file' (Tables A.14, A.16, A.20, A.24, A.26, and A.28 of Appendix A). If more than two files are to be added, multiple 'ADD-TO' commands should be used due to the fact that each command adds the contents of two files only. In such cases, some auxiliary (temporary) files have to be created. Appendix C (Tables C.1 through C.5) contains the example of the INFLOW program input files and the output 'new reservoir inflow file'. The files originate from the second iteration of the sequential (downstream moving) decomposition algorithm. The program is run following the commands from the 'manage file' presented in the Table A.14 (Appendix A).

• THE 'ADD-TO' COMMAND •

This command is used for adding up the contents of two '**flow files**', or a '**flow file**' and the flow section of a '**reservoir data file**'. The program distinguishes a 'flow file' from a 'reservoir data file' in the following: (1) the first character of the first word in the first record of a 'flow file' must be a digit; whereas (2) the corresponding character in a 'reservoir data file' must be a letter.

Important: *The lengths (number of years) of inflow records in both input files have to be identical. If not, the INFLOW program terminates with error status.*

The output file is always of the 'flow file' format and it is called the '**new reservoir inflow file**'. The syntax of the 'ADD-TO' command is:

ADD 'flow file 1' 'flow file 2' TO 'flow file 3'

```
INFLOW
ADD C:\SY\BH.RES  C:\CU\BM.DRS TO C:\CU\BH1.ERS
ADD C:\CU\BH1.ERS C:\CU\BM.DRE TO C:\CU\BH2.ERS
ADD C:\CU\BH2.ERS C:\CU\BM.FDF TO C:\CU\BH.NIF
```

Figure 5.3 The INFLOW section of a 'manage' file

Example: BH reservoir is situated downstream of BM reservoir, thus being the 'DRD reservoir' of BM (see Section 3.4.6). In order to add the 'downstream reservoir supply' flows (DRS), 'downstream reservoir extra supply' flows (DRES), and 'free downstream flows' (FDF) from BM to the own (unregulated) inflow of BH, the commands given in

Figure 5.3 have to be put into the 'manage file' of BH. The flows from BM are added to the own inflow of BH (which can be found in the 'reservoir data file' BH.RES). Note that downstream flows from BM are separated into three components (see Section 3.4.6). The operation requires two interim result files (BH1.ERS and BH2.ERS). The final result is the 'new reservoir inflow file' designated as BH.NIF.

Note: *The description of the *.DRS, *.DRE, and *.FDF files is given in Section 5.8.*

• PROGRAM EXECUTION •

The program execution is carried out in two steps: (1) first, a MANAGE.TMP copy of the current reservoir's 'manage file' is opened (if the proper copy does not already exist it should be created prior to calling the INFLOW program); and (2) the program is initiated by entering the 'INFLOW' command at the DOS-prompt (or from the SHELL program). The INFLOW program searches through the MANAGE.TMP file for the 'INFLOW' section, reads the following lines, and performs the specified actions. In case of errors, error messages are displayed. Execution should take no more than 15 seconds.

Important: *The size of the inflow section of a 'manage file' can be maximum 20 lines, thus limiting the number of inflow files to be added to 21.*

Note: *Additional features of the INFLOW program, which are not presented in this section can be found in Appendix C (Table C.6).*

5.4 The POLICY Program

The POLICY program carries out the SDP-based optimization of a reservoir's operation. This program follows the computational algorithm described in Section 3.4.4.

• FILES •

As initial input data (the instructions are stored in the corresponding 'manage file') the program requires the following (see Figure 5.4):

- The **number of characteristic classes representing the reservoir storage** (see Section 2.2). This value is a part of the input set in the 'POLICY' section of the 'manage file'. The maximum number of storage discretizations in this model is limited to 55. This restriction is introduced due to hardware capacities.

- The '**reservoir data file**' contains the description of the reservoir (maximum capacity, dead storage volume, maximum outflow, inflow correlation coefficient threshold, observed inflow sequence, characteristic curves, and estimates of evaporation losses). Tables A.1 to A.5 (Appendix A) display 'reservoir data files' for all five reservoirs. This file has to be created by the user. The format of the file is described in Appendix L.

- Optional: A '**new reservoir inflow file**', which was created by the INFLOW program (see Section 5.3). If there are no inflow records in addition to the one from the 'reservoir data file' then a hyphen ('-') should be entered instead.

- The '**distributed demand file**', which has been created by the DEMAND program (see Section 5.2).

The 'POLICY' section continues with the list of output files. Optimization procedure results are stored in two files:

- The '**policy file**', which contains inflow and storage volume class margin values, and the derived operational policy tables. The example and a description of a 'policy file' is presented in Table D.1 of Appendix D, and a more detailed description of one policy table is presented in Table D.2 (Appendix D).

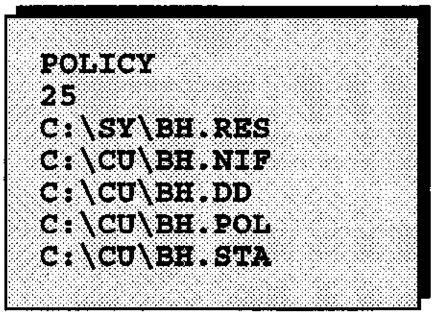
- The '**statistical details file**' is an additional output file which consists of optimization statistical details, such as representative inflow values, inflow transition probabilities, and policy tables. The illustration of this file is displayed in Table D.3 of Appendix D.

The presented results of the SDP based optimization procedure performed by the POLICY program are derived on the basis of the instructions given in the 'manage file' from Table A.14 of Appendix A. The files originate from the second iteration of the sequential (downstream moving) decomposition algorithm.

The input and output file names (including full paths) have to be written in the appropriate 'manage file', following the 'POLICY' code word. The POLICY program reads those records and considers them, in the following order, as:

- the number of storage discretizations (input);
- 'reservoir data file' (input);
- 'new reservoir inflow file' (input);
- 'distributed demand file' (input);
- 'policy file' (output);
- 'statistical details file' (output).

Example: For the BH reservoir, the 'POLICY' section in the 'manage file' is presented in Figure 5.4. The number of storage classes is 25; the 'reservoir data file' is BH.RES; the BH.NIF is the 'new reservoir inflow file'; the distributed demand is to be found in the BH.DD file; the output 'policy file' is BH.POL; and the 'statistical details file' is BH.STA.



```
POLICY
25
C:\SY\BH.RES
C:\CU\BH.NIF
C:\CU\BH.DD
C:\CU\BH.POL
C:\CU\BH.STA
```

Figure 5.4 The POLICY section of a 'manage' file

• PROGRAM EXECUTION •

The program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP. Note that this is not needed if the proper copy of MANAGE.TMP already exists. The process is continued by entering the 'POLICY' command at the DOS-prompt (or from the SHELL program). On indicating the 'POLICY' section of the MANAGE.TMP file, the program reads the following input data and continues the execution. In case of errors, error messages are displayed. The POLICY program is, considering the elapsed processing time for one execution, the most demanding one of the package. This is due to a large number of possible state transitions which is the consequence of the stochastic nature of the inflow state. Depending on the computer type, the number of discretizations of storage and inflow space, the hydrological regime, and whether transitional probabilities or only independent ones are considered etc., it can take from less than one up to thirty minutes.

Important: *Before running the POLICY program, the DIRCHK (DIRectory CHecK) program should be executed. It is an auxiliary program which checks the existing directory structure and, if necessary, creates the proper one before the POLICY program is run. The* *term "proper directory structure" refers to the POLICY program requirement that all the directories specified in the policy section of the 'manage file' (Figure 5.4) have to be created before the POLICY is run. When the SHELL program is used to run the* ***ShellDP****, the inspection of the directory structure is done automatically, thus the DIRCHK has to be executed only if batch processing mode is applied (see Appendix A, Tables A.30, A.32, and A.33). However, if the user is confident that the "proper" directory structure exists, the execution of the DIRCHK can be avoided.*

5.5 The MODIFPOL Program

Operational policy derived by the POLICY program strictly follows all the initial criteria, such as: (1) minimization of the objective function value; and (2) constraints related to the limiting values of reservoir storage (dead and maximum storage). If any additional changes of operational policy are required (regardless of their influence on effectiveness of reservoir operation), the MODIFPOL program performs those adjustments before the SIMULATE program is run. It is clear that any policy modifications are individual choices, depending on the problem that is being solved. This was the main reason to create the MODIFPOL program. The present version of the program checks whether the proposed release policy fulfils two different criteria and, if not, changes it accordingly. These policy modifications are introduced to make releases more consistent with conventional reservoir operational practice:

- **Comparison of the actual monthly demand with the characteristic inflow value**: If the characteristic inflow value is less than the actual demand of the same month, then the targeted final storage volume must be at least one class lower than the initial storage volume. If the optimal policy defines a final storage class which does not comply with this condition, the original final storage target is adjusted by replacing the original value by the class one step lower than the initial one (of course, the minimum storage limit must not be violated).

- **Reservoir filling**: After the previous check and possible modifications are finished, an additional control has to be carried out only for the initial storage states representing reservoir fillings over 50% of the live storage volume. The following criteria are used:

if $0.5\,(S_{\max} - S_{\min}) \geq SI_i$

and $Inflow_{m,j} - (SF_{i,j} - SI_i) < Demand_m$

and $SF_{i,j} > S_{\min}$

then *reduce the* $SF_{i,j}$ *target by one more class.*

where

- $Inflow_{m,j}$ represents the inflow class ***j*** in month ***m***;
- SI_i is the initial storage state (class ***i***);
- $SF_{i,j}$ is the decision to be taken (the final storage state) as a function of the initial storage state (class ***i***) and the inflow class ***j*** during month ***m***;
- S_{min} and S_{max} are the minimum and maximum storage volumes of the reservoir, respectively;
- $Demand_m$ represents the demand for water in month ***m***.

These policy modifications ensure that at least some releases are made from a "non-empty" reservoir to mitigate shortages. The second modification might allow further releases from a "well-filled" reservoir. While these policy modifications are clearly non-optimal, they reflect possible pressure on reservoir managers in real-world on-line operation.

• FILES •

The MODIFPOL program requires two input files:

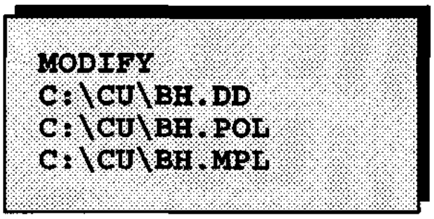
- The '**distributed demand file**' (created by the DEMAND program: see Section 5.2).
- The '**policy file**', with the derived operational policy tables (see Section 5.4).

The output is a '**modified policy file**' which is, as far as file structure is concerned, identical to the input 'policy file'. The only changes can be recognized in different targeted storage volumes for certain combinations of initial states (initial storage and inflow to the reservoir). The 'modified policy file', derived on the basis of the instructions given in the 'manage file' from Table A.14 of Appendix A, is presented in Appendix E (Table E.1). The file originates from the second iteration of the sequential (downstream moving) decomposition algorithm.

The input and output file names (including full paths) have to be written in the appropriate 'manage file', following the 'MODIFY' code word. The MODIFPOL program reads those records and considers them, in the following order, as:

- 'distributed demand file' (input);
- 'policy file' (input);
- 'modified policy file' (output).

Example: For the BH reservoir, the 'MODIFY' section in the 'manage file' is presented in Figure 5.5. The distributed demand is to be found in the BH.DD file; the input 'policy file' is BH.POL; and the results are stored in the 'modified policy file' named BH.MPL.



```
MODIFY
C:\CU\BH.DD
C:\CU\BH.POL
C:\CU\BH.MPL
```

Figure 5.5 The MODIFY section of a 'manage' file

• PROGRAM EXECUTION •

The program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP (note that this is not needed if the proper copy of MANAGE.TMP already exists) and then entering the 'MODIFPOL' command at the DOS-prompt (or from the SHELL program). On indicating the 'MODIFY' section of the MANAGE.TMP file, the program reads the names of input and output files and continues the execution. In case of errors, error messages are displayed. Execution should take no more than five seconds.

Note: *It has to be mentioned that the use of the MODIFPOL program is optional. The user can require that the optimal operational policy derived by the POLICY is used in simulation. If this is the case, the run of the MODIFPOL program can be avoided. There are three ways of doing so:*

- ***Removing the MODIFPOL program section from the 'manage file'.*** *This option can be used in both interactive and batch execution modes. It provides that the MODIFPOL run is terminated with the message "NOTHING TO DO" (see Section 5.1.2). The "NOTHING TO DO" mode is assumed if any of the three input lines of the MODIFPOL section in a 'manage file' is empty.*

- ***Omitting the execution of the MODIFPOL in the corresponding batch file.*** *This option can be implemented only in batch processing mode. It does not require the removal of the MODIFPOL program section from the 'manage file'.*

- ***Omitting the execution of the MODIFPOL from the SHELL program.*** *This option can be implemented only in individual, one-by-one, execution of separate programs of the package (the* ***PROGRAMS*** *option of the SHELL). It does not require the removal of the MODIFPOL program section from the 'manage file'. However, if the* ***TOOLS/RUN ALL*** *option of the SHELL is to be used, the MODIFPOL program section has to be removed from the 'manage file'.*

5.6 The AGGRMD Program

This routine is used only if a 'monitored demand concept' of simulation and the subsequent release allocation are applied (see Sections 3.4.5 and 3.4.6). Namely, the program is needed to aggregate individual demand centres' (and DRD) time series into a single record associated with the reservoir in question. Only this simulation option provides means to continuously update the information on the extent of each demand target fulfilment throughout the entire simulation period. However, this feature requires that each time series is kept in a separate file (see also Section 5.10). Therefore, it is necessary to aggregate all the respective demand records prior to carrying out 'monitored' simulation.

• FILES •

The AGGRMD program input filenames are listed in the 'AGGREGATE' section of a 'manage file' (Figure 5.6). Note that the 'AGGREGATE' section contains *only a partial set of input and no output file names.* This safeguarded approach is selected to prevent accidental switching from 'average' to 'monitored' simulation because both methods are initiated by the same simulation code (see Sections 3.4.1 and 3.4.5). Namely, unlike 'average' simulation concept, the latter requires some additional files to be available. These files are initially created by the DEMGEN program and subsequently shared by AGGRMD, SIMULATE, and DEFICIT programs. Input files listed in the 'AGGREGATE' section of a 'manage file' are:

- The '**demand allocation file**' (see Section 5.2).
- The name of the '**simulation output file**' which will be created in the subsequent step by the SIMULATE program.

From the 'demand allocation file' of a reservoir the AGGRMD program reads the respective demand names and searches for specific files to read demand time series. These files, in a standard 'flow file' format (see SHELL HELP and Section 5.3), are named according to the following rules:

- The path is the same as the path of the 'simulation output file'. Note that the 'simulation output file' does not exist and has yet to be created. The information given here is only to prepare the complete input for the 'monitored' simulation.
- The file name is the demand centre's code name from the 'demand allocation file'.
- The extension is 'RMD'.

Important: *If the AGGRMD program could not find all the files bearing the expected names it would terminate execution with error status.*

The resulting '**aggregated demand file**' name is also created by the program automatically (this file is also in a standard 'flow file' format):

- The path is the same as the path of the 'simulation output file'.
- The name is created by adding suffix 'DEM' to the 'simulation output file' name.
- The extension is 'AGG'.

Example: *According to the 'AGGREGATE' section given in Figure 5.6 (excerpt from the 4_ME.MAN 'manage file' given in Table A.15 of Appendix A), the AGGRMD program sums the corresponding demand values from the files C:\CU\INE.RMD, C:\CU\IBH.RMD, and C:\CU\DSS.RMD, and creates the output file named C:\CU\MEDEM.AGG.*

An example of the AGGRMD program output file is are given in Appendix J (Table J.1). The example originates from the second iteration of the sequential (downstream moving) decomposition algorithm employing the 'real demand' approach of optimization with respect to the objective function type 2 and the 'monitored demand concept' of simulation. It is derived on the basis of the instructions listed in the 'manage file' from Table A.15 of Appendix A.

Note: *This type of analysis could be achieved by performing the following modifications:*

- *'demand allocation files' (Tables A.6 through A.10): the annual median inflow value should be replaced by* ***'-999.999'****; the objective function code and the simulation codes should both be set to* ***'2'*** *instead of* ***'1'****;*

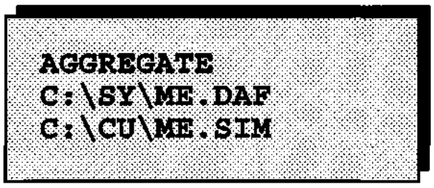
- *'entire process batch file' (Table A.29): the* ***'rem'*** *DOS commands from the three iteration blocks should be removed to enable execution of the DEMGEN program;*

- *'single iteration batch file' (Table A.30): the* ***'rem'*** *DOS commands from the five reservoir optimization/simulation blocks should be removed to enable execution of the AGGRMD program;*

The input file names (including full paths) have to be written in the appropriate 'manage file', following the 'AGGREGATE' code word. The AGGRMD program reads those records and considers them, in the following order, as:

- 'demand allocation file' (input);
- 'simulation output file' (input);

Example: For the BH reservoir (Figure 5.6), the demand time series are stored in files named on the basis of data from the BH.DAF ('demand allocation file') and according to the expected name of the 'simulation output file' BH.SIM. The results are written to a file ('aggregated demand file') named C:\CU\BHDEM.AGG.



```
AGGREGATE
C:\SY\ME.DAF
C:\CU\ME.SIM
```

Figure 5.6 The AGGREGATE section of a 'manage' file

• PROGRAM EXECUTION •

The program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP (note that this is not needed if the proper copy of MANAGE.TMP already exists) and then entering 'AGGRMD' at the DOS-prompt (or from the SHELL program). The program searches through the MANAGE.TMP file for the 'AGGREGATE' section, reads the list of input instructions and continues with calculations. In case of errors, error messages are displayed. Execution takes not more than thirty seconds for a simulation period of 40-50 years with monthly time steps.

5.7 The SIMULATE Program

Assessment of a reservoir operational policy derived by the POLICY program (or adjusted by the MODIFPOL) is carried out by simulation of the reservoir performance. The SIMULATE program provides results on reservoir operation efficiency on the basis of the specified inflow sequence, reservoir operational policy, demand, and initial storage volume of the reservoir. The SIMULATE program calculates values of reservoirs final storage volumes at the end of each month according to the derived operational policy and with respect to the initial states (storage volume and inflow to the reservoir). Given these three state values and the estimate of evaporation losses, reservoir releases during the current month are fully determined. Now, having the value of the demand for a certain month, it is possible to assess whether it is met or not, to define reservoir supply deficit, spillage, and free downstream releases.

As described in Sections 3.4.1 and 3.4.5, simulation can be carried out in four different modes. The mode is defined by an integer code in the respective 'demand allocation file':

- 0 - 'overrule' simulation approach;
- 1 - simulation strictly following the derived policy;
- 2 - 'avoid excess release' simulation comprises two different approaches: the 'average' and the 'monitored' demand concepts (the latter requires use of the DEMGEN and AGGRMD programs).

Note: *If any value other than 0, 1, or 2 is given, the simulation model assumes the simulation mode 1. In addition, to distinguish between the two suboptions of the simulation mode 2, if the SIMULATE program could find the appropriate 'AGG' file (e.g., the file C:\CU\BHDEM.AGG in the previous section) it would assume the 'monitored demand concept'. Otherwise, the 'average demand concept' of the 'avoid excess release' simulation would be performed. In either of the four cases, the appropriate message is written to the 'simulation output file'.*

• FILES •

The SIMULATE program input and output filenames are listed in the 'SIMULATE' section of a 'manage file' (Figure 5.7). In addition to the 'demand allocation file', the input files are the same as the input files for the POLICY program, followed by the 'policy file' or the 'modified policy file' (see Sections 5.4 and 5.5). Note that the only file that is not listed is the 'aggregated demand file' which is needed in the 'monitored demand' simulation. Input data and files for the program are:

- The '**reservoir data file**' (see Sections 3.4.1 and 5.4).

- The '**demand allocation file**' (see Section 5.2).

- Optional: A '**new reservoir inflow file**', which has been created by the INFLOW program (see Section 5.3). If there are no additional inflows to the current reservoir a hyphen ('-') should be entered instead.

- The '**distributed demand file**', which has been created by the DEMAND program (see Section 5.2).

- The '**policy file**' or the '**modified policy file**', which contains inflow and storage volume class margin values, and the derived operational policy tables (see Sections 5.4 and 5.5).

- The '**initial filling state factor**' (IFS) which determines the initial storage volume of the reservoir as a fraction of its active storage volume (e.g., 1.0 = full; 0.5 = half full; 0.0 = empty). This factor provides the opportunity of reservoir operation assessment for different initial reservoir fillings.

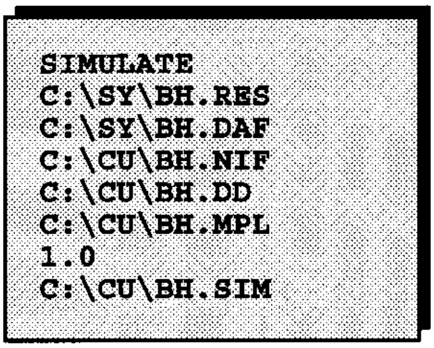
The SIMULATE program stores the results in a '**simulation output file**'. It contains the reservoir water balance data for every month and every year of the period considered, specifying initial and final storage volumes, inflows, releases, and evaporation losses. The 'simulation output file' example is presented in the Table F.1 (Appendix F). The example originates from the second iteration of the sequential (downstream moving) decomposition algorithm. It is derived on the basis of the instructions listed in the 'manage file' from Table A.14 of Appendix A.

The input and output file names (including full paths) have to be written in the appropriate 'manage file', following the 'SIMULATE' code word. The SIMULATE program reads those records and considers them, in the following order, as:

- 'reservoir data file' (input);
- 'demand allocation file' (input);

- 'new reservoir inflow file' (input);
- 'distributed demand file' (input);
- 'policy file' or 'modified policy file' (input);
- initial filling state factor (input);
- 'simulation output file' (output).

Example: For the BH reservoir, the 'SIMULATE' section in the 'manage file' is presented in Figure 5.7: the 'reservoir data file' is BH.RES; the 'demand allocation file' is BH.DAF; the 'new reservoir inflow file' is BH.NIF; the distributed demand is to be found in the BH.DD file; the 'modified policy file' is BH.MPL; the initial storage volume is adopted to be equal to full live storage capacity; the simulation results are written in the BH.SIM file.



```
SIMULATE
C:\SY\BH.RES
C:\SY\BH.DAF
C:\CU\BH.NIF
C:\CU\BH.DD
C:\CU\BH.MPL
1.0
C:\CU\BH.SIM
```

Figure 5.7 The SIMULATE section of a 'manage' file

• PROGRAM EXECUTION •

The program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP (note that this is not needed if the proper copy of MANAGE.TMP already exists) and then entering 'SIMULATE' at the DOS-prompt (or from the SHELL program). The program searches through the MANAGE.TMP file for the 'SIMULATE' section, reads the list of input/output instructions and continues with calculations. In case of errors, error messages are displayed. Execution takes not more than thirty seconds for a simulation period of 40-50 years with monthly time steps.

5.8 The DEFICIT Program

On the basis of simulation results, the DEFICIT program allocates the available water to demand centres according to the specified order in the 'demand allocation file'. This program actually calculates average reservoir supply deficits, non-consumptive water releases towards a downstream reservoir, and the remaining demands that have not been supplied by the current reservoir. It follows the procedure described in the Section 3.4.6.

• FILES •

As input data, the DEFICIT program requires:

- The '**simulation output file**', which was created by the SIMULATE program (see Section 5.7).
- The '**general demand file**' (see Section 5.2), the file that contains water demand data for the whole system.
- The '**demand allocation file**' of the current reservoir (see Section 5.2).
- The '**reservoir deficit name**' is the code name to which the reservoir supply deficit record is attached in the 'new general demand file'.
- The '**downstream reservoir deficit name**' is the code name of the 'DRD reservoir'. This information determines that, although it is considered as a demand, water allocated to meet the 'DRD demand' will be treated differently than consumptive demand components (see Section 3.4.6). If there is no 'DRD reservoir', a hyphen ('-') must be entered instead.
- The **capacity of the water transfer structure** towards the reservoir denoted as the 'DRD reservoir' (see Section 3.4.6). If there is no 'DRD reservoir' a hyphen ('-') must be entered instead. If a 'DRD reservoir' is on the same river course as the current one a hyphen should also be entered, meaning that the capacity would be automatically set to an extremely high value (beyond the possible range of reservoir releases).

Note: *If the 'monitored demand concept' of simulation is selected the DEFICIT program requires several additional input files. Similarly to the adopted approach in simulation (as described in the previous section) the DEFICIT program assumes automatically the names of the 'aggregated demand file' and the respective 'individual demand time series files'. If, in case when simulation mode 2 is selected, the DEFICIT programme could find the appropriate 'AGG' file (e.g., the file C:\CU\BHDEM.AGG in Sections 5.6 and 5.7) it would assume the 'monitored demand concept'. Otherwise, the 'average demand concept' of the 'avoid excess release' simulation would be performed. In either case, the appropriate message is written to the 'interim results file'.*

The output files are described in the following:

- The '**new general demand file**' (Table G.1 of Appendix G) contains the new demand values left after the current reservoir has allocated all the available water to its demand centres, and the updated supply deficits of the 'current' and a potential 'DRD reservoir' (see Section 3.4.6). The remaining records of the input 'general demand file' stay unchanged.

- The '**free downstream flow file**' (Table G.2 of Appendix G) contains a set of free releases from a reservoir. These flows are the part of reservoir releases that has remained after all demands are covered as much as possible (see Section 3.4.6).

- The '**interim results file**' contains detailed results of the DEFICIT program execution. These data describe each step of the water allocation procedure. The example of this file is displayed in Table G.3 of Appendix G.

- A **'downstream reservoir supply file'** is created if a 'DRD reservoir' exists. The file contains monthly volumes of water (up to the water transfer structure capacity) allocated to the 'DRD reservoir'. If there is no 'DRD reservoir' a hyphen ('-') must be entered instead. This file is created according to the algorithm described in the Section 3.4.6 and the example is presented in the Table G.4 of Appendix G.

- A **'downstream reservoir extra supply file'** consists of the deviations between the water transfer structure capacity and the monthly volumes allocated towards the 'DRD reservoir'. If there is no 'DRD reservoir' a hyphen ('-') must be entered instead. The form of the file is displayed in the Table G.5 of Appendix G.

Note: *If the 'monitored demand' simulation is selected, the DEFICIT program updates information on monthly demands in the respective 'individual demand time series files'. Namely, throughout the entire simulation period the program deducts the actual monthly supply volumes towards a certain demand from the input demand information stored in the 'individual demand time series file' for each demand centre associated with the reservoir in question. In this way the remaining reservoirs on the system are provided with the updated information on demand fulfilment over the entire time span.*

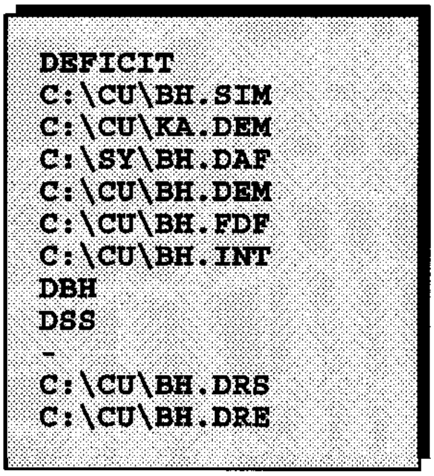
The output files presented in Appendix G are created during the DEFICIT program execution which is controlled by the instructions from the 'manage file' in Table A.14 of

Appendix A. They originate from the second iteration of the sequential (downstream moving) decomposition algorithm.

The input and output file names (including full paths), together with other input data described, have to be written in the appropriate 'manage file', following the 'DEFICIT' code word. The DEFICIT reads those records and considers them in the following order as:

- 'simulation output file' (input);
- 'general demand file' (input);
- 'demand allocation file' (input);
- 'new general demand file' (output);
- 'free downstream flow file' (output);
- 'interim results file' (output);
- reservoir deficit name (input);
- downstream reservoir deficit name (input);
- water transfer structure capacity (input);
- 'downstream reservoir supply file' (output);
- 'downstream reservoir extra supply file' (output).

Example: For the BH reservoir (BH), the 'DEFICIT' section in the 'manage file' is presented in Figure 5.8: the 'simulation output file' is BH.SIM; the 'general demand file' is KA.DEM; the 'demand allocation file' is BH.DAF; the 'new general demand file' BH.DEM will be created; the 'free downstream flow file' is BH.FDF; the 'interim results file' is BH.INT; the DBH is the code name assigned to BH supply deficits record; DSS denotes that SS is the 'DRD reservoir'; the hyphen ('-') indicates that there are no limitations to the capacity of the water transfer towards SS; the 'downstream reservoir supply file' is BH.DRS; and the 'downstream reservoir extra supply file' is BH.DRE.



```
DEFICIT
C:\CU\BH.SIM
C:\CU\KA.DEM
C:\SY\BH.DAF
C:\CU\BH.DEM
C:\CU\BH.FDF
C:\CU\BH.INT
DBH
DSS
-
C:\CU\BH.DRS
C:\CU\BH.DRE
```

Figure 5.8 The DEFICIT section of a 'manage' file

• PROGRAM EXECUTION •

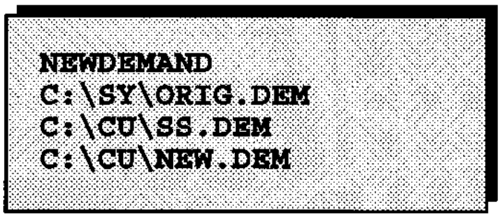
The program is executed by first copying the 'manage file' for the current reservoir to a file called MANAGE.TMP (note that this is not needed if the proper copy of MANAGE.TMP already exists) and then entering 'DEFICIT' at the DOS-prompt (or from the SHELL program). The program searches through the MANAGE.TMP file for the 'DEFICIT' section, reads the following records and continues execution. In case of errors, error messages are displayed. Execution takes not more than a minute, depending mainly on the number of years in the data set and the number of reservoir's supply targets.

5.9 The NEWDEM Program

The sequential decomposition approach requires a specific data transfer between two consecutive iteration steps (see Section 3.3). One iteration cycle results, among all, in reservoirs' supply deficits which are, in the following iteration, used as supplementary demands in optimizing the system operation. Each iteration starts by using the original consumptive demand distributions which are stored in the 'general demand file' (Table A.11 of Appendix A), but it should also consider reservoirs' supply deficits obtained in the previous iteration cycle. However, this file does not contain the updated values of reservoirs' supply deficits. These data are stored in the 'new general demand file' of the lowest reservoir in the system (see Section 5.8). The NEWDEM program takes the original consumptive demand distributions from the 'general demand file' and reservoirs' supply deficits from the 'new general demand file' and puts them, separated by a dashed line, into a new file. To be more specific: (1) the program reads records from the first input file until a dashed line appears; then (2) it takes the data that follow the dashed line in the second input file; and finally, (3) it creates a new file containing the data read from the two files. The example of the NEWDEM program input and output files from the first calculation step in sequential (downstream moving) decomposition approach is presented in Tables H.1 to H.3 of Appendix H. The tables are selected according to the commands which are stored in the NEWDEM.MAN 'manage file' which is presented in Table A.17 (Appendix A).

The NEWDEM program provides the necessary data transfer between two consecutive iterations in sequential decomposition algorithm. Its main contribution is towards maintaining the convergence of the iterative process. Thus, it is obvious that the first run of the NEWDEM program is carried out after the first iteration is completed. To exemplify this the case of the presented water resources system (the application of downstream moving sequential decomposition) will be used. Each iteration ends up by optimization and simulation of the SS reservoir operation. Consequently, the NEWDEM program would take the original consumptive demand distributions from the 'general demand file' and reservoirs' supply deficits from the 'new general demand file' created for the SS reservoir.

The NEWDEM program requires a special 'manage file' due to the fact that the NEWDEM program and the corresponding 'manage file' are not related to an individual reservoir but to the system configuration and chosen decomposition technique. This file is called NEWDEM.MAN (Figure 5.9). In this case, the original demands will be read from the ORIG.DEM file, the reservoirs' supply deficits will be read from the SS.DEM file and the 'new general demand file' will be NEW.DEM. It is very important to point out that for the chosen reservoir system and decomposition algorithm there is only one NEWDEM 'manage file'. Any change in either system configuration or decomposition approach requires an investigation of this file's validity.



```
NEWDEMAND
C:\SY\ORIG.DEM
C:\CU\SS.DEM
C:\CU\NEW.DEM
```

Figure 5.9 The NEWDEM.MAN 'manage' file

• PROGRAM EXECUTION •

The program is executed by entering 'NEWDEM' at the DOS-prompt (or from the SHELL program). The program searches through the NEWDEM.MAN file for the 'NEWDEMAND' code word, reads the following input/output instructions, and continues with calculations. Execution takes no more than few seconds.

5.10 The DEMGEN Program

Coupled with the AGGRMD program, this routine is used only in a 'monitored demand concept' of simulation (see Sections 3.4.5 and 3.4.6). However, this program is not associated with individual reservoirs but with the system as a whole. Therefore, there is no separate section in a reservoir 'manage file' reserved for this program execution control. The DEMGEN, like the DEMAND program, has its own 'manage file' named DEMGEN.MAN. The program is executed at the beginning of each iteration to create 'individual demand time series files' for all demand centres (and DRD-type demands) associated with the system in question. An individual demand time series is created by simply repeating the particular demand record that can be found in a 'general demand file' (for the first iteration) or a 'new general demand file' (for the rest of iterations). Obviously, at the onset of an iteration, the generated demand time series reflects the assumption used in the remaining three simulation approaches that a demand imposed upon a system is recurring in annual cycles. However, the joint approach of the AGGRMD, SIMULATE, and DEFICIT programs, which continuously check and update records on how much water has actually been allocated towards a particular demand in each month over the entire simulation period, provides that 'individual demand time series files' loose this periodicity.

The DEMGEN should be used only in conjunction with the AGGRMD program. It is not sufficient only to generate initial 'individual demand time series' to ensure that the 'monitored demand' simulation will be carried out. The SIMULATE and DEFICIT programs need to find, as the primary condition, the output 'aggregated demand file' from the AGGRMD program to proceed with the 'monitored' simulation. 'Individual demand time series files' are only the secondary requirement which is, by the way, already fulfilled by a successful execution of the AGGRMD program. Thus, if only the DEMGEN was executed without running the AGGRMD, both the simulation and release allocation models would assume 'average demand' simulation within the 'avoid excess release' approach.

• FILES •

The DEMGEN.MAN file comprises several input instructions necessary for running the DEMGEN followed by a list of input file names. The word 'GENERATE' marks the beginning of the file section where the program should start reading the instructions:

- The starting year and the length (in years) of the demand record to be generated.
- The '**new general demand file**' which was created at the end of the previous iteration cycle and is to be used as initial demand for the current iteration. Note that it only points to the file which copy is used by the program (see the following item).
- The name of a **temporary** copy of the '**new general demand file**'. This file is actually used by the DEMGEN program.
- The set of '**demand allocation files**' of all reservoirs of the system considered.

Note: *The 'new general demand file' is mentioned in the DEMGEN program's 'manage file' because it was necessary to provide this piece of information for the SHELL option* *which controls the execution of the DEMGEN. Namely, to maintain full compatibility among the DEMGEN, AGGRMD, SIMULATE, and DEFICIT programs which all should utilize and create files in the current iteration directory, the 'new general demand file' could not be used because it is originally placed in the directory where the previous iteration results are. This problem is easily resolved in batch processing mode by simply executing a single DOS 'COPY' command prior to starting the program in the corresponding batch file. However, the SHELL option required a software solution which was only possible by explicitly specifying the names of both the source and target files.*

No output file names need to be mentioned in the DEMGEN.MAN. The program itself automatically creates output file names. This is due to the imposed necessity of maintaining full compatibility among the four programs that use these files (DEMGEN, AGGRMD, SIMULATE, and DEFICIT). In fact, the DEMGEN only creates the files, whereas the other three actually manipulate their contents. The output files of the DEMGEN are '**individual demand time series files**' created for each demand target (including DRD demand types) found in all listed 'demand allocation files'. Their names are generated as follows:

- The path is the same as the path of the temporary copy of the 'new general demand file'. This is the directory where all the results of the current iteration will be kept, including the 'simulation output file' (see Section 5.7).
- The file name is the demand code name found in a 'demand allocation file'.
- The extension is 'RMD'.

An example of input and output files of the DEMGEN program are given in Appendix I (Tables I.1 through I.3). The example originates from the onset of the second iteration of the sequential (downstream moving) decomposition algorithm employing the 'real demand' approach of optimization with respect to the objective function type 2 and the 'monitored demand concept' of simulation. It is derived on the basis of the instructions listed in the DEMGEN.MAN 'manage file' from Table A.18 of Appendix A.

Note: *This type of analysis could be achieved by performing the following modifications:*

- *'demand allocation files' (Tables A.6 through A.10): the annual median inflow value should be replaced by '-999.999'; the objective function code and the simulation codes should both be set to '2' instead of '1';*

- *'entire process batch file' (Table A.29): the* ***'rem'*** *DOS commands from the three iteration blocks should be removed to enable execution of the DEMGEN program;*

- *'single iteration batch file' (Table A.30): the* ***'rem'*** *DOS commands from the five reservoir optimization/simulation blocks should be removed to enable execution of the AGGRMD program;*

The input instructions (including full paths in file names) have to be written in the appropriate DEMGEN.MAN 'manage file'. Following the 'GENERATE' code word the DEMGEN program reads those records and considers them, in the following order, as:

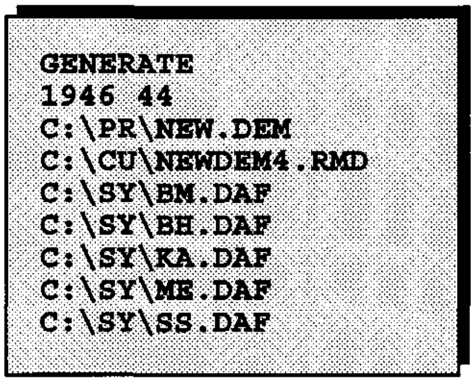
- the starting year and the record length;
- 'new general demand file';
- temporary copy of the 'new general demand file' (input);
- 'demand allocation file' of the first reservoir (input);
- 'demand allocation file' of the second reservoir (input);

  .

  .

- 'demand allocation file' of the last reservoir (input);

Example: A DEMGEN.MAN file for the case study system presented in Figure 4.1 could look like the one shown in Figure 5.10: the 'new general demand file' C:\PR\NEW.DEM will be copied to its temporary counterpart C:\CU\NEWDEM4.RMD; subsequently, using data from the temporary file and starting from the year 1946, sets of 44-year long demand time series will be created for each demand centre specified in the following five 'demand allocation files': C:\SY\BM.DAF, C:\SY\BH.DAF, C:\SY\KA.DAF, C:\SY\ME.DAF, and C:\SY\SS.DAF.



```
GENERATE
1946 44
C:\PR\NEW.DEM
C:\CU\NEWDEM4.RMD
C:\SY\BM.DAF
C:\SY\BH.DAF
C:\SY\KA.DAF
C:\SY\ME.DAF
C:\SY\SS.DAF
```

Figure 5.10 TheDEMGEN.MAN 'manage' file

• PROGRAM EXECUTION •

The program is executed by entering 'DEMGEN' at the DOS-prompt (or from the SHELL program). The program searches through the DEMGEN.MAN file for the 'GENERATE' code word, reads the following instructions, and continues with the execution which takes no more than few seconds.

Important: *In batch processing, it is crucial to make a temporary copy of the 'new general demand file' using DOS 'COPY' command prior to starting the DEMGEN program.*

5.11 The *ShellDP* SHELL Program

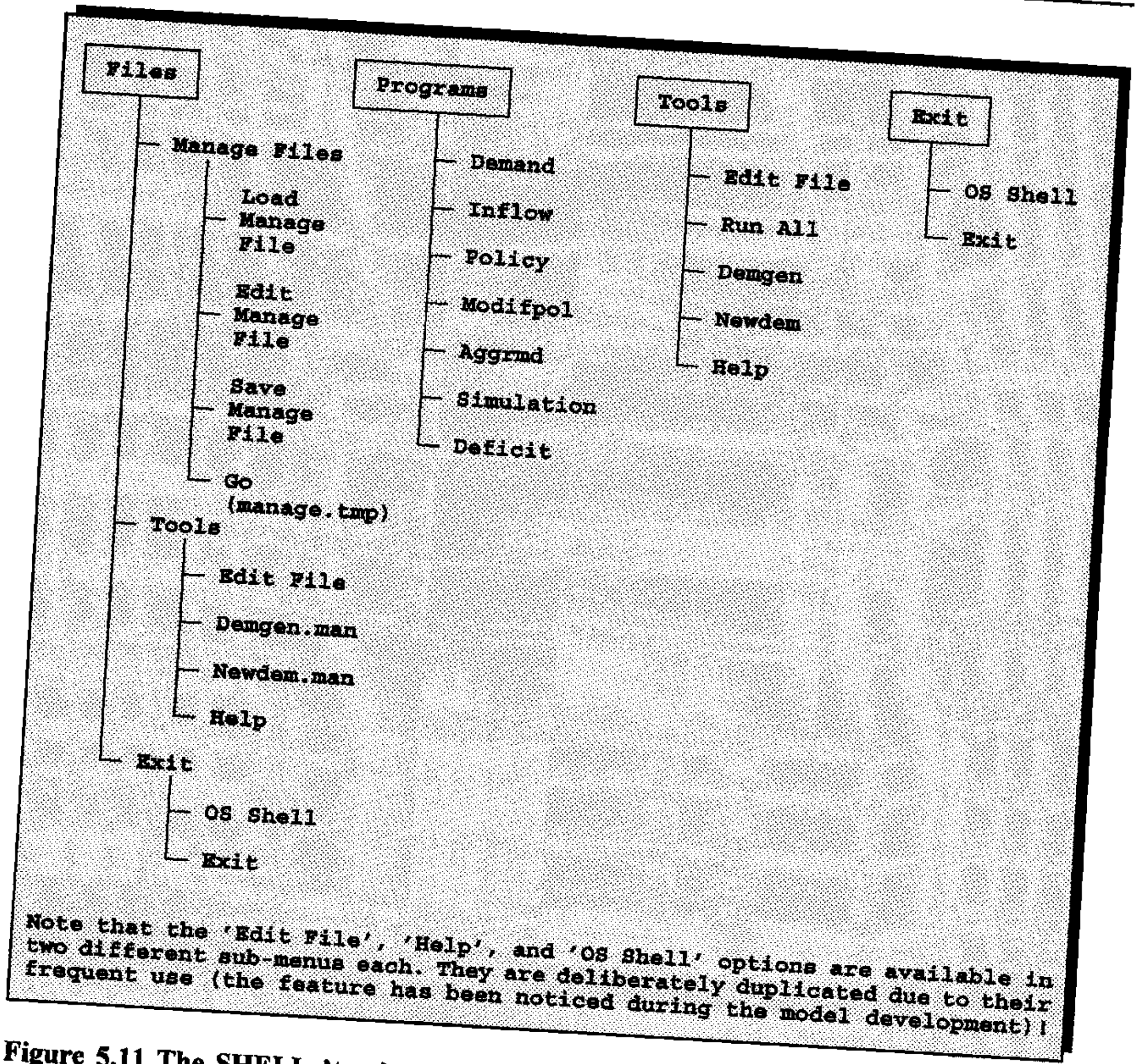
The ***ShellDP*** package has been developed to carry out the SDP-based optimization of both single and multi-unit reservoir systems operation. The applied optimization procedure of complex water resources systems operation employs one of the decomposition algorithms described in Section 3.3 which are, obviously, iterative procedures. One iterative cycle comprises repeated optimization/simulation routines of individual reservoirs of the system in the chosen sequence. These cycles are repeated until no significant improvement of the system return is encountered, which is concluded by the user. As mentioned in Section 5.1.2, there are two ways of performing a complete optimization cycle:

- Interactively, using the **SHELL** program.
- Using **batch processing**, where the complete process control is carried out by appropriate '**batch files**' (Section 5.12).

Interactive execution of one complete iteration cycle can be performed by using the SHELL program. It is a menu operated shell routine that controls 9 programs from the package: DEMAND, INFLOW, POLICY, MODIFPOL, AGGRMD, SIMULATE, DEFICIT, NEWDEM, and DEMGEN. Actual aims of the SHELL are:

- creating and editing 'manage files';
- starting program executions;
- providing more information about the ***ShellDP*** from the HELP sub-menu.

However, as mentioned in the previous chapter, interactive run of one optimization cycle requires more sustained attention by the user than batch processing. Although the possibility of making mistakes is larger in interactive approach, the use of the SHELL program highlights the main features of the optimization technique and makes a novice acquainted with computer "way of thinking".



Note that the 'Edit File', 'Help', and 'OS Shell' options are available in two different sub-menus each. They are deliberately duplicated due to their frequent use (the feature has been noticed during the model development)!

Figure 5.11 The SHELL 'tree'

• THE SHELL PROGRAM OPTIONS •

The SHELL is a menu operated shell program. It consists of four main options which further branch into several sub-options each. The 'tree' representing the SHELL options is given in Figure 5.11. To start the program, enter 'SHELL' at the DOS-prompt. After a short self-advertising (until a key is pressed), the SHELL responds with the main menu:

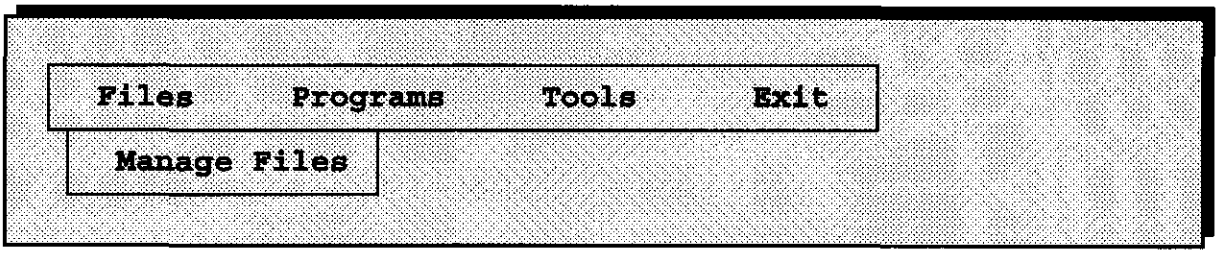


Figure 5.12 The SHELL main menu

The menu option can be selected by moving the menu-bar using arrow keys to the desired option and pressing the **<ENTER>** key.

• Working with 'manage files' •

Choosing the '**Files/Manage Files**' option activates the following menu:

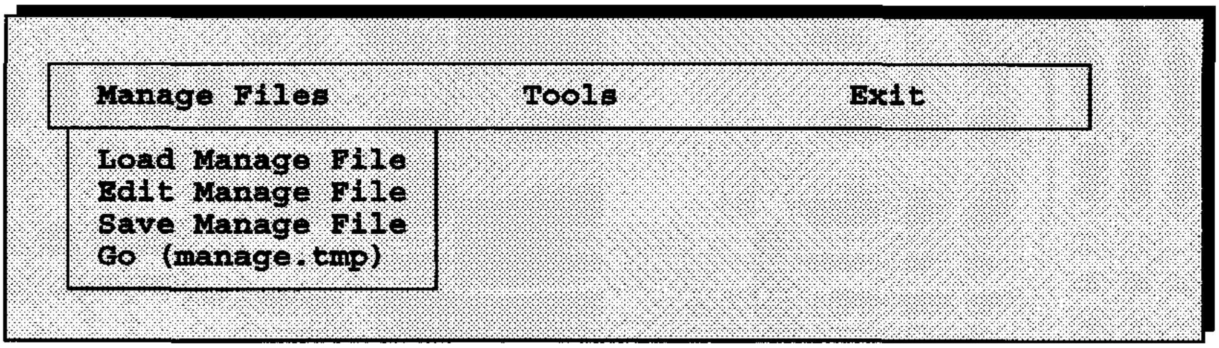


Figure 5.13 The SHELL 'Files/Manage Files' menu

The '**Manage Files**' menu consists of four options used to manipulate the 'manage files':

- '**Load Manage File**': Choose this option in order to load an already existing 'manage file'. This file can then be viewed and/or edited from the '**Edit Manage File**' sub-menu unit. The '**Load Manage File**' window is presented in Appendix K (Table K.1).

- '**Edit Manage File**': This option can be used for editing an existing 'manage file', or for creating a new 'manage file'. For every program section the names of the input and output files and additional data can be entered (for more information on each program section refer to Sections 5.2 to 5.8). The '**Files/Manage Files**' option windows are presented in Appendix K (Tables K.2 through K.9).

- '**Save Manage File**': After editing a file, use this option to save it. The '**Save Manage File**' window is presented in Appendix K (Table K.10).

- '**Go (manage.tmp)**': This option copies the 'manage file' (the one that is currently in the memory of the computer) to a file called MANAGE.TMP. The ***ShellDP*** programs (see Sections 5.2 to 5.8) read the input and output filenames from this file. Thus, if the interactive procedure is run, this option is required in order to create the currently active (MANAGE.TMP) 'manage file'.

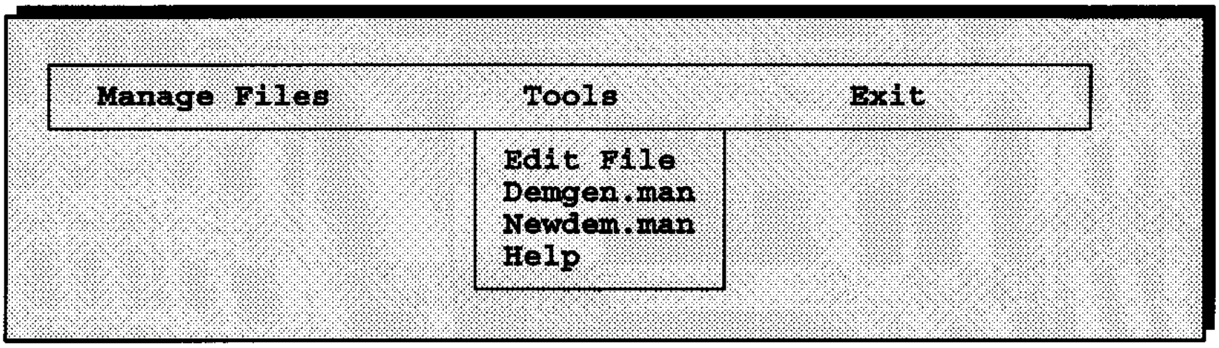


Figure 5.14 The SHELL 'Files/Tools' menu

The '**Tools**' menu item (Figure 5.14) introduces four more features of the SHELL:

- The '**Edit File**' menu item is used to edit files. The '**Edit File**' window which facilitates the selection of the file to be edited is given in Appendix K (Table K.13).

- The '**Demgen.man**' menu item provides a means to create and edit the DEMGEN.MAN 'manage file' for the DEMGEN program (see Section 5.10). This option's editing window is presented in Appendix K (Table K.11).

- The '**Newdem.man**' menu item provides a means to create and edit the NEWDEM.MAN 'manage file' for the NEWDEM program (see Section 5.9). This option's editing window is presented in Appendix K (Table K.12).

- The '**Help**' provides information on programs and files used in the optimization process. The SHELL HELP is presented in Appendix L.

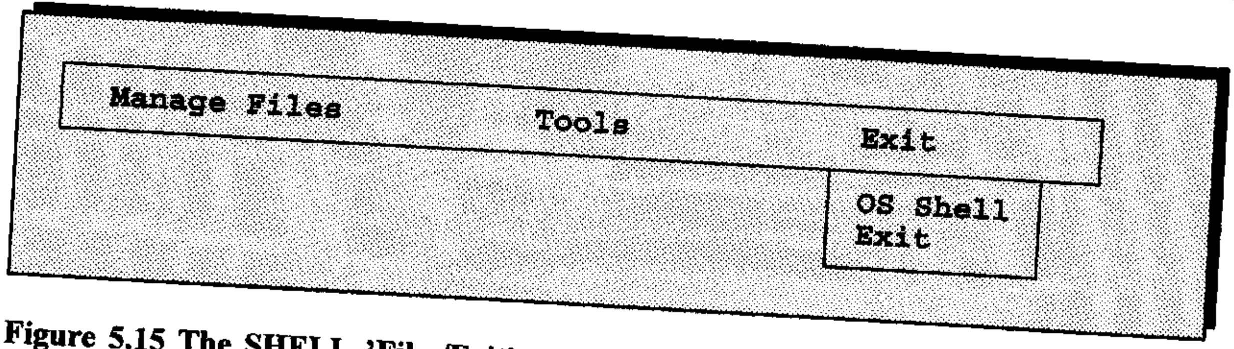


Figure 5.15 The SHELL 'Files/Exit' menu

The '**Exit**' menu item (Figure 5.15) is used for exiting the '**Files**' sub-menu:

- The '**OS Shell**' sub-menu item for exiting the program temporarily ('go to DOS'). Once at DOS, type 'EXIT' to return to the program.
- Choose the '**Exit**' option item to terminate the '**Files**' sub-menu.

• Running the programs •

The '**Programs**' main menu item gives the following sub-menu:

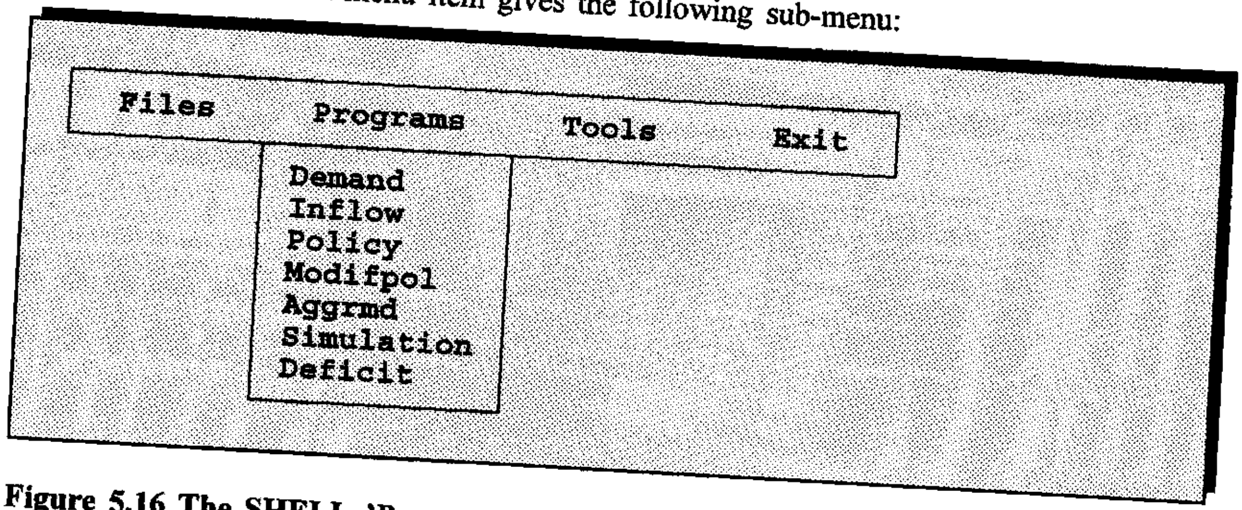


Figure 5.16 The SHELL 'Programs' menu

To run one of the programs, simply choose the sub-menu item and press enter. The order in which the programs are listed in the sub-menu, corresponds to the order in which they should be run for a complete optimization/simulation of a single reservoir operation.

Important: *A program execution requires a proper 'manage file' to be created and selected beforehand. This means that the '**Programs**' sub-menu can successfully be activated only if the respective temporary 'manage file' (MANAGE.TMP) has been created.*

• The tools •

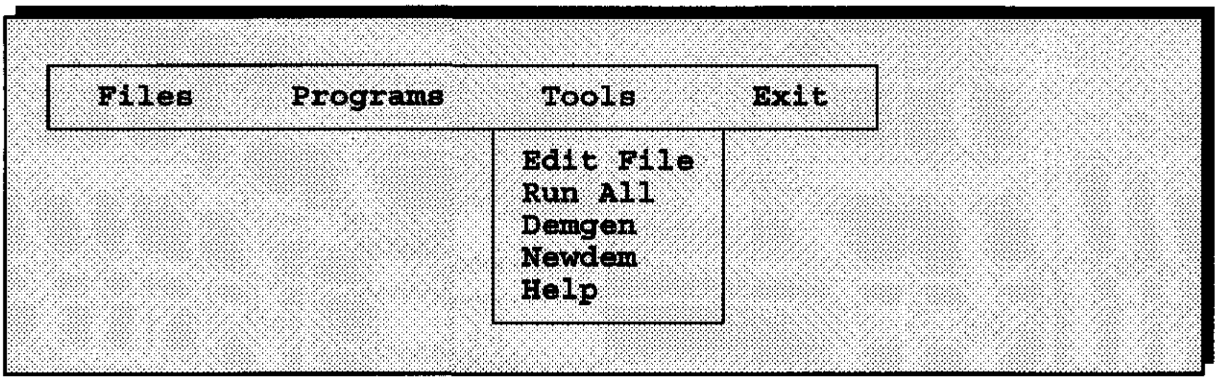


Figure 5.17 The SHELL 'Tools' menu

The '**Tools**' menu item (Figure 5.17) provides some simple tools and options to execute two additional programs from the SHELL:

- The '**Edit File**' sub-menu item can be used to edit a selected file. The '**Edit File**' window is presented in Appendix K (Table K.13).

- The '**Run All**' sub-menu item performs the execution of all the programs automatically in the order listed in the '**Programs**' sub-menu. By selecting this option, the user can avoid individual executions of the programs. Note that a 'manage file' should also be created and selected beforehand.

- The '**Demgen**' item executes the DEMGEN program (see Section 5.10).

- The '**Newdem**' item executes the NEWDEM program (see Section 5.9).

- The '**Help**' sub-menu item provides information on programs and files used in the optimization process. This option is identical to the one presented in the '**Files**' menu description. The SHELL HELP is presented in Appendix L.

• Exiting the SHELL •

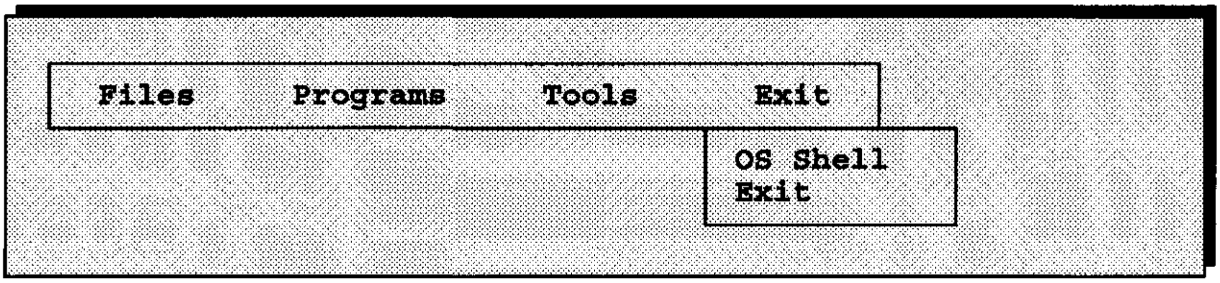


Figure 5.18 The SHELL 'Exit' menu

The '**Exit**' main menu item (Figure 5.18) contains two options:

- The '**OS Shell**' sub-menu item for exiting the program temporarily ('go to DOS'). Once at DOS, type 'EXIT' at the DOS-prompt to return to the program.

- Choose the '**Exit**' sub-menu item to terminate the SHELL.

5.12 Batch Processing

As explained before, the best way for performing a complete iteration cycle or simulation with other data is with the help of batch files. These files can be created "manually" using a conventional editor or by the SHELL program facilities (the '**Tools/Edit File**' or the '**Files/Tools/Edit File**' options). In order to create these files a thorough knowledge of the considered water resources system is required. The example of batch files in Appendix A (Tables A.29 through A.33) can be used as a guideline for handling batch processing.

Batch processing for complete system optimization: In order to start an iteration (in this example for three iteration steps, see Appendix A), the name of the main batch file has to be entered at the DOS-prompt. This file then calls the other batch file which carries out one iteration step of the optimization of the system operation. For every reservoir in the system, the appropriate 'manage file' is copied to the file MANAGE.TMP and all the programs are run in the proper sequence. Note that the use of the DEMGEN, AGGRMD, and MODIFPOL programs depends on the selected simulation mode and the user's choice on alternative policy modifications.

The control is then returned to the main batch file. The NEWDEM program is used in sequential decomposition approach for creating a 'new general demand file' (see Section 5.9), necessary for starting a new iteration step. Note that, when applying up-and-downstream or upstream moving decomposition of a multi-unit reservoir system, the NEWDEM program is not required to provide the link between successive iteration cycles. In this case, the data transfer between two consecutive iterations consists of three components created in the prior iteration: (1) 'downstream reservoir supply files', (2) 'downstream reservoir extra supply files', and (3) 'free downstream flow files'. These files contain data about available additional inflows that can be utilized by 'DRD reservoirs' to improve their operation. Before starting the next iteration, the directory names are renamed in order to provide a safe storage of results from each iteration (see Section 5.1.3). Then the process is repeated for a new iteration step.

The completion of the optimization procedure which is controlled by batch files provides separated results from each iteration. Further investigations can then be made in order to check whether a stabilized system return has been achieved from one iteration to another. Considering that the model does not employ any routine to determine a stable system return one can imagine that, in batch processing, the number of iterations is due to user's decision and experience. Interactive run of the model (using the SHELL program), as opposed to batch processing, gives the user the opportunity to assess the operation of the system considered after each iteration. This facilitates the decision making process about the termination of the computations.

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APPENDICES

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APPENDIX A

Reservoir characteristic data files; reservoir demand allocation files; sequential and iterative decomposition algorithms' 'manage' and batch files;

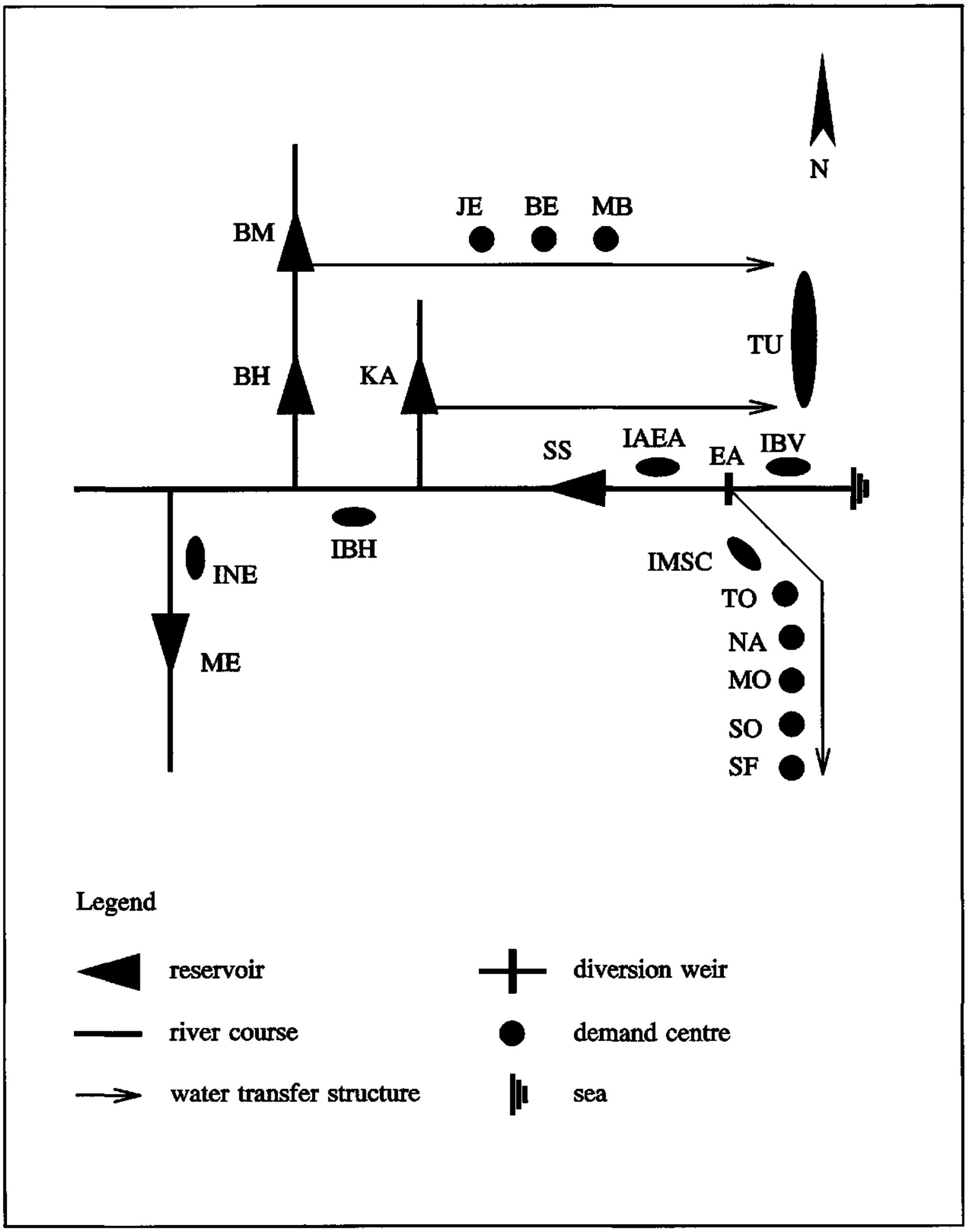

Figure A.1 Five-Reservoir Water Resources System (schematic representation)

Table A.1 BH reservoir data file

```
RESERVOIR BH 1991 ------------------------------------ reservoir name (comment)

   44 ------------------------------------------------ number of years in historical inflow sequence

                                                       maximum reservoir volume [10^6m^3]
                                                       minimum reservoir volume [10^6m^3]
                                                       maximum outlet capacity (monthly volume) [10^6m^3]
                                                       number of discrete value pairs for the characteristic curves of a reservoir
                                                       inflow transition probabilities code
  117.5     15.0    429.24      13         1

                                                       year
                 observed inflow sequence (September - August) [10^6m^3]

   46    0.610    1.450    3.960  101.240   18.150    8.360    6.110    5.670    1.320    0.610    0.630    0.900
   47    0.320    3.900    2.970   11.680   15.210    7.290    6.840    4.820    1.470    0.680    0.330    0.310
   48    0.370    0.320   23.250   17.040   57.650   26.920   36.310    4.590    1.700    1.490    1.140    1.000
   49    0.880    0.860    4.180    2.010   12.990   17.370   36.330   25.170    1.800    1.460    1.090    0.920
   50    0.850    1.430    5.190    4.170   11.650   25.140    8.420    2.720    1.350    1.090    0.950    0.860
   51    0.820    6.410   14.880   18.300   21.480   42.170   12.750   13.590    2.670    1.410    0.890    0.850
   52    0.870    0.880   10.060   47.910   30.080   15.030   13.700    4.040    3.580    1.850    1.210    1.700
   53    0.940   11.600   17.300   10.220   36.350   59.360   14.480   15.200    3.490    1.420    1.220    1.050
   54    0.940    2.160    4.520   17.810    9.830   17.170   10.880    4.750    1.490    1.150    0.990    0.870
   55    2.140    4.700    6.150   16.570   14.180   75.980   11.710    5.190    3.040    2.100    1.270    1.000
   56    0.450    1.250    2.370   27.350   29.260    7.350    5.530    8.410    2.450    2.420    1.130    0.990
   57    0.550    3.200    4.050   27.930   48.070    2.830   20.130    3.940    0.910    0.690    0.000    0.700
   58    0.160    1.400   14.600    8.660   24.590    3.980   76.980   41.080    1.480    2.230    0.840    0.000
   59    0.550    0.860    5.760   15.900   25.750    3.250    5.190    8.330   20.860    0.590    0.240    0.330
   60    0.000    0.220    0.260    8.280   26.210    3.760    2.450    0.420    1.510    0.840    0.630    0.130
   61    0.200    0.960    1.340    1.190    4.260   18.410    4.860   10.920    1.060    0.480    0.470    0.250
   62    0.460   12.700   10.000   28.700   13.600   29.300    2.960   13.420    0.370    0.290    2.750    4.420
   63    2.550    2.060    2.800    9.740   20.100   22.710    5.670    3.410    1.730    0.550    0.490    0.720
   64    1.250    1.460    4.010    2.230   28.300   46.570   16.400    2.690    1.730    1.110    0.770    0.510
   65    0.330    0.230    0.150    2.050    4.940    2.910   12.600   35.770    6.870    1.510    0.880    0.810
   66    3.970    0.790    1.970    8.340   13.600   19.050    3.950    2.490    2.010    1.330    0.620    0.780
```

Table A.1 BH reservoir data file (continued)

67	0.740	0.680	0.770	3.930	15.800	4.640	1.760	0.690	0.680	1.470	0.420	0.290
68	0.410	0.640	0.950	5.370	13.600	4.880	2.570	3.720	0.730	0.470	0.300	0.440
69	0.840	9.070	1.730	54.600	9.010	9.530	23.730	3.140	1.620	0.910	0.730	0.240
70	0.090	0.370	0.070	15.650	30.780	32.350	16.650	18.640	2.070	0.000	0.350	0.000
71	0.480	3.240	0.840	1.680	17.210	20.220	7.130	19.580	3.340	0.670	0.000	0.000
72	0.550	0.340	0.080	0.470	26.770	22.610	71.490	5.740	0.740	0.100	0.230	0.180
73	0.000	2.660	0.000	2.620	0.620	6.480	4.520	13.320	1.170	0.020	0.000	0.000
74	0.190	1.330	27.560	8.460	3.250	26.680	9.530	3.290	12.410	0.420	0.260	0.310
75	0.480	0.160	3.610	7.590	3.700	10.570	27.000	4.320	10.170	0.780	0.430	0.190
76	3.360	1.850	20.720	13.720	8.130	4.430	1.250	1.990	1.400	1.540	0.980	2.350
77	1.170	0.220	7.900	1.190	5.740	29.600	4.240	13.170	3.480	2.770	2.540	2.270
78	0.000	0.270	5.300	4.150	4.980	8.880	2.840	25.540	3.640	2.040	2.890	2.350
79	0.000	0.000	20.210	2.450	5.310	11.640	21.620	5.260	4.210	0.050	0.000	0.000
80	0.490	0.900	1.110	19.780	30.490	12.510	5.890	4.220	1.770	0.870	0.000	0.000
81	0.210	0.210	0.930	3.610	7.940	14.750	22.800	16.470	6.550	0.000	0.000	0.140
82	0.130	0.410	16.850	35.880	15.550	3.670	9.960	3.800	1.140	0.290	0.000	0.000
83	0.420	0.510	5.950	11.010	15.460	43.980	45.480	2.950	0.000	0.120	0.000	0.020
84	0.350	0.300	0.670	34.820	83.570	31.340	6.210	0.020	0.030	0.000	0.000	0.000
85	0.680	0.060	0.230	0.250	10.450	16.370	10.590	1.530	4.480	0.070	1.280	0.150
86	2.550	1.810	3.680	18.000	47.020	77.150	25.210	60.970	5.010	3.690	0.010	0.220
87	0.720	2.440	1.980	2.200	4.160	5.790	33.430	0.070	0.630	1.220	0.110	0.940
88	0.730	1.570	0.560	2.760	1.290	3.260	6.310	2.950	1.480	0.640	0.690	0.820
89	1.050	1.140	0.570	1.060	1.420	0.740	0.680	0.310	1.360	0.340	0.150	0.540

reservoir characteristic curves

elevation above datum [m]

corresponding storage volume [$10^6 m^3$]

corresponding surface area [ha]

0	6.400	84.000
3	10.300	144.000
5	14.500	188.000
7	18.500	236.000
10	25.750	322.000
13	35.500	416.000
15	44.500	494.000
17	54.000	560.000
20	71.200	676.000
23	92.300	784.000
25	112.000	854.000
26	117.500	894.000
27	123.000	934.000

Table A.1 BH reservoir data file (continued)

evaporation losses (September - August) [m]

```
0.079
0.051
0.025
0.022
0.020
0.020
0.032
0.033
0.061
0.099
0.131
0.125
```

one empty line, dividing these two sets of data

reservoir's own demand (not used in optimization of the complex system operation) $[10^6 m^3]$

```
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
```

Table A.2 BM reservoir data file

```
RESERVOIR BM 1991
   44
 57.2    13.0    933.12      15        1
   46   0.110     0.350   1.210   56.600    7.540    3.000    2.060    1.880    0.310    0.110    0.120    0.190
   47   0.050     1.180   0.850    4.480    6.140    2.540    2.360    1.540    0.350    0.180    0.050    0.040
   48   0.060     0.050  10.100    7.000   29.500   12.000   17.100    1.450    0.430    0.360    0.260    0.220
   49   0.180     0.180   1.290    0.520    5.080    7.190   17.100   11.100    0.450    0.350    0.240    0.190
   50   0.170     0.340   1.680    1.290    4.460   11.100    3.030    0.760    0.320    0.240    0.200    0.180
   51   0.170     2.170   5.980    7.640    9.250   20.400    4.980    5.360    0.740    0.330    0.190    0.170
   52   0.180     0.180   3.750   23.800   13.700    6.050    5.420    1.240    1.070    0.470    0.280    0.420
   53   0.200     4.450   7.170    3.830   17.200   30.600    5.810    6.160    1.040    0.340    0.280    0.230
   54   0.200     0.570   1.420    7.370    3.650    7.070    4.110    1.510    0.360    0.260    0.210    0.180
   55   0.560     1.490   2.060    6.760    5.630   40.500    4.480    1.690    0.880    0.550    0.290    0.220
   56   0.080     0.290   0.640   12.300   13.400    2.560    1.820    3.020    0.670    0.650    0.250    0.210
   57   0.180     2.040   4.700   13.500   23.400    2.470    5.320    1.220    0.360    0.250    0.220    0.200
   58   0.180     0.230   8.500    2.380    8.770    2.800   21.100   20.300    1.030    1.420    0.420    0.270
   59   0.230     0.270   2.110    2.790    7.670    2.730    2.610    2.260    2.500    0.950    0.410    0.270
   60   1.870     0.200   0.240    3.490   10.300    4.980    2.430    0.760    0.340    0.250    0.190    0.190
   61   0.180     0.430   0.860    0.770    3.990   25.000    2.310    4.760    0.820    0.330    0.140    0.200
   62   0.090     3.820   3.680   10.900    5.190   12.100    0.880    6.420    0.190    0.090    0.900    1.220
   63   0.730     0.600   0.610    3.400    7.970   11.400    3.980    1.070    0.470    0.120    0.110    0.160
   64   0.330     0.510   1.270    0.660   11.700   23.000    6.390    0.830    0.490    0.300    0.180    0.110
   65   0.060     0.040   0.020    0.590    1.660    0.910    4.730   16.000    2.480    0.420    0.220    0.190
   66   1.740     0.180   0.540    2.950    5.170    8.400    1.270    0.720    0.560    0.350    0.140    0.180
   67   0.170     0.160   0.180    1.250    6.030    1.530    1.710    0.430    0.160    0.380    0.090    0.060
   68   0.070     0.120   0.200    1.760    5.380    1.570    0.710    1.120    0.140    0.080    0.040    0.070
   69   0.190     3.090   0.470   23.500    3.230    3.470   10.100    0.980    0.440    0.220    0.170    0.040
   70   0.180     1.820   0.280    4.750    5.490   12.000    5.320    9.780    0.570    0.350    0.260    0.290
   71   0.760     2.770   0.940    1.020    6.530   10.700    5.270    7.590    0.830    0.560    0.270    0.230
   72   0.470     0.410   0.340    0.430    8.180   10.400   20.900    4.370    0.580    0.730    0.320    0.260
   73   0.200     1.040   0.660    2.710    1.990    5.460    2.450    4.150    0.460    0.280    0.230    0.210
   74   0.540     1.040  13.000    3.110    2.350    9.300    3.640    1.530    0.640    0.360    0.280    0.220
   75   0.200     0.170   1.220    1.540    2.650    4.620    5.170    0.770    0.690    0.390    0.340    0.250
   76   1.100     1.580  12.400    4.010    6.230    2.900    0.460    2.290    0.480    0.400    0.010    0.440
   77   0.160     0.010   3.530    0.460    4.920   22.000    2.410    8.910    1.290    0.600    0.540    0.770
   78   0.000     0.280   1.070    2.810    3.750    9.230    2.060   16.900    1.320    0.220    0.000    0.000
   79   0.100     0.130  14.900    0.920    3.060    7.100   14.800    3.880    2.930    0.100    0.010    0.040
   80   0.160     0.480   1.810   14.540   47.260    5.190   40.140    1.370    0.530    0.000    0.000    0.000
   81   0.020     0.080   0.050    2.780    6.380    9.400   17.050    6.320    3.150    0.080    0.000    0.000
   82   0.020     0.480  10.440   14.120    4.630    1.010    8.920    2.060    0.070    0.040    0.000    0.000
   83   0.150     0.510   3.360    5.890   12.730   15.020   13.920    2.390    0.000    0.020    0.000    0.000
   84   0.110     0.210   0.760   23.640   25.210    7.310    2.570    0.730    0.430    0.000    0.000    0.000
```

Table A.2 BM reservoir data file (continued)

```
    85   0.050    0.070   0.110   0.280   5.630   9.260   5.450   0.630   5.430   0.020   0.020   0.000
    86   0.210    2.830   3.540  15.660  27.330  25.490  10.750  11.350   0.830   0.050   0.000   0.000
    87   0.030    0.030   0.620   0.060   2.870   2.790  19.280   0.130   0.040   0.080   0.100   0.000
    88   0.130    0.010   0.090   1.600   0.720   2.810   5.310   6.070   3.470   0.060   0.000   0.040
    89   0.040    1.110   0.060   0.450   0.940   0.230   0.180   0.530   0.140   0.010   0.000   0.050
     0   0.000   20.000
     5   1.850   40.000
    10   4.670   68.000
    15   8.810   98.000
    17  10.870  105.000
    20  14.580  130.000
    25  22.300  170.000
    27  25.900  182.000
    30  31.840  206.000
    32  36.300  220.000
    35  43.630  250.000
    37  48.690  262.000
    40  56.870  290.000
    42  63.330  310.000
    45  73.430  345.000
 0.111
 0.072
 0.044
 0.033
 0.031
 0.031
 0.053
 0.064
 0.099
 0.130
 0.162
 0.152

 0.000
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Table A.3 KA reservoir data file

```
RESERVOIR KA 1991
   44
 81.9       9.7    198.29        13         1
   46     0.790     0.930     0.530    55.400     9.800     3.680     2.210     3.520     1.000     0.990     0.680     1.050
   47     0.260     2.280     1.620     5.640     8.110     1.240     2.990     1.930     1.260     0.810     0.520     0.270
   48     0.220     0.360     8.790     7.560    18.300    10.800    12.100     2.550     1.700     0.950     0.600     0.670
   49     0.830     0.890     2.260     1.580     7.920     7.190    16.100    13.800     1.930     0.610     0.370     0.570
   50     0.940     0.500     1.680     4.750    12.000    10.800     4.570     0.850     0.480     0.280     0.140     0.100
   51     0.100     5.960     9.210     8.380    15.000    11.000     5.680     3.310     1.390     0.400     0.220     0.160
   52     0.230     0.190    14.800    17.800    18.600     6.210     5.450     1.030     5.490     0.590     0.240     0.190
   53     0.080     4.250     6.830     4.230    25.000    20.700     5.020     3.350     0.700     0.350     0.250     0.190
   54     0.160     0.170     2.000    12.400     7.970     6.780     6.740     1.890     0.700     0.290     0.210     0.110
   55     3.390    10.500     5.140     9.690    11.100    36.000     5.800     1.380     0.780     0.370     0.280     0.180
   56     0.240     0.330     1.070    14.100    21.700     3.040     1.130     3.160     1.890     0.760     0.440     0.250
   57     0.120     1.800     5.590    17.100    17.900     1.820     7.570     1.210     0.380     0.210     1.520     0.150
   58     0.120     1.480     7.310     5.560    12.700     2.540    14.700     7.880     1.350     0.860     0.200     0.300
   59     0.250     1.080     1.740    11.700    12.900     1.880     2.120     1.940     7.480     0.870     0.520     0.310
   60     2.380     0.950     1.140     4.860    14.900     4.400     2.210     1.680     1.330     1.130     1.110     1.030
   61     0.900     1.250     1.930     2.680     3.680    14.100     2.360     2.810     1.680     0.740     1.140     1.170
   62     1.110     5.270     4.150     6.780     6.450    16.500     1.900    12.200     2.560     1.730     1.110     1.020
   63     2.310     1.240     1.300     2.520     7.720     9.690     1.710     1.410     1.130     1.130     1.140     1.300
   64     1.140     1.220     2.640     1.220    13.700    14.800     2.020     2.070     1.090     1.120     1.030     0.940
   65     1.110     1.110     1.090     2.880     1.550     1.080     8.960    16.400     7.830     0.730     0.400     0.280
   66     0.850     1.010     1.270     6.990     8.960     8.340     1.930     2.220     1.230     0.650     0.910     0.180
   67     0.860     1.040     1.090     3.530    16.700     2.990     4.760     1.520     1.180     1.470     1.000     0.970
   68     0.810     0.220     1.080     4.350    10.700     4.460     2.390     3.740     0.840     0.640     0.830     0.860
   69     1.040     4.870     1.060    25.700     2.490     1.970     5.340     1.970     1.210     0.510     0.090     0.570
   70     0.830     2.580     0.720     5.150     7.900    10.300     6.420    12.500     2.320     1.040     1.040     1.150
   71     1.890     4.390     1.830     2.390     8.780     9.260     7.100    10.700     3.430     1.540     1.160     1.060
   72     1.340     1.310     0.900     1.260    14.300    10.400    28.600     6.040     1.490     0.930     0.930     0.610
   73     0.560     1.350     0.570     2.930     0.600     2.680     1.420     2.360     0.550     0.710     0.470     1.030
   74     0.740     0.900    13.300     3.820     1.770     5.840     2.660     1.150     1.750     1.170     0.860     0.920
   75     0.870     0.720     2.200     2.890     2.910     3.780     3.210     0.900     2.360     1.310     1.020     1.110
   76     0.320     1.260    13.400     3.910     6.020     2.180     0.840     2.580     0.860     0.610     0.470     0.360
   77     0.470     0.050     2.770     1.210     7.030    21.000     2.850     4.570     1.020     0.620     0.610     0.550
   78     0.000     0.170     0.990     6.430     3.370    11.400     4.060     7.430     1.650     0.720     0.570     0.260
   79     0.890     0.540    15.800     1.690     4.370     4.440    10.000     2.310     1.950     0.560     0.440     0.340
   80     0.150     0.740     1.780    22.420    58.260     5.130    50.010     1.220     0.470     0.510     0.390     0.500
   81     0.000     0.000     0.230     4.220     8.470    10.210    11.190    46.810     2.200     0.510     0.410     0.130
   82     0.170     0.150    13.080    15.370     4.790     0.980     6.900     2.100     0.430     0.350     0.410     0.180
   83     0.030     1.500     3.210     8.270     9.240    12.510     9.110     1.200     0.170     0.370     0.300     0.100
   84     0.090     0.160     0.380    15.750    29.070     8.120     1.710     0.030     0.080     0.040     0.370     0.050
```

Table A.3 KA reservoir data file (continued)

```
    85    0.230    0.210    0.340    0.330    6.250    9.750    5.010    1.300    1.920    0.370    0.360    0.360
    86    0.540    1.860    3.760   10.480   20.700   20.010    7.430   14.190    0.440    0.000    0.200    0.520
    87    0.420    0.380    1.510    1.060    4.310    3.990   15.700    0.980    0.500    0.380    0.510    0.130
    88    0.220    0.030    0.080    2.040    1.210    3.280    4.800    3.010    1.910    0.300    0.220    0.220
    89    0.000    1.040    0.570    1.060    3.380    0.720    0.340    0.270    0.190    0.010    0.120    0.140
     0    0.500   10.000
     5    2.000   38.000
     8    3.180   58.000
    10    4.300   72.000
    15    9.500  115.000
    20   16.000  164.000
    25   26.500  224.000
    30   38.500  290.000
    35   51.000  346.000
    40   73.500  410.000
    42   81.800  434.000
    45   91.590  468.000
    48  108.500  532.000
 0.111
 0.055
 0.029
 0.022
 0.021
 0.018
 0.030
 0.040
 0.089
 0.135
 0.191
 0.172

 0.000
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Table A.4 ME reservoir data file

```
RESERVOIR ME 1991
    44
 120.0      31.0    1620.0        10         1
    46     2.710     9.330     7.310    23.900     0.880     1.960     0.410    19.700     2.770     2.200     2.240    18.700
    47     4.800   130.000     1.320     2.240     2.000    86.100    17.400    55.100     7.200    25.800     2.800     0.770
    48     9.230    27.200    37.400    31.600    86.200     3.930    27.800    26.300    23.700     6.110     4.020     0.890
    49     1.250     4.190     1.160     1.450     6.070     1.560     7.190    22.200    32.600     3.480     0.460     7.820
    50    13.600    24.800     5.270     1.120     1.890     1.380     0.900     3.340    30.600    21.500    12.800    14.500
    51    44.400   117.000     2.080    12.400     9.490     7.650     5.270    22.800    17.000    11.200    22.000    42.200
    52    33.600    15.200     3.880    17.900    10.900     4.070    29.400     9.520    19.300    24.500     7.860    34.200
    53    10.400    42.400    14.000     3.180     7.670     8.230     4.500    16.400     9.740    18.800     0.260     0.120
    54     2.570     2.390     3.440     2.220     1.830     2.540     1.790    12.500    24.200    13.100     1.170    16.800
    55    46.400    67.000    21.800     4.070     4.440     6.790     4.210     4.090     1.280     1.270     0.520     1.210
    56    18.700     8.420     2.460     2.250     1.710     1.310     1.280    11.300    33.300    17.100     3.240     2.800
    57    25.300   127.000    27.200    11.000    24.500     4.440     7.910     2.330     1.310     3.150     0.640     0.640
    58     2.470    10.800    37.000     7.220     3.240     3.630     6.860     7.630    14.100    52.400     1.770     9.580
    59    11.800    21.900     7.880     4.160     3.570     2.670     5.960    27.100    30.500    20.600     3.880     2.430
    60     3.330    10.500     1.740     4.050     5.020     2.260     2.010     1.700     1.010     6.300    10.700     5.020
    61     4.860    12.600     2.160     1.640     1.590    35.900     5.410    18.600    11.700    12.100     1.310     6.810
    62     6.910    14.700     5.390     1.560     1.620     3.070    16.800    12.700     9.340    21.200     5.790    24.500
    63    84.700     1.910     1.110    48.500    46.700    15.600     6.810     3.510     8.100     8.530     1.500    13.300
    64     3.050    47.000    18.600     2.430    15.700     5.080     3.340     2.790     5.540     0.890     5.330    16.200
    65    19.300     1.150     9.370    16.100     3.580     1.300     6.350     3.000    24.800     4.190     3.380     4.520
    66    16.700    34.300    13.700     1.430     1.560     1.520     7.320    16.700    11.300     3.220     2.110     5.320
    67    69.900     1.280     9.120    14.100     6.170    10.400     5.550     4.750     5.320    57.500     1.080     0.830
    68     6.230     1.060     1.030     6.200     1.950     1.260    12.000     4.350     0.840     2.780     5.200    15.100
    69   253.000   405.000    48.400    34.200    12.600     3.360     2.840     4.770    20.400     6.440    10.100     3.740
    70     4.790    16.400     1.500     2.570    12.200    35.200     3.720     2.230    22.200     1.600     8.400    25.700
    71    79.500    34.800     3.230     4.140     6.380     2.900     1.900    34.600     6.250    25.200     1.770     3.050
    72    22.200    99.600     2.360     2.670    20.200     8.180   204.000    68.200     7.730     4.930     5.170    11.600
    73     1.930     2.130     2.460    35.100     4.040     2.880     3.500     5.480     2.380     2.300     1.680     1.090
    74     5.420    11.200     2.370     2.050     2.090    54.400     2.900    51.400    19.900     8.370     1.260    17.500
    75    19.200     2.270    25.600     2.020     2.230     2.170     5.220     5.510    14.600    28.400    41.500     7.230
    76    18.000    10.900    61.500     6.320     6.180     2.970    14.500     6.940    15.800    30.600     0.910     8.710
    77    10.600     2.910    33.700     3.120     2.020     7.610    18.100    12.500    16.800    20.400     0.970    11.400
    78     1.190     7.330     1.860     2.000     1.360     2.640     4.970    81.800    16.600    39.600     7.500    14.000
    79    62.300     5.830     8.990     2.000     1.960     2.050    17.700     1.970     2.240     1.310     1.060     1.110
    80    17.440     6.900     9.370    58.230    11.080     5.490     5.110     5.560     1.640     9.250     1.000    15.100
    81    43.660     8.540     1.410     5.930     2.030    11.350     8.580    85.230    51.610     5.000     0.710     0.820
    82     5.390    27.880    50.720     9.180     2.710     0.740     0.920     0.680     0.750     5.600     0.670     6.120
    83     7.060    11.020    22.600     0.840     3.560    29.380    12.420     1.370     0.680     0.940     0.680     4.920
    84     6.910    13.610     0.750    45.560    17.850    20.340     5.530     5.540    20.630     0.890     0.660     0.530
```

Table A.4 ME reservoir data file (continued)

```
   85    7.690   10.310    2.300    1.990    2.990    3.180   12.260    1.940   17.520   27.060   12.430    3.570
   86   30.490   31.030   14.770    7.210    3.530    3.260    7.940    4.310    4.860    1.940    8.370   10.400
   87   11.560   14.090    3.860    1.500    3.030    2.370    2.940   14.500   53.270   26.340    6.780    3.990
   88    2.560   50.700   19.260    7.910    0.750    4.060    1.470    0.510    9.420   24.270   14.920   26.880
   89   45.380    8.320    1.820    2.100   44.360    0.370   12.500   17.980   42.460    6.550    4.950   88.430
    0    0.000    0.000
    5    2.000   65.000
   10    7.000  125.000
   15   15.000  190.000
   20   26.000  300.000
   25   45.500  480.000
   30   75.000  750.000
   35  120.000 1050.000
   40  180.000 1370.000
   45  225.000 1570.000
0.099
0.057
0.032
0.021
0.021
0.025
0.046
0.061
0.099
0.132
0.166
0.155

0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
```

Table A.5 SS reservoir data file

```
RESERVOIR SS 1991
    44
 555.0      45.0    1594.1        11         1
    46     1.285     0.375     0.068   237.840   171.000    45.900     8.490    17.310     4.490     0.915     0.254    13.110
    47     1.026    82.690     4.800    29.670    19.100     6.760    40.170     6.240     3.510     2.431     0.729     1.366
    48     0.239     2.206    72.550    77.570   237.510   136.040   168.220    57.190    18.040     4.801     2.422     2.883
    49     1.541     4.888    14.210    11.950    62.790    34.930   114.680   104.550    25.800     2.818     0.743     3.440
    50     4.816     7.713     6.760    14.670    37.750    57.580    13.960     2.882     2.258     2.847     0.982     0.560
    51     7.081    53.600    18.570    44.990   150.320   202.940    79.140    36.150    42.180     4.831     0.357    12.774
    52     5.758    13.905    46.720   218.590   260.790    90.090   128.830    29.520    34.370    18.040     2.675     4.882
    53     1.742    26.090    70.720    22.770   234.270   195.030    91.310   109.290    23.661     8.028     5.931     5.031
    54     3.886     8.563    10.230    36.510    35.520    35.870    30.820    14.960     6.714     1.708     0.691     2.095
    55    31.110    34.440    16.200    43.970    65.490   229.770    62.570    36.350    20.945     8.245     7.998     8.934
    56    10.866     7.398    13.000    50.060    81.400    34.120     9.230    16.430    21.010     7.334     4.746    25.958
    57    10.437    80.610    74.430   125.790   190.440    38.960    64.250    18.330     8.671     7.027     8.250     8.677
    58     8.175    23.520    26.300    38.490    80.970    39.490   191.410   219.730    51.170    35.271    32.638    23.717
    59    24.347    16.140    48.400    68.490    93.940    54.130    29.850    28.690    54.780    23.135    19.157    18.813
    60    22.780    30.036    30.100    30.520    73.570    50.930    17.540     9.280     4.770     4.040     0.900     2.850
    61     8.061    14.960     8.230     8.600    11.250   186.670    37.070    11.610     6.530     4.093     2.730     5.540
    62     4.130    13.010    26.390    15.200    15.530    80.390    28.230    79.820    24.470    10.790     5.250     2.400
    63    12.930     5.840     5.280    19.720    67.950    92.960    40.690    16.510     6.900     8.930     5.590     7.640
    64     8.510    26.410    27.820    14.240   178.350   205.210    76.000    30.730    15.810     6.800     4.830     7.883
    65     9.490     6.030     7.130    28.800    23.140    11.810    57.640    67.360    50.900     7.092     1.814     2.437
    66     1.402     5.560     2.420    32.820    41.920    38.850    26.350    10.300     5.550     0.524     0.565     0.720
    67    10.894     2.990     3.720    25.200   141.600    34.200    33.440     7.920     4.360     8.830     1.610     2.514
    68     2.551     1.722     2.720    16.820    67.000    15.860    14.510    21.460     2.908     0.549     1.146     6.035
    69    65.330   169.720    61.190   150.440    33.440    16.910    38.770    22.490     8.550     1.940     0.810     2.070
    70     4.651     7.890     3.623     3.000    19.060   106.310    73.160    77.470    19.070     8.130     4.020     8.590
    71    22.370    32.070    11.860    15.400    57.180    32.960    43.930   108.810    37.530    12.820     7.570     9.340
    72    24.310    59.760    11.547    16.050   150.850   117.321   650.740   176.850    36.300    22.974    20.626    13.031
    73    10.177    17.620    11.968    50.250    18.681    29.730    34.320    28.160     9.213     5.458     3.108    10.050
    74     6.687     6.198    13.980    13.330    13.690    71.510    24.580    13.160     8.187     5.250     2.452     8.535
    75    12.534     5.548    37.240    14.230    21.180    19.710    32.220    13.936    96.230    21.420    20.970    15.000
    76    12.087    44.630   121.270    35.160    38.070    17.900    11.116    28.560    13.114    10.795     2.365     7.569
    77     4.196     6.423    12.690     9.460    20.710   104.630    23.200    58.160    10.630     5.548     0.643    10.423
    78     1.850     7.110     9.492    14.400    18.850    35.690    28.890   130.290    19.330     4.278     0.229     4.448
    79    18.544     7.898    77.910     8.860    24.670    12.850    58.850    24.040    11.340     1.364     1.447     0.555
    80     5.947     5.353     7.958   110.599   220.407    86.947   158.799    15.650     7.238     2.579     0.904    17.801
    81     9.240     1.810    12.310   129.081   144.534    77.667    48.157    27.199    22.168     6.430     0.956    28.265
    82     4.902    15.464    62.607    96.834    47.009    12.790    41.914    21.407     3.120     0.838     0.068     1.152
    83     0.988     7.720    21.916    40.031   118.094   257.973    97.697    21.496     5.548     2.248     0.285     1.160
    84     4.582     7.009     6.636   176.862   195.960    54.970    34.846    19.018    15.970     1.277     0.448     0.817
```

Table A.5 SS reservoir data file (continued)

```
   85    4.058    7.348   10.096   23.877   42.738   44.141   34.300   21.341   14.046    9.042    4.071    2.849
   86   10.647   17.093   23.204   54.518   93.246   89.361   50.860   59.749   11.479    3.650    3.480    5.480
   87   30.823   32.244   31.669   67.875  116.996  141.497   41.473   88.935   25.865    9.914    5.056   10.089
   88    4.066   18.097   17.253   38.690   51.719   53.911   48.139   34.581   17.677   10.008    5.367    8.781
   89   14.787   14.312   21.138   52.138   92.263   71.410   60.167   46.723   27.065    7.745    4.076   23.459
    0    0.000    0.000
    5    2.100   20.000
   15   10.800  160.000
   20   26.580  500.000
   25   62.990 1080.000
   30  132.030 1740.000
   35  235.000 2340.000
   40  370.000 3160.000
   45  555.000 4300.000
   50  812.600 5780.000
   55 1136.000 7400.000
0.120
0.077
0.048
0.036
0.033
0.034
0.057
0.069
0.107
0.141
0.176
0.164

0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
0.000
```

Table A.6 BH demand allocation file *

annual median inflow [$10^6 m^3$]

objective function type

weight for the first term of the objective function type 3 only

weight for the second term of the objective function type 3 only

simulation mode

```
119.41 1 0 0 1
IBH
DSS
```

demand centre codes

Table A.7 BM demand allocation file

```
40.44 1 0 0 1
TU
BE
JE
MB
DBH
```

Table A.8 KA demand allocation file

```
43.15 1 0 0 1
TU
DSS
```

Table A.9 ME demand allocation file

```
139.46 1 0 0 1
 INE
 IBH
 DSS
```

Table A.10 SS demand allocation file

```
681.35 1 0 0 1
 IAEA
 TU
 TO
 NA
 MO
 SO
 SF
 IBV
 IMSC
```

---

* DAF file - demand allocation file

Table A.11 General demand file

demand center and reservoir supply defict codes

monthly demands (September - August) [$10^6 m^3$]

```
  TU   4.634   4.538   4.305   4.181   4.529   4.048   4.515   4.691   4.977   5.243   5.743   5.738
  MO   0.101   0.090   0.082   0.079   0.069   0.065   0.084   0.094   0.100   0.110   0.129   0.128
  NA   0.116   0.099   0.086   0.081   0.080   0.073   0.090   0.098   0.108   0.119   0.145   0.150
  SO   0.290   0.275   0.252   0.229   0.205   0.190   0.250   0.264   0.274   0.296   0.355   0.372
  SF   0.762   0.654   0.626   0.567   0.544   0.484   0.615   0.675   0.715   0.739   0.766   0.801
  JE   0.108   0.103   0.092   0.090   0.096   0.084   0.096   0.099   0.104   0.106   0.105   0.130
  BE   0.136   0.125   0.120   0.119   0.105   0.108   0.128   0.128   0.137   0.147   0.166   0.162
  MB   0.039   0.036   0.034   0.034   0.030   0.031   0.037   0.037   0.039   0.042   0.047   0.046
  TO   1.624   1.459   0.914   0.777   0.716   0.765   1.138   1.211   1.388   1.531   1.892   2.077
IAEA   2.881   2.131   1.391   0.000   0.000   0.235   2.287   4.820   7.488   9.350  10.001   7.519
 IBV   1.250   0.627   0.305   0.002   0.002   0.003   0.154   0.768   1.813   2.736   3.089   2.715
IMSC  12.784   5.420   2.258   0.606   0.505   2.020   6.586   7.675  13.132  21.709  26.502  25.250
 INE   0.204   0.079   0.060   0.000   0.000   0.000   0.070   0.119   0.224   0.487   0.654   0.585
 IBH  20.154  10.369   6.283   0.000   4.363   6.611   7.790  16.018  10.660  16.661  21.693  13.170
-----------------------------------------------------------------------------------------------------
 DSS   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DKA   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DME   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DBH   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DBM   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DXX   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
```

demand centers

reservoir supply deficits

— a 'dummy' line

Table A.12 BM manage file; sequential decomposition

```
1_BM.MAN  ------------------  manage file name

COMMENTS                    ]
BM RESERVOIR                ]  comment section
GOING DOWNSTREAM ONLY       ]

DEMAND                      ]
C:\PR\NEW.DEM               ]  The DEMAND program
C:\SY\BM.DAF                ]  section
C:\CU\BM.DD                 ]

INFLOW  --------------------   The INFLOW program
                               section
POLICY                      ]
25                          ]
C:\SY\BM.RES                ]
-                           ]  The POLICY program
C:\CU\BM.DD                 ]  section
C:\CU\BM.POL                ]
C:\CU\BM.STA                ]

MODIFY                      ]
C:\CU\BM.DD                 ]  The MODIFPOL program
C:\CU\BM.POL                ]  section
C:\CU\BM.MPL                ]

AGGREGATE                   ]
C:\SY\BM.DAF                ]  The AGGRMD program
C:\CU\BM.SIM                ]  section

SIMULATE                    ]
C:\SY\BM.RES                ]
C:\SY\BM.DAF                ]
-                           ]
C:\CU\BM.DD                 ]  The SIMULATE program
C:\CU\BM.MPL                ]  section
1.0                         ]
C:\CU\BM.SIM                ]

DEFICIT                     ]
C:\CU\BM.SIM                ]
C:\PR\NEW.DEM               ]
C:\SY\BM.DAF                ]
C:\CU\BM.DEM                ]
C:\CU\BM.FDF                ]  The DEFICIT program
C:\CU\BM.INT                ]  section
DBM                         ]
DBH                         ]
-                           ]
C:\CU\BM.DRS                ]
C:\CU\BM.DRE                ]
```

Table A.13 KA manage file; sequential decomposition

```
2_KA.MAN

COMMENTS
KA RESERVOIR
GOING DOWMSTREAM ONLY

DEMAND
C:\CU\BM.DEM
C:\SY\KA.DAF
C:\CU\KA.DD

INFLOW

POLICY
25
C:\SY\KA.RES
-
C:\CU\KA.DD
C:\CU\KA.POL
C:\CU\KA.STA

MODIFY
C:\CU\KA.DD
C:\CU\KA.POL
C:\CU\KA.MPL

AGGREGATE
C:\SY\KA.DAF
C:\CU\KA.SIM

SIMULATE
C:\SY\KA.RES
C:\SY\KA.DAF
-
C:\CU\KA.DD
C:\CU\KA.MPL
1.0
C:\CU\KA.SIM

DEFICIT
C:\CU\KA.SIM
C:\CU\BM.DEM
C:\SY\KA.DAF
C:\CU\KA.DEM
C:\CU\KA.FDF
C:\CU\KA.INT
DKA
DSS
-
C:\CU\KA.DRS
C:\CU\KA.DRE
```

Table A.14 BH manage file; sequential decomposition

```
3_BH.MAN

COMMENTS
BH RESERVOIR
GOING DOWNSTREAM ONLY

DEMAND
C:\CU\KA.DEM
C:\SY\BH.DAF
C:\CU\BH.DD

INFLOW
ADD C:\SY\BH.RES  C:\CU\BM.DRS TO C:\CU\BH1.ERS
ADD C:\CU\BH1.ERS C:\CU\BM.DRE TO C:\CU\BH2.ERS
ADD C:\CU\BH2.ERS C:\CU\BM.FDF TO C:\CU\BH.NIF
```

Table A.14 (continued)

```
POLICY
25
C:\SY\BH.RES
C:\CU\BH.NIF
C:\CU\BH.DD
C:\CU\BH.POL
C:\CU\BH.STA

MODIFY
C:\CU\BH.DD
C:\CU\BH.POL
C:\CU\BH.MPL

AGGREGATE
C:\SY\BH.DAF
C:\CU\BH.SIM
```

Table A.14 (continued)

```
SIMULATE
C:\SY\BH.RES
C:\SY\BH.DAF
C:\CU\BH.NIF
C:\CU\BH.DD
C:\CU\BH.MPL
1.0
C:\CU\BH.SIM

DEFICIT
C:\CU\BH.SIM
C:\CU\KA.DEM
C:\SY\BH.DAF
C:\CU\BH.DEM
C:\CU\BH.FDF
C:\CU\BH.INT
DBH
DSS
-
C:\CU\BH.DRS
C:\CU\BH.DRE
```

Table A.15 ME manage file; sequential decomposition

```
4_ME.MAN

COMMENTS
ME RESERVOIR
GOING DOWNSTREAM ONLY

DEMAND
C:\CU\BH.DEM
C:\SY\ME.DAF
C:\CU\ME.DD

INFLOW

POLICY
25
C:\SY\ME.RES
-
C:\CU\ME.DD
C:\CU\ME.POL
C:\CU\ME.STA

MODIFY
C:\CU\ME.DD
C:\CU\ME.POL
C:\CU\ME.MPL

AGGREGATE
C:\SY\ME.DAF
C:\CU\ME.SIM

SIMULATE
C:\SY\ME.RES
C:\SY\ME.DAF
-
C:\CU\ME.DD
C:\CU\ME.MPL
1.0
C:\CU\ME.SIM

DEFICIT
C:\CU\ME.SIM
C:\CU\BH.DEM
C:\SY\ME.DAF
C:\CU\ME.DEM
C:\CU\ME.FDF
C:\CU\ME.INT
DME
DSS
-
C:\CU\ME.DRS
C:\CU\ME.DRE
```

Table A.16 SS manage file; sequential decomposition

```
5_SS.MAN

COMMENTS
SS RESERVOIR
GOING DOWNSTREAM ONLY

DEMAND
C:\CU\ME.DEM
C:\SY\SS.DAF
C:\CU\SS.DD

INFLOW
ADD C:\SY\SS.RES  C:\CU\ME.DRS TO C:\CU\SS1.ERS
ADD C:\CU\SS1.ERS C:\CU\ME.DRE TO C:\CU\SS2.ERS
ADD C:\CU\SS2.ERS C:\CU\ME.FDF TO C:\CU\SS3.ERS
ADD C:\CU\SS3.ERS C:\CU\BH.DRS TO C:\CU\SS4.ERS
ADD C:\CU\SS4.ERS C:\CU\BH.DRE TO C:\CU\SS5.ERS
ADD C:\CU\SS5.ERS C:\CU\BH.FDF TO C:\CU\SS6.ERS
ADD C:\CU\SS6.ERS C:\CU\KA.DRS TO C:\CU\SS7.ERS
ADD C:\CU\SS7.ERS C:\CU\KA.DRE TO C:\CU\SS8.ERS
ADD C:\CU\SS8.ERS C:\CU\KA.FDF TO C:\CU\SS.NIF
```

Table A.16 (continued)

```
POLICY
25
C:\SY\SS.RES
C:\CU\SS.NIF
C:\CU\SS.DD
C:\CU\SS.POL
C:\CU\SS.STA

MODIFY
C:\CU\SS.DD
C:\CU\SS.POL
C:\CU\SS.MPL

AGGREGATE
C:\SY\SS.DAF
C:\CU\SS.SIM
```

Table A.16 (continued)

```
SIMULATE
C:\SY\SS.RES
C:\SY\SS.DAF
C:\CU\SS.NIF
C:\CU\SS.DD
C:\CU\SS.MPL
1.0
C:\CU\SS.SIM

DEFICIT
C:\CU\SS.SIM
C:\CU\ME.DEM
C:\SY\SS.DAF
C:\CU\SS.DEM
C:\CU\SS.FDF
C:\CU\SS.INT
DSS
-
-
-
-
```

Table A.17 The new demand manage file (sequential decomposition)

```
Manage file for creating the new demand
file for the following iteration
(sequential decomposition).
```
[*]

```
NEWDEMAND
C:\SY\ORIG.DEM
C:\CU\SS.DEM
C:\CU\NEW.DEM
```

The NEWDEM program section

Table A.18 The DEMGEN.MAN manage file (sequential decomposition)

```
The DEMGEN.MAN manage file
for generating individual
demand time series;
(sequential decomposition).
```
[*]

```
GENERATE
1946 44
C:\PR\NEW.DEM
C:\CU\NEWDEM4.RMD
C:\SY\BM.DAF
C:\SY\BH.DAF
C:\SY\KA.DAF
C:\SY\ME.DAF
C:\SY\SS.DAF
```

The DEMGEN program section

---

[*] The number of lines at the beginning of the file has no impact on the program execution. It serves only as a description of the file contents.

Table A.19 SS manage file 1; iterative decomposition; first iteration

```
1FIRS_SS.MAN

COMMENTS
SS RESERVOIR
GOING UP-AND-DOWNSTREAM; FIRST ITERATION

DEMAND
C:\SY\ORIG.DEM
C:\SY\SS.DAF
C:\CU\UP\SS.DD

INFLOW *

POLICY
25
C:\SY\SS.RES
-
C:\CU\UP\SS.DD
C:\CU\UP\SS.POL
C:\CU\UP\SS.STA

MODIFY
C:\CU\UP\SS.DD
C:\CU\UP\SS.POL
C:\CU\UP\SS.MPL

AGGREGATE

SIMULATE
C:\SY\SS.RES
C:\SY\SS.DAF
-
C:\CU\UP\SS.DD
C:\CU\UP\SS.MPL
1.0
C:\CU\UP\SS.SIM

DEFICIT
C:\CU\UP\SS.SIM
C:\SY\ORIG.DEM
C:\SY\SS.DAF
C:\CU\UP\SS.DEM
C:\CU\UP\SS.FDF
C:\CU\UP\SS.INT
DSS
-
-
-
-
```

---

[*] The INFLOW program section is empty due to unknown releases from upstream reservoirs.

Table A.20 SS manage file 1; iterative decomposition

```
1_SS.MAN

COMMENTS
SS RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\SY\ORIG.DEM
C:\SY\SS.DAF
C:\CU\UP\SS.DD

INFLOW
ADD C:\SY\SS.RES     C:\PR\UP\ME.DRS TO C:\CU\UP\SS1.ERS
ADD C:\CU\UP\SS1.ERS C:\PR\UP\ME.DRE TO C:\CU\UP\SS2.ERS
ADD C:\CU\UP\SS2.ERS C:\PR\UP\ME.FDF TO C:\CU\UP\SS3.ERS
ADD C:\CU\UP\SS3.ERS C:\PR\DO\BH.DRS TO C:\CU\UP\SS4.ERS
ADD C:\CU\UP\SS4.ERS C:\PR\DO\BH.DRE TO C:\CU\UP\SS5.ERS
ADD C:\CU\UP\SS5.ERS C:\PR\DO\BH.FDF TO C:\CU\UP\SS6.ERS
ADD C:\CU\UP\SS6.ERS C:\PR\UP\KA.DRS TO C:\CU\UP\SS7.ERS
ADD C:\CU\UP\SS7.ERS C:\PR\UP\KA.DRE TO C:\CU\UP\SS8.ERS
ADD C:\CU\UP\SS8.ERS C:\PR\UP\KA.FDF TO C:\CU\UP\SS.NIF
```

Table A.20 (continued)

```
POLICY
25
C:\SY\SS.RES
C:\CU\UP\SS.NIF
C:\CU\UP\SS.DD
C:\CU\UP\SS.POL
C:\CU\UP\SS.STA

MODIFY
C:\CU\UP\SS.DD
C:\CU\UP\SS.POL
C:\CU\UP\SS.MPL

AGGREGATE
```

Table A.20 (continued)

```
SIMULATE
C:\SY\SS.RES
C:\SY\SS.DAF
C:\CU\UP\SS.NIF
C:\CU\UP\SS.DD
C:\CU\UP\SS.MPL
1.0
C:\CU\UP\SS.SIM

DEFICIT
C:\CU\UP\SS.SIM
C:\SY\ORIG.DEM
C:\SY\SS.DAF
C:\CU\UP\SS.DEM
C:\CU\UP\SS.FDF
C:\CU\UP\SS.INT
DSS
-
-
-
-
```

Table A.21 KA manage file; iterative decomposition

```
2_KA.MAN

COMMENTS
KA RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\UP\OSS.DEM
C:\SY\KA.DAF
C:\CU\UP\KA.DD

INFLOW

POLICY
25
C:\SY\KA.RES
-
C:\CU\UP\KA.DD
C:\CU\UP\KA.POL
C:\CU\UP\KA.STA

MODIFY
C:\CU\UP\KA.DD
C:\CU\UP\KA.POL
C:\CU\UP\KA.MPL

AGGREGATE

SIMULATE
C:\SY\KA.RES
C:\SY\KA.DAF
-
C:\CU\UP\KA.DD
C:\CU\UP\KA.MPL
1.0
C:\CU\UP\KA.SIM

DEFICIT
C:\CU\UP\KA.SIM
C:\CU\UP\OSS.DEM
C:\SY\KA.DAF
C:\CU\UP\KA.DEM
C:\CU\UP\KA.FDF
C:\CU\UP\KA.INT
DKA
DSS
-
C:\CU\UP\KA.DRS
C:\CU\UP\KA.DRE
```

Table A.22 KA new demand manage file; iterative decomposition

```
2_KA_DEM.MAN

Manage file for creating a
demand file for the KA
reservoir optimization


NEWDEMAND
C:\SY\ORIG.DEM
C:\CU\UP\SS.DEM
C:\CU\UP\OSS.DEM
```

Table A.23 BH manage file 1; iterative decomposition; first iteration

```
3FIRS_BH.MAN

COMMENTS
BH RESERVOIR
GOING UP-AND-DOWNSTREAM; FIRST ITERATION

DEMAND
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\UP\BH.DD

INFLOW *

POLICY
25
C:\SY\BH.RES
-
C:\CU\UP\BH.DD
C:\CU\UP\BH.POL
C:\CU\UP\BH.STA

MODIFY
C:\CU\UP\BH.DD
C:\CU\UP\BH.POL
C:\CU\UP\BH.MPL

AGGREGATE

SIMULATE
C:\SY\BH.RES
C:\SY\BH.DAF
-
C:\CU\UP\BH.DD
C:\CU\UP\BH.MPL
1.0
C:\CU\UP\BH.SIM

DEFICIT
C:\CU\UP\BH.SIM
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\UP\BH.DEM
C:\CU\UP\BH.FDF
C:\CU\UP\BH.INT
DBH
DSS
-
C:\CU\UP\BH.DRS
C:\CU\UP\BH.DRE
```

---

[*] The INFLOW program section is empty due to unknown releases from upstream reservoirs.

Table A.24 BH manage file 1; iterative decomposition

```
3_BH.MAN

COMMENTS
BH RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\UP\BH.DD

INFLOW
ADD C:\SY\BH.RES     C:\PR\UP\BM.DRS TO C:\CU\UP\BH1.ERS
ADD C:\CU\UP\BH1.ERS C:\PR\UP\BM.DRE TO C:\CU\UP\BH2.ERS
ADD C:\CU\UP\BH2.ERS C:\PR\UP\BM.FDF TO C:\CU\UP\BH.NIF
```

Table A.24 (continued)

```
POLICY
25
C:\SY\BH.RES
C:\CU\UP\BH.NIF
C:\CU\UP\BH.DD
C:\CU\UP\BH.POL
C:\CU\UP\BH.STA

MODIFY
C:\CU\UP\BH.DD
C:\CU\UP\BH.POL
C:\CU\UP\BH.MPL

AGGREGATE
```

Table A.24 (continued)

```
SIMULATE
C:\SY\BH.RES
C:\SY\BH.DAF
C:\CU\UP\BH.NIF
C:\CU\UP\BH.DD
C:\CU\UP\BH.MPL
1.0
C:\CU\UP\BH.SIM

DEFICIT
C:\CU\UP\BH.SIM
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\UP\BH.DEM
C:\CU\UP\BH.FDF
C:\CU\UP\BH.INT
DBH
DSS
-
C:\CU\UP\BH.DRS
C:\CU\UP\BH.DRE
```

Table A.25 BM manage file; iterative decomposition

```
4_BM.MAN

COMMENTS
BM RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\UP\BH.DEM
C:\SY\BM.DAF
C:\CU\UP\BM.DD

INFLOW

POLICY
25
C:\SY\BM.RES
-
C:\CU\UP\BM.DD
C:\CU\UP\BM.POL
C:\CU\UP\BM.STA

MODIFY
C:\CU\UP\BM.DD
C:\CU\UP\BM.POL
C:\CU\UP\BM.MPL

AGGREGATE

SIMULATE
C:\SY\BM.RES
C:\SY\BM.DAF
-
C:\CU\UP\BM.DD
C:\CU\UP\BM.MPL
1.0
C:\CU\UP\BM.SIM

DEFICIT
C:\CU\UP\BM.SIM
C:\CU\UP\BH.DEM
C:\SY\BM.DAF
C:\CU\UP\BM.DEM
C:\CU\UP\BM.FDF
C:\CU\UP\BM.INT
DBM
DBH
-
C:\CU\UP\BM.DRS
C:\CU\UP\BM.DRE
```

Table A.26 BH manage file 2; iterative decomposition

```
5_BH.MAN

COMMENTS
BH RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\DO\BH.DD

INFLOW
ADD C:\SY\BH.RES     C:\CU\UP\BM.DRS TO C:\CU\DO\BH1.ERS
ADD C:\CU\DO\BH1.ERS C:\CU\UP\BM.DRE TO C:\CU\DO\BH2.ERS
ADD C:\CU\DO\BH2.ERS C:\CU\UP\BM.FDF TO C:\CU\DO\BH.NIF
```

Table A.26 (continued)

```
POLICY
25
C:\SY\BH.RES
C:\CU\DO\BH.NIF
C:\CU\DO\BH.DD
C:\CU\DO\BH.POL
C:\CU\DO\BH.STA

MODIFY
C:\CU\DO\BH.DD
C:\CU\DO\BH.POL
C:\CU\DO\BH.MPL

AGGREGATE
```

Table A.26 (continued)

```
SIMULATE
C:\SY\BH.RES
C:\SY\BH.DAF
C:\CU\DO\BH.NIF
C:\CU\DO\BH.DD
C:\CU\DO\BH.MPL
1.0
C:\CU\DO\BH.SIM

DEFICIT
C:\CU\DO\BH.SIM
C:\CU\UP\KA.DEM
C:\SY\BH.DAF
C:\CU\DO\BH.DEM
C:\CU\DO\BH.FDF
C:\CU\DO\BH.INT
DBH
DSS
-
C:\CU\DO\BH.DRS
C:\CU\DO\BH.DRE
```

Table A.27 ME manage file; iterative decomposition

```
6_ME.MAN

COMMENTS
ME RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\DO\BH.DEM
C:\SY\ME.DAF
C:\CU\UP\ME.DD

INFLOW

POLICY
25
C:\SY\ME.RES
-
C:\CU\UP\ME.DD
C:\CU\UP\ME.POL
C:\CU\UP\ME.STA

MODIFY
C:\CU\UP\ME.DD
C:\CU\UP\ME.POL
C:\CU\UP\ME.MPL

AGGREGATE

SIMULATE
C:\SY\ME.RES
C:\SY\ME.DAF
-
C:\CU\UP\ME.DD
C:\CU\UP\ME.MPL
1.0
C:\CU\UP\ME.SIM

DEFICIT
C:\CU\UP\ME.SIM
C:\CU\DO\BH.DEM
C:\SY\ME.DAF
C:\CU\UP\ME.DEM
C:\CU\UP\ME.FDF
C:\CU\UP\ME.INT
DME
DSS
-
C:\CU\UP\ME.DRS
C:\CU\UP\ME.DRE
```

Table A.28 SS manage file 2; iterative decomposition

```
7_SS.MAN

COMMENTS
SS RESERVOIR
GOING UP-AND-DOWNSTREAM

DEMAND
C:\CU\UP\BM.DEM
C:\SY\SS.DAF
C:\CU\DO\SS.DD

INFLOW
ADD C:\SY\SS.RES     C:\CU\UP\ME.DRS TO C:\CU\DO\SS1.ERS
ADD C:\CU\DO\SS1.ERS C:\CU\UP\ME.DRE TO C:\CU\DO\SS2.ERS
ADD C:\CU\DO\SS2.ERS C:\CU\UP\ME.FDF TO C:\CU\DO\SS3.ERS
ADD C:\CU\DO\SS3.ERS C:\CU\DO\BH.DRS TO C:\CU\DO\SS4.ERS
ADD C:\CU\DO\SS4.ERS C:\CU\DO\BH.DRE TO C:\CU\DO\SS5.ERS
ADD C:\CU\DO\SS5.ERS C:\CU\DO\BH.FDF TO C:\CU\DO\SS6.ERS
ADD C:\CU\DO\SS6.ERS C:\CU\UP\KA.DRS TO C:\CU\DO\SS7.ERS
ADD C:\CU\DO\SS7.ERS C:\CU\UP\KA.DRE TO C:\CU\DO\SS8.ERS
ADD C:\CU\DO\SS8.ERS C:\CU\UP\KA.FDF TO C:\CU\DO\SS.NIF
```

Table A.28 (continued)

```
POLICY
25
C:\SY\SS.RES
C:\CU\DO\SS.NIF
C:\CU\DO\SS.DD
C:\CU\DO\SS.POL
C:\CU\DO\SS.STA

MODIFY
C:\CU\DO\SS.DD
C:\CU\DO\SS.POL
C:\CU\DO\SS.MPL

AGGREGATE
```

Table A.28 (continued)

```
SIMULATE
C:\SY\SS.RES
C:\SY\SS.DAF
C:\CU\DO\SS.NIF
C:\CU\DO\SS.DD
C:\CU\DO\SS.MPL
1.0
C:\CU\DO\SS.SIM

DEFICIT
C:\CU\DO\SS.SIM
C:\CU\UP\BM.DEM
C:\SY\SS.DAF
C:\CU\DO\SS.DEM
C:\CU\DO\SS.FDF
C:\CU\DO\SS.INT
DSS
-
-
-
-
```

Table A.29 The entire process batch file; sequential decomposition

```
rem docomp.bat
rem Master iteration file;                 comment section
rem sequential                             general information
rem decomposition

echo - iteration 1 -                       iteration message
rem assuming that c:\cu does not exist
rem md c:\cu                                         The DEMGEN program
rem copy c:\pr\new.dem c:\cu\newdem4.rmd             control section*
rem demgen
call doonce.bat                            single iteration execution
newdem                                     creation of the new demand
rendir c:\pr c:\do0                        saving the results
rendir c:\cu c:\pr                         adjusting directory structure

echo - iteration 2 -
rem md c:\cu
rem copy c:\pr\new.dem c:\cu\newdem4.rmd
rem demgen
call doonce.bat
newdem
rendir c:\pr c:\do1
rendir c:\cu c:\pr

echo - iteration 3 -
rem md c:\cu
rem copy c:\pr\new.dem c:\cu\newdem4.rmd
rem demgen
call doonce.bat
newdem
rendir c:\pr c:\do2
rendir c:\cu c:\do3
```

---

* Remove DOS command 'rem' to use the 'monitored demand' simulation.

Table A.30 Single iteration batch file; sequential decomposition

```
rem doonce.bat                                ]
rem single iteration batch file               ]  comment section
rem sequential decomposition                  ]

copy 1_bm.man manage.tmp  ---------  creation of a temporary 'manage file'
demand      -------------------------  the DEMAND program execution
inflow      -------------------------  the INFLOW program execution
dirchk      -------------------------  the DIRCHK program execution
policy      -------------------------  the POLICY program execution
modifpol    -------------------------  the MODIFPOL program execution
rem aggrmd  -------------------------  the AGGRMD program execution*
simulate    -------------------------  the SIMULATE program execution
deficit     -------------------------  the DEFICIT program execution
```

Table A.30 (continued)

```
copy 2_ka.man manage.tmp
demand
inflow
dirchk
policy
modifpol
rem aggrmd*
simulate
deficit

copy 3_bh.man manage.tmp
demand
inflow
dirchk
policy
modifpol
rem aggrmd*
simulate
deficit
```

Table A.30 (continued)

```
copy 4_me.man manage.tmp
demand
inflow
dirchk
policy
modifpol
rem aggrmd*
simulate
deficit

copy 5_ss.man manage.tmp
demand
inflow
dirchk
policy
modifpol
rem aggrmd*
simulate
deficit

del c:\cu\*.ers
```

---

[*] Remove DOS command 'rem' to use the 'monitored demand' simulation.

Table A.31 The entire process batch file; iterative decomposition

```
rem upcomp.bat
rem Master iteration file;
rem going up-and-downstream

echo - iteration 1 -
call upfirs.bat
rendir c:\pr c:\up0
rendir c:\cu c:\pr

echo - iteration 2 -
call uponce.bat
rendir c:\pr c:\up1
rendir c:\cu c:\pr

echo - iteration 3 -
call uponce.bat
rendir c:\pr c:\up2
rendir c:\cu c:\up3
```

Table A.32 Initial iteration batch file; iterative decomposition

```
rem upfirs.bat
rem first iteration
rem batch file
rem iterative decomposition

copy 1firs_ss.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 2_ka.man manage.tmp
copy 2_ka_dem.man newdem.man
newdem
del newdem.man
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 3firs_bh.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit
```

Table A.32 (continued)

```
copy 4_bm.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 5_bh.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 6_me.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 7_ss.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

del c:\cu\up\*.ers
del c:\cu\do\*.ers
```

Table A.33 Single iteration batch file; iterative decomposition

```
rem uponce.bat
rem single iteration
rem batch file
rem iterative decomposition

copy 1_ss.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 2_ka.man manage.tmp
copy 2_ka_dem.man newdem.man
newdem
del newdem.man
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 3_bh.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit
```

Table A.33 (continued)

```
copy 4_bm.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 5_bh.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 6_me.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

copy 7_ss.man manage.tmp
demand
inflow
dirchk
policy
modifpol
simulate
deficit

del c:\cu\up\*.ers
del c:\cu\do\*.ers
```

APPENDIX B

The DEMAND program input and output files

Table B.1 General demand file KA.DEM (input)

```
  TU    0.125    0.181    0.276    0.119    0.199    0.017    0.062    0.024    0.057    0.043    0.132    0.244
  MO    0.101    0.090    0.082    0.079    0.069    0.065    0.084    0.094    0.100    0.110    0.129    0.128
  NA    0.116    0.099    0.086    0.081    0.080    0.073    0.090    0.098    0.108    0.119    0.145    0.150
  SO    0.290    0.275    0.252    0.229    0.205    0.190    0.250    0.264    0.274    0.296    0.355    0.372
  SF    0.762    0.654    0.626    0.567    0.544    0.484    0.615    0.675    0.715    0.739    0.766    0.801
  JE    0.086    0.103    0.092    0.088    0.085    0.069    0.083    0.091    0.104    0.098    0.103    0.130
  BE    0.106    0.125    0.120    0.116    0.093    0.088    0.111    0.103    0.137    0.129    0.162    0.162
  MB    0.031    0.036    0.034    0.033    0.027    0.025    0.032    0.034    0.039    0.041    0.046    0.046
  TO    1.624    1.459    0.914    0.777    0.716    0.765    1.138    1.211    1.388    1.531    1.892    2.077
IAEA    2.881    2.131    1.391    0.000    0.000    0.235    2.287    4.820    7.488    9.350   10.001    7.519
 IBV    1.250    0.627    0.305    0.002    0.002    0.003    0.154    0.768    1.813    2.736    3.089    2.715
IMSC   12.784    5.420    2.258    0.606    0.505    2.020    6.586    7.675   13.132   21.709   26.502   25.250
 INE    0.204    0.079    0.060    0.000    0.000    0.000    0.070    0.119    0.224    0.487    0.654    0.585
 IBH   20.154   10.369    6.283    0.000    4.363    6.611    7.790   16.018   10.660   16.661   21.693   13.170
-------------------------------------------------------------------
 DSS    0.368    0.101    0.018    0.144    0.149    0.099    0.104    0.094    0.018    0.053    0.221    0.556
 DKA    0.493    0.282    0.294    0.263    0.347    0.116    0.166    0.118    0.076    0.095    0.353    0.800
 DME    0.102    0.000    0.056    0.000    0.036    0.028    0.098    0.008    0.092    0.007    0.000    0.063
 DBH    8.706    5.844    3.585    0.000    2.339    2.131    1.621    3.676    3.304    5.691    7.968    6.681
 DBM    9.965    7.304    6.202    3.361    4.419    3.855    3.525    5.136    5.552    7.305    9.896    9.016
 DXX    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

Table B.2 Demand allocation file BH.DAF (input)

```
119.41 1 0 0 1
IBH
DSS
```

Table B.3 Distributed demand file BH.DD (output)

```
Demands on the reservoir: ------------------------------- title
                                                          month
                                                          individual demands [10^6m^3]
     Mth    IBH      DSS
       1   20.154   0.368
       2   10.369   0.101
       3    6.283   0.018
       4    0.000   0.144
       5    4.363   0.149
       6    6.611   0.099
       7    7.790   0.104
       8   16.018   0.094
       9   10.660   0.018
      10   16.661   0.053
      11   21.693   0.221
      12   13.170   0.556
DISTRIBUTED DEMAND
                                                          month
                                                          total distributed demands [10^6m^3]
       1   18.059
       2    9.213
       3    5.545
       4    0.127
       5    3.970
       6    5.905
       7    6.947
       8   14.178
       9    9.396
      10   14.708
      11   19.284
      12   12.079
Distributed Demand calculated according to:
Total monthly demand * Annual Median Flow / Total Annual Demand    description of
                                                                   the calculation process
Annual Median Flow  :    119.410                                   and
Total Annual Demand :    135.697                                   the objective function type
Objective function  :          1                                   input data
OF=3; Weights 1 & 2 :      0.000      0.000
```

APPENDIX C

The INFLOW program input and output files; Additional options of the INFLOW program

Table C.1 Reservoir data file BH.RES (input)

```
RESERVOIR BH 1991
    44
   117.5      15.0    429.24        13         1
      46     0.610     1.450     3.960   101.240    18.150     8.360     6.110     5.670     1.320     0.610     0.630     0.900
      47     0.320     3.900     2.970    11.680    15.210     7.290     6.840     4.820     1.470     0.680     0.330     0.310
      48     0.370     0.320    23.250    17.040    57.650    26.920    36.310     4.590     1.700     1.490     1.140     1.000
      49     0.880     0.860     4.180     2.010    12.990    17.370    36.330    25.170     1.800     1.460     1.090     0.920
      50     0.850     1.430     5.190     4.170    11.650    25.140     8.420     2.720     1.350     1.090     0.950     0.860
      51     0.820     6.410    14.880    18.300    21.480    42.170    12.750    13.590     2.670     1.410     0.890     0.850
      52     0.870     0.880    10.060    47.910    30.080    15.030    13.700     4.040     3.580     1.850     1.210     1.700
      53     0.940    11.600    17.300    10.220    36.350    59.360    14.480    15.200     3.490     1.420     1.220     1.050
      54     0.940     2.160     4.520    17.810     9.830    17.170    10.880     4.750     1.490     1.150     0.990     0.870
      55     2.140     4.700     6.150    16.570    14.180    75.980    11.710     5.190     3.040     2.100     1.270     1.000
      56     0.450     1.250     2.370    27.350    29.260     7.350     5.530     8.410     2.450     2.420     1.130     0.990
      57     0.550     3.200     4.050    27.930    48.070     2.830    20.130     3.940     0.910     0.690     0.000     0.700
      58     0.160     1.400    14.600     8.660    24.590     3.980    76.980    41.080     1.480     2.230     0.840     0.000
      59     0.550     0.860     5.760    15.900    25.750     3.250     5.190     8.330    20.860     0.590     0.240     0.330
      60     0.000     0.220     0.260     8.280    26.210     3.760     2.450     0.420     1.510     0.840     0.630     0.130
      61     0.200     0.960     1.340     1.190     4.260    18.410     4.860    10.920     1.060     0.480     0.470     0.250
      62     0.460    12.700    10.000    28.700    13.600    29.300     2.960    13.420     0.370     0.290     2.750     4.420
      63     2.550     2.060     2.800     9.740    20.100    22.710     5.670     3.410     1.730     0.550     0.490     0.720
      64     1.250     1.460     4.010     2.230    28.300    46.570    16.400     2.690     1.730     1.110     0.770     0.510
      65     0.330     0.230     0.150     2.050     4.940     2.910    12.600    35.770     6.870     1.510     0.880     0.810
      66     3.970     0.790     1.970     8.340    13.600    19.050     3.950     2.490     2.010     1.330     0.620     0.780
      67     0.740     0.680     0.770     3.930    15.800     4.640     1.760     0.690     0.680     1.470     0.420     0.290
      68     0.410     0.640     0.950     5.370    13.600     4.880     2.570     3.720     0.730     0.470     0.300     0.440
      69     0.840     9.070     1.730    54.600     9.010     9.530    23.730     3.140     1.620     0.910     0.730     0.240
      70     0.090     0.370     0.070    15.650    30.780    32.350    16.650    18.640     2.070     0.000     0.350     0.000
      71     0.480     3.240     0.840     1.680    17.210    20.220     7.130    19.580     3.340     0.670     0.000     0.000
      72     0.550     0.340     0.080     0.470    26.770    22.610    71.490     5.740     0.740     0.100     0.230     0.180
      73     0.000     2.660     0.000     2.620     0.620     6.480     4.520    13.320     1.170     0.020     0.000     0.000
      74     0.190     1.330    27.560     8.460     3.250    26.680     9.530     3.290    12.410     0.420     0.260     0.310
      75     0.480     0.160     3.610     7.590     3.700    10.570    27.000     4.320    10.170     0.780     0.430     0.190
      76     3.360     1.850    20.720    13.720     8.130     4.430     1.250     1.990     1.400     1.540     0.980     2.350
      77     1.170     0.220     7.900     1.190     5.740    29.600     4.240    13.170     3.480     2.770     2.540     2.270
      78     0.000     0.270     5.300     4.150     4.980     8.880     2.840    25.540     3.640     2.040     2.890     2.350
      79     0.000     0.000    20.210     2.450     5.310    11.640    21.620     5.260     4.210     0.050     0.000     0.000
      80     0.490     0.900     1.110    19.780    30.490    12.510     5.890     4.220     1.770     0.870     0.000     0.000
      81     0.210     0.210     0.930     3.610     7.940    14.750    22.800    16.470     6.550     0.000     0.000     0.140
      82     0.130     0.410    16.850    35.880    15.550     3.670     9.960     3.800     1.140     0.290     0.000     0.000
      83     0.420     0.510     5.950    11.010    15.460    43.980    45.480     2.950     0.000     0.120     0.000     0.020
      84     0.350     0.300     0.670    34.820    83.570    31.340     6.210     0.020     0.030     0.000     0.000     0.000
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Table C.1 Reservoir data file (continued)

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   85     0.680     0.060     0.230     0.250    10.450    16.370    10.590     1.530     4.480     0.070     1.280     0.150
   86     2.550     1.810     3.680    18.000    47.020    77.150    25.210    60.970     5.010     3.690     0.010     0.220
   87     0.720     2.440     1.980     2.200     4.160     5.790    33.430     0.070     0.630     1.220     0.110     0.940
   88     0.730     1.570     0.560     2.760     1.290     3.260     6.310     2.950     1.480     0.640     0.690     0.820
   89     1.050     1.140     0.570     1.060     1.420     0.740     0.680     0.310     1.360     0.340     0.150     0.540
    0     6.400    84.000
    3    10.300   144.000
    5    14.500   188.000
    7    18.500   236.000
   10    25.750   322.000
   13    35.500   416.000
   15    44.500   494.000
   17    54.000   560.000
   20    71.200   676.000
   23    92.300   784.000
   25   112.000   854.000
   26   117.500   894.000
   27   123.000   934.000
0.079
0.051
0.025
0.022
0.020
0.020
0.032
0.033
0.061
0.099
0.131
0.125

0.000
0.000
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0.000
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Table C.2 Downstream reservoir supply file BM.DRS (input)

46	0.405	0.000	0.000	0.000	2.562	0.112	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	2.472	1.817	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.545	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
52	0.256	0.000	0.000	0.000	1.633	1.689	0.490	0.000	0.000	0.000	0.000	0.000
53	0.278	0.000	0.000	0.000	0.000	2.472	0.880	1.019	0.000	0.000	0.000	0.000
54	0.568	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.000	0.000	2.472	0.000	0.000	0.000	0.000	0.000	0.000
56	0.457	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.875	0.000	0.000	0.000	0.000
59	0.592	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.000
63	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	2.562	0.829	1.817	0.000	0.000	0.000	0.000	0.000
81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
82	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000	0.000	1.817	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.000	2.562	2.472	0.000	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.000	0.478	2.472	1.817	3.875	0.000	0.000	0.000	0.000
87	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
88	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.3 Downstream reservoir extra supply file BM.DRE (input)

46	0.000	0.000	0.000	39.717	0.128	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.737	10.353	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
52	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
53	0.000	0.000	0.000	0.000	0.000	16.404	0.000	0.000	0.000	0.000	0.000	0.000
54	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.000	0.000	2.964	0.000	0.000	0.000	0.000	0.000	0.000
56	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11.007	0.000	0.000	0.000	0.000
59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	19.794	0.000	33.393	0.000	0.000	0.000	0.000	0.000
81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000	0.000	5.995	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.000	6.754	0.477	0.000	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.000	0.000	18.657	4.003	2.334	0.000	0.000	0.000	0.000
87	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
88	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.4 Free downstream flow file BM.FDF (input)

46	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
49	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
52	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
53	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
54	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
56	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
59	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
63	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
81	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
82	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
87	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
88	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table C.5 New reservoir inflow file BH.NIF (output)

```
46    1.015    1.450    3.960  140.957   20.840    8.472    6.110    5.670    1.320    0.610    0.630    0.900
47    0.320    3.900    2.970   11.680   15.210    7.290    6.840    4.820    1.470    0.680    0.330    0.310
48    0.370    0.320   23.250   17.040   57.650   30.129   48.480    4.590    1.700    1.490    1.140    1.000
49    0.880    0.860    4.180    2.010   12.990   17.370   36.330   25.170    1.800    1.460    1.090    0.920
50    1.395    1.430    5.190    4.170   11.650   25.140    8.420    2.720    1.350    1.090    0.950    0.860
51    0.820    6.410   14.880   18.300   21.480   42.170   12.750   13.590    2.670    1.410    0.890    0.850
52    1.126    0.880   10.060   47.910   31.713   16.719   14.190    4.040    3.580    1.850    1.210    1.700
53    1.218   11.600   17.300   10.220   36.350   78.236   15.360   16.219    3.490    1.420    1.220    1.050
54    1.508    2.160    4.520   17.810    9.830   17.170   10.880    4.750    1.490    1.150    0.990    0.870
55    2.140    4.700    6.150   16.570   14.180   81.416   11.710    5.190    3.040    2.100    1.270    1.000
56    0.907    1.250    2.370   27.350   29.260    7.350    5.530    8.410    2.450    2.420    1.130    0.990
57    0.550    3.200    4.050   27.930   48.070    2.830   20.130    3.940    0.910    0.690    0.000    0.700
58    0.160    1.400   14.600    8.660   24.590    3.980   76.980   55.962    1.480    2.230    0.840    0.000
59    1.142    0.860    5.760   15.900   25.750    3.250    5.190    8.330   20.860    0.590    0.240    0.330
60    0.000    0.220    0.260    8.280   26.210    3.760    2.450    0.420    1.510    0.840    0.630    0.130
61    0.200    0.960    1.340    1.190    4.260   18.410    4.860   10.920    1.060    0.480    0.470    0.250
62    0.460   12.700   10.000   28.700   13.600   29.300    2.960   13.420    0.370    0.290    2.766    4.420
63    2.550    2.060    2.800    9.740   20.100   22.710    5.670    3.410    1.730    0.550    0.490    0.720
64    1.250    1.460    4.010    2.230   28.300   46.570   16.400    2.690    1.730    1.110    0.770    0.510
65    0.330    0.230    0.150    2.050    4.940    2.910   12.600   35.770    6.870    1.510    0.880    0.810
66    3.970    0.790    1.970    8.340   13.600   19.050    3.950    2.490    2.010    1.330    0.620    0.780
67    0.740    0.680    0.770    3.930   15.800    4.640    1.760    0.690    0.680    1.470    0.420    0.290
68    0.410    0.640    0.950    5.370   13.600    4.880    2.570    3.720    0.730    0.470    0.300    0.440
69    0.840    9.070    1.730   54.600    9.010    9.530   23.730    3.140    1.620    0.910    0.730    0.240
70    0.090    0.370    0.070   15.650   30.780   32.350   16.650   18.640    2.070    0.000    0.350    0.000
71    0.480    3.240    0.840    1.680   17.210   20.220    7.130   19.580    3.340    0.670    0.000    0.000
72    0.550    0.340    0.080    0.470   26.770   22.610   71.490    5.740    0.740    0.100    0.230    0.180
73    0.000    2.660    0.000    2.620    0.620    6.480    4.520   13.320    1.170    0.020    0.000    0.000
74    0.190    1.330   27.560    8.460    3.250   26.680    9.530    3.290   12.410    0.420    0.260    0.310
75    0.480    0.160    3.610    7.590    3.700   10.570   27.000    4.320   10.170    0.780    0.430    0.190
76    3.360    1.850   20.720   13.720    8.130    4.430    1.250    1.990    1.400    1.540    0.980    2.350
77    1.170    0.220    7.900    1.190    5.740   29.600    4.240   13.170    3.480    2.770    2.540    2.270
78    0.000    0.270    5.300    4.150    4.980    8.880    2.840   25.540    3.640    2.040    2.890    2.350
79    0.000    0.000   20.210    2.450    5.310   11.640   21.620    5.260    4.210    0.050    0.000    0.000
80    0.490    0.900    1.110   19.780   52.846   13.339   41.100    4.220    1.770    0.870    0.000    0.000
81    0.210    0.210    0.930    3.610    7.940   14.750   22.800   16.470    6.550    0.000    0.000    0.140
82    0.521    0.410   16.850   35.880   15.550    3.670    9.960    3.800    1.140    0.290    0.000    0.000
83    0.420    0.510    5.950   11.010   15.460   43.980   53.292    2.950    0.000    0.120    0.000    0.020
84    0.350    0.300    0.670   34.820   92.886   34.289    6.210    0.020    0.030    0.000    0.000    0.000
85    0.680    0.060    0.230    0.250   10.450   16.370   10.590    1.530    4.480    0.070    1.280    0.150
86    2.550    1.810    3.680   18.000   47.498   98.279   31.030   67.179    5.010    3.690    0.010    0.220
87    1.120    2.440    1.980    2.200    4.160    5.790   33.430    0.070    0.630    1.220    0.110    0.940
88    0.730    1.570    0.560    2.760    1.290    3.260    6.310    2.950    1.480    0.640    0.690    0.820
89    1.050    1.140    0.570    1.060    1.420    0.740    0.680    0.310    1.360    0.340    0.150    0.540
```

Table C.6 Additional options of the INFLOW program

```
-----------------------------------------------------------------------------

ADD 'flow_file_1' 'flow_file_2' TO 'flow_file_3'
    Adds two files

SUBSTRACT 'flow_file_1' 'flow_file_2' TO 'flow_file_3'
    Subtracts 'flow_file_2' from 'flow_file_1'

SPLIT 'flow_file' TO 'pos_flow_file' 'neg_flow_file'
    Splits the contents of the 'flow_file' into files 'pos_flow_file' and
    'neg_flow_file' containing positive and negative values respectively.

RESIZE 'flow_file_1' TO 'flow_file_2' BY 'integer'
    Expands one-line flow file to a file with more lines.

SIM2GEN 'simulation_file' TO 'flow_file' [/TOTAL] [/NOLOCAL] [/SPILLAGE]
    Extracts data from a simulation output file. The switch specified
    indicates which data are to be extracted.

DAT2GEN 'reservoir_data_file' TO 'flow_file'
    Extracts the flow matrix from a reservoir data file.


Additional command:

EXTRACTDEMAND 'general_demand_file' 'demand_name' TO 'one_line_demand_file'
    Extracts a specified demand line from a general demand data file.

-----------------------------------------------------------------------------
```

APPENDIX D

The POLICY program output files

Table D.1 Policy file BH.POL (output)

```
MIC     ----------------------------------------  inflow class number leading string

                          number of inflow classes for each month (September - August)
        4        5        6        6        8        9        8        7        4        4        3        3

CMVAL   ----------------------------------------  inflow class margin values leading string

                          inflow class margin values [10^6m^3]
     .000    1.243    2.485    3.728    4.970
     .000    2.740    5.480    8.220   10.960   13.700
     .000    4.760    9.520   14.280   19.040   23.800   28.560
     .000    9.318   18.636   27.955   37.273   55.909  141.957
     .000    8.535   17.070   25.605   34.140   42.675   51.211   59.746   93.886
     .000    9.025   18.051   27.076   36.101   45.127   54.152   81.228   90.254   99.279
     .000    7.798   15.596   23.394   31.192   38.990   46.788   54.586   77.980
     .000    7.575   15.151   22.726   30.302   37.877   60.604   68.179
     .000    4.372    8.744   13.116   21.860
     .000    1.173    2.345    3.517    4.690
     .000     .973    1.945    2.918
     .000    1.355    2.710    5.420

CHFLOW  ----------------------------------------  characteristic flow values leading string

                 characteristic values representing each inflow class [10^6m^3]
     .556    1.573    2.820    3.970
     .950    3.760    6.410    9.070   12.150
    1.799    6.042   10.030   15.907   21.393   27.560
    3.683   14.637   25.020   33.133   51.255  140.957
    4.288   13.148   20.844   28.398   36.350   47.784   55.248   92.886
    4.860   14.162   22.117   31.134   43.075   46.570   78.236   81.416   98.279
    4.267   11.599   19.520   27.253   34.880   41.100   50.886   74.235
    3.169   11.594   17.727   25.355   35.770   55.962   67.179
    1.747    5.727   11.290   20.860
     .494    1.621    2.595    3.690
     .357    1.146    2.732
     .448    2.168    4.420

O.F. = Single sided squared deviation  ----------  objective function used in optimization

    117.5     15.0    429.2       25   ----------  reservoir characteristics: maximum storage, minimum storage, outlet capacity (all in [10^6m^3]),
                                                   number of storage classes
```

Table D.1 Policy file (continued)

```
 1  5  5  5  4
 2  6  6  6  5
 3  7  7  7  6
 4  8  8  8  7
 5  9  9  9  8
 6 10 10  9  9
 7 11 11 10 10
 8 12 12 11 11
 9 13 13 12 12
10 14 14 13 13
11 15 15 14 14
12 16 15 15 15
13 17 16 16 16                     September
14 18 17 17 17
15 19 18 18 18
16 20 19 19 19
17 20 20 20 20
18 21 21 21 21
19 22 22 22 22
20 23 23 23 22
21 24 24 24 23
22 25 25 24 24
23 25 25 25 25
24 25 25 25 25
25 25 25 25 25
 1  3  3  2  1  1
 2  4  4  3  2  2
 3  5  5  4  3  3
 4  6  5  5  4  4
 5  7  6  6  5  5
 6  8  7  7  6  5
 7  9  8  8  7  6
 8 10  9  9  8  7
 9 11 10 10  9  8
10 12 11 11 10  9
11 13 12 11 11 10
12 14 13 12 12 11
13 15 14 13 13 12                  October
14 16 15 14 14 13
15 17 16 15 15 14
16 17 17 16 16 15
17 18 18 17 17 16
18 19 19 18 18 17
19 20 20 19 19 18
20 21 21 20 19 19
21 22 22 21 20 20
22 23 22 22 21 21
23 24 23 23 22 22
24 25 24 24 23 23
25 25 25 25 24 23
```

Table D.1 Policy file (continued)

1	2	1	1	1	1	1	November
2	3	2	1	1	1	1	
3	4	3	2	1	1	1	
4	5	4	3	2	1	1	
5	6	5	4	3	2	1	
6	7	6	5	4	3	1	
7	8	7	6	5	4	2	
8	9	8	7	6	4	3	
9	10	9	8	7	5	4	
10	11	10	9	8	6	5	
11	12	11	10	9	7	6	
12	13	12	11	9	8	7	
13	14	13	12	10	9	8	
14	14	14	13	11	10	9	
15	15	14	14	12	11	10	
16	16	15	15	13	12	11	
17	17	16	16	14	13	12	
18	18	17	16	15	14	13	
19	19	18	17	16	15	14	
20	20	19	18	17	16	14	
21	21	20	19	18	17	15	
22	22	21	20	19	18	16	
23	23	22	21	20	19	17	
24	24	23	22	21	20	18	
25	25	24	23	22	21	19	
1	1	1	1	1	1	1	December
2	2	1	1	1	1	1	
3	3	1	1	1	1	1	
4	4	1	1	1	1	1	
5	5	2	1	1	1	1	
6	6	3	1	1	1	1	
7	7	4	2	1	1	1	
8	8	5	3	1	1	1	
9	9	6	4	2	1	1	
10	10	7	5	3	1	1	
11	11	8	6	4	1	1	
12	12	9	7	5	1	1	
13	13	10	8	6	2	1	
14	14	11	9	7	3	1	
15	15	12	10	8	4	1	
16	16	13	11	9	5	1	
17	17	14	12	10	6	1	
18	18	15	13	11	7	1	
19	19	16	14	12	8	1	
20	20	17	15	13	9	1	
21	21	18	16	14	10	1	
22	22	19	17	15	11	1	
23	23	20	18	16	12	1	
24	24	21	19	17	13	1	
25	25	22	20	18	14	1	

Table D.1 Policy file (continued)

1	1	1	1	1	1	1	1	1		January
2	2	1	1	1	1	1	1	1		
3	3	1	1	1	1	1	1	1		
4	4	2	1	1	1	1	1	1		
5	5	3	1	1	1	1	1	1		
6	6	4	2	1	1	1	1	1		
7	7	5	3	1	1	1	1	1		
8	8	6	4	2	1	1	1	1		
9	9	7	5	3	2	1	1	1		
10	10	8	6	4	2	1	1	1		
11	11	8	7	5	3	1	1	1		
12	12	9	8	6	4	2	1	1		
13	13	10	9	7	5	3	1	1		
14	14	11	10	8	6	4	2	1		
15	15	12	11	9	7	5	3	1		
16	16	13	12	10	8	6	4	1		
17	17	14	13	11	9	6	5	1		
18	18	15	14	12	10	7	6	1		
19	19	16	15	13	11	8	7	1		
20	20	17	16	14	12	9	8	1		
21	21	18	17	15	13	10	9	1		
22	22	19	18	16	14	11	10	1		
23	23	20	19	17	15	12	11	2		
24	24	21	20	18	16	13	12	3		
25	25	22	21	19	17	14	13	4		
1	1	1	1	1	1	1	1	1	1	February
2	2	1	1	1	1	1	1	1	1	
3	3	1	1	1	1	1	1	1	1	
4	4	2	1	1	1	1	1	1	1	
5	5	3	1	1	1	1	1	1	1	
6	6	4	2	1	1	1	1	1	1	
7	7	5	3	1	1	1	1	1	1	
8	8	6	4	2	1	1	1	1	1	
9	9	7	5	3	1	1	1	1	1	
10	10	8	6	4	1	1	1	1	1	
11	11	8	7	5	2	1	1	1	1	
12	11	9	8	6	3	2	1	1	1	
13	12	10	9	7	4	3	1	1	1	
14	13	11	10	8	5	4	1	1	1	
15	14	12	11	9	6	5	1	1	1	
16	15	13	11	9	7	6	1	1	1	
17	16	14	12	10	8	7	1	1	1	
18	17	15	13	11	9	8	1	1	1	
19	18	16	14	12	10	9	2	1	1	
20	19	17	15	13	11	10	3	2	1	
21	20	18	16	14	12	11	4	3	1	
22	21	19	17	15	12	12	5	4	1	
23	22	20	18	16	13	13	6	5	1	
24	23	21	19	17	14	14	7	6	2	
25	24	22	20	18	15	15	8	7	3	

Table D.1 Policy file (continued)

1	1	1	1	1	1	1	1	1	
2	2	1	1	1	1	1	1	1	
3	3	2	1	1	1	1	1	1	
4	4	2	1	1	1	1	1	1	
5	5	3	2	1	1	1	1	1	
6	6	4	3	1	1	1	1	1	
7	7	5	4	2	1	1	1	1	
8	8	6	5	3	1	1	1	1	
9	9	7	5	4	2	1	1	1	
10	10	8	6	5	3	2	1	1	
11	11	9	7	6	4	3	1	1	
12	12	10	8	7	5	4	1	1	
13	13	11	9	8	6	4	2	1	March
14	14	12	10	9	7	5	3	1	
15	15	13	11	9	8	6	4	1	
16	16	14	12	10	9	7	5	1	
17	17	15	13	11	10	8	6	1	
18	18	16	14	12	11	9	7	2	
19	19	17	15	13	12	10	8	3	
20	20	18	16	14	12	11	9	4	
21	21	19	17	15	13	12	10	5	
22	22	20	18	16	14	13	11	6	
23	23	21	19	17	15	14	12	7	
24	24	22	20	18	16	15	13	8	
25	25	23	21	19	17	16	14	9	
1	3	1	1	1	1	1	1		
2	4	2	1	1	1	1	1		
3	5	3	2	1	1	1	1		
4	6	4	3	1	1	1	1		
5	7	5	4	2	1	1	1		
6	8	6	5	3	1	1	1		
7	9	7	6	4	2	1	1		
8	10	8	7	5	3	1	1		
9	11	9	8	6	3	1	1		
10	12	10	8	7	4	1	1		
11	13	11	9	8	5	1	1		
12	13	12	10	9	6	2	1		
13	14	13	11	10	7	3	1		April
14	15	13	12	11	8	4	1		
15	16	14	13	12	9	5	2		
16	17	15	14	12	10	6	3		
17	18	16	15	13	11	7	4		
18	19	17	16	14	12	8	5		
19	19	18	17	15	13	9	6		
20	20	19	17	16	14	9	7		
21	21	20	18	17	15	10	8		
22	22	20	19	18	16	11	9		
23	23	21	20	19	16	12	10		
24	24	22	21	19	17	13	11		
25	25	23	21	20	18	14	12		

Table D.1 Policy file (continued)

1	2	2	1	1	May
2	3	3	1	1	
3	4	3	2	1	
4	5	4	3	1	
5	6	5	4	2	
6	7	6	5	3	
7	8	7	6	4	
8	9	8	7	5	
9	10	9	8	6	
10	11	10	9	7	
11	12	11	10	8	
12	13	12	11	9	
13	14	13	12	10	
14	15	14	13	11	
15	16	15	14	12	
16	16	16	14	12	
17	17	16	15	13	
18	18	17	16	14	
19	19	18	17	15	
20	20	19	18	16	
21	21	20	19	17	
22	22	21	20	18	
23	23	22	21	19	
24	24	23	22	20	
25	25	24	23	21	
1	4	4	4	3	June
2	5	5	5	4	
3	6	6	6	5	
4	7	7	7	6	
5	8	8	7	7	
6	9	9	8	8	
7	10	10	9	9	
8	11	11	10	10	
9	12	12	11	11	
10	13	12	12	12	
11	14	13	13	13	
12	15	14	14	14	
13	15	15	15	15	
14	16	16	16	16	
15	17	17	17	16	
16	18	18	18	17	
17	19	19	18	18	
18	19	19	19	19	
19	20	20	20	20	
20	21	21	21	20	
21	22	22	21	21	
22	22	22	22	22	
23	23	23	23	23	
24	24	24	24	24	
25	25	25	25	25	

Table D.1 Policy file (continued)

```
  1  5  5  5
  2  6  6  6
  3  7  7  7
  4  8  8  8
  5  9  9  9
  6 10 10 10
  7 11 11 11
  8 12 12 12
  9 13 13 12
 10 14 14 13
 11 15 15 14
 12 16 16 15
 13 17 17 16                        July
 14 18 18 17
 15 19 18 18
 16 19 19 19
 17 20 20 20
 18 21 21 21
 19 22 22 21
 20 22 22 22
 21 23 23 23
 22 24 24 23
 23 24 24 24
 24 25 25 24
 25 25 25 25
  1  4  3  3
  2  5  4  4
  3  6  5  5
  4  7  6  6
  5  8  7  7
  6  9  8  8
  7 10  9  9
  8 10 10 10
  9 11 11 11
 10 12 12 12
 11 13 13 12
 12 14 14 13
 13 15 15 14                        August
 14 16 16 15
 15 17 17 16
 16 18 18 17
 17 19 19 18
 18 20 20 19
 19 21 20 20
 20 22 21 21
 21 22 22 22
 22 23 23 22
 23 23 23 23
 24 24 24 24
 25 25 25 25
```

```
Program completed at  16:41:21  on  94/11/23
Elapsed time =    11 secs
```

Table D.2 Detailed description of the policy table (operational policy for November)

initial storage class	inflow class 1	inflow class 2	inflow class 3	inflow class 4	inflow class 5	inflow class 6
1	2	1	1	1	1	1
2	3	2	1	1	1	1
3	4	3	2	1	1	1
4	5	4	3	2	1	1
5	6	5	4	3	2	1
6	7	6	5	4	3	1
7	8	7	6	5	4	2
8	9	8	7	6	4	3
9	10	9	8	7	5	4
10	11	10	9	8	6	5
11	12	11	10	9	7	6
12	13	12	11	9	8	7
13	14	13	12	10	9	8
14	14	14	13	11	10	9
15	15	14	14	12	11	10
16	16	15	15	13	12	11
17	17	16	16	14	13	12
18	18	17	16	15	14	13
19	19	18	17	16	15	14
20	20	19	18	17	16	14
21	21	20	19	18	17	15
22	22	21	20	19	18	16
23	23	22	21	20	19	17
24	24	23	22	21	20	18
25	25	24	23	22	21	19

final storage class as a function of

initial storage class and inflow class

Table D.3 Statistical details file BH.STA (output)

```
O.F. = Single sided squared deviation
```

objective function used in optimization

previous month (September - August)

following month (October - September)

```
CORRELATION COEFFICIENTS
MONTH 1   MONTH 2      COEFFICIENT
   1         2            .085
   2         3            .178
   3         4            .050
   4         5            .253
   5         6            .333
   6         7            .137
   7         8            .339
   8         9            .122
   9        10            .016
  10        11            .434
  11        12            .825
  12         1            .245
```

correlation coefficients

between each of the pairs of

consecutive month inflows

month (September - August)

representative inflow class values [$10^6 m^3$]

```
MONTH        REPRESENTATIVE  INFLOWS
  1      .6       1.6       2.8      4.0
  2      .9       3.8       6.4      9.1     12.1
  3     1.8       6.0      10.0     15.9     21.4     27.6
  4     3.7      14.6      25.0     33.1     51.3    141.0
  5     4.3      13.1      20.8     28.4     36.3     47.8     55.2     92.9
  6     4.9      14.2      22.1     31.1     43.1     46.6     78.2     81.4     98.3
  7     4.3      11.6      19.5     27.3     34.9     41.1     50.9     74.2
  8     3.2      11.6      17.7     25.4     35.8     56.0     67.2
  9     1.7       5.7      11.3     20.9
 10      .5       1.6       2.6      3.7
 11      .4       1.1       2.7
 12      .4       2.2       4.4
```

month (September - August)

```
            actual inflows            repres. inflows
month      mean       stddev         mean      stddev
  1         .881        .868          .880       .777
  2        2.023       2.844         2.023      2.728
  3        5.955       7.109         5.955      6.900
  4       15.416      23.176        15.416     22.724
  5       19.658      18.120        19.658     17.787
  6       20.709      21.633        20.709     21.264
  7       16.762      18.036        16.762     17.700
  8       10.237      13.809        10.237     13.550
  9        2.977       3.707         2.977      3.517
 10         .995        .827          .995       .746
 11         .680        .704          .680       .638
 12         .694        .844          .694       .753
```

actual and representative

inflows mean and

standard deviation values

Table D.3 Statistical details file (continued)

```
                                                               month (September - August)
               number of inflow classes

INFLOW PROBABILITIES
MONTH                PROBABILITY
  1   .818 .091 .068 .023
  2   .818 .091 .023 .023 .045
  3   .636 .136 .045 .091 .068 .023
  4   .523 .273 .068 .068 .045 .023
  5   .295 .295 .114 .159 .023 .045 .045 .023
  6   .386 .205 .159 .114 .045 .023 .023 .023 .023             inflow probabilities
  7   .432 .227 .114 .068 .045 .023 .045 .045
  8   .636 .159 .091 .045 .023 .023 .023
  9   .841 .091 .045 .023
 10   .636 .295 .045 .023
 11   .727 .205 .068
 12   .886 .091 .023

TRANSITION PROBABILITIES

FROM MONTH    1 TO MONTH    2 ---------  probability of having inflow class j in month 2 (October)
                                         given the inflow class i is observed in month 1 (September)

   r  number of rows represent the number of inflow classes for month 1 (September).

 .806 .083 .028 .028 .056 ------------  number of columns represent the number
 .750 .250 .000 .000 .000               of inflow classes for month 2 (October)
1.000 .000 .000 .000 .000
1.000 .000 .000 .000 .000

FROM MONTH    2 TO MONTH    3
 .667 .139 .028 .056 .083 .028
 .750 .250 .000 .000 .000 .000                                   inflow transition probabilities
 .000 .000 .0001.000 .000 .000
1.000 .000 .000 .000 .000 .000                                   from October to November
 .000 .000 .500 .500 .000 .000

FROM MONTH    3 TO MONTH    4
 .607 .179 .107 .036 .036 .036
 .500 .500 .000 .000 .000 .000                                   inflow transition probabilities
 .000 .000 .000 .500 .500 .000
 .250 .500 .000 .250 .000 .000                                   from November to December
 .333 .667 .000 .000 .000 .000
1.000 .000 .000 .000 .000 .000

FROM MONTH    4 TO MONTH    5
 .522 .261 .087 .130 .000 .000 .000 .000
 .083 .333 .167 .167 .083 .083 .083 .000                         inflow transition probabilities
 .000 .000 .000 .333 .000 .333 .333 .000
 .000 .667 .000 .000 .000 .000 .000 .333                         from December to January
 .000 .500 .000 .500 .000 .000 .000 .000
 .000 .0001.000 .000 .000 .000 .000 .000

FROM MONTH    5 TO MONTH    6
 .538 .231 .154 .077 .000 .000 .000 .000 .000
 .308 .308 .154 .077 .077 .000 .000 .077 .000
 .400 .000 .400 .000 .200 .000 .000 .000 .000                    inflow transition probabilities
 .429 .143 .143 .143 .000 .143 .000 .000 .000
 .000 .000 .000 .000 .000 .0001.000 .000 .000                    from January to February
 .500 .000 .000 .000 .000 .000 .000 .000 .500
 .000 .500 .000 .500 .000 .000 .000 .000 .000
 .000 .000 .0001.000 .000 .000 .000 .000 .000
```

Table D.3 Statistical details file (continued)

```
FROM MONTH    6 TO MONTH    7
  .706 .118 .059 .000 .059 .000 .000 .059
  .000 .333 .222 .222 .111 .111 .000 .000
  .571 .286 .000 .000 .000 .000 .000 .143
  .600 .000 .200 .000 .000 .000 .200 .000                            inflow transition probabilities
  .000 .500 .000 .000 .000 .000 .500 .000
  .000 .0001.000 .000 .000 .000 .000 .000                            from February to March
  .0001.000 .000 .000 .000 .000 .000 .000
  .0001.000 .000 .000 .000 .000 .000 .000
  .000 .000 .0001.000 .000 .000 .000 .000

FROM MONTH    7 TO MONTH    8
  .579 .316 .053 .053 .000 .000 .000
  .700 .100 .100 .000 .100 .000 .000
  .600 .000 .400 .000 .000 .000 .000
  .667 .000 .000 .000 .000 .000 .333                                 inflow transition probabilities
  .500 .000 .000 .500 .000 .000 .000
 1.000 .000 .000 .000 .000 .000 .000                                 from March to April
 1.000 .000 .000 .000 .000 .000 .000
  .500 .000 .000 .000 .000 .500 .000

FROM MONTH    8 TO MONTH    9
  .893 .036 .071 .000
  .857 .000 .000 .143
  .750 .250 .000 .000                                                inflow transition probabilities
 1.000 .000 .000 .000
  .0001.000 .000 .000                                                from April to May
 1.000 .000 .000 .000
  .0001.000 .000 .000

FROM MONTH    9 TO MONTH   10
  .622 .324 .054 .000
  .500 .250 .000 .250                                                inflow transition probabilities
 1.000 .000 .000 .000                                                from May to June
 1.000 .000 .000 .000

FROM MONTH   10 TO MONTH   11
  .893 .071 .036
  .462 .462 .077                                                     inflow transition probabilities
  .000 .500 .500                                                     from June to July
 1.000 .000 .000

FROM MONTH   11 TO MONTH   12
 1.000 .000 .000
  .778 .222 .000                                                     inflow transition probabilities
  .000 .667 .333                                                     from July to August

FROM MONTH   12 TO MONTH    1
  .821 .103 .051 .026
 1.000 .000 .000 .000                                                inflow transition probabilities
  .000 .0001.000 .000                                                from August to September
```

Table D.3 Statistical details file (continued)

Policy convergence — policy tables expressed in terms of storage volume values [10^6m^3]

PERIOD 1 — operation policy for month 1 (September)

initial storage volume

inflow class 1

inflow class 2

inflow class 3

inflow class 4

```
FLOW            .6     1.6     2.8     4.0
     117.5   100.4   100.4   100.4   104.7
     113.2    96.1    96.1    96.1   100.4
     109.0    91.9    91.9    91.9    96.1
     104.7    87.6    87.6    87.6    91.9
     100.4    83.3    83.3    83.3    87.6
      96.1    79.1    79.1    83.3    83.3
      91.9    74.8    74.8    79.1    79.1
      87.6    70.5    70.5    74.8    74.8
      83.3    66.3    66.3    70.5    70.5
      79.1    62.0    62.0    66.3    66.3
      74.8    57.7    57.7    62.0    62.0
      70.5    53.4    57.7    57.7    57.7
      66.3    49.2    53.4    53.4    53.4
      62.0    44.9    49.2    49.2    49.2
      57.7    40.6    44.9    44.9    44.9
      53.4    36.4    40.6    40.6    40.6
      49.2    36.4    36.4    36.4    36.4
      44.9    32.1    32.1    32.1    32.1
      40.6    27.8    27.8    27.8    27.8
      36.4    23.5    23.5    23.5    27.8
      32.1    19.3    19.3    19.3    23.5
      27.8    15.0    15.0    19.3    19.3
      23.5    15.0    15.0    15.0    15.0
      19.3    15.0    15.0    15.0    15.0
      15.0    15.0    15.0    15.0    15.0
PERIOD       2
FLOW            .9     3.8     6.4     9.1    12.1
     117.5   109.0   109.0   113.2   117.5   117.5
     113.2   104.7   104.7   109.0   113.2   113.2
     109.0   100.4   100.4   104.7   109.0   109.0
     104.7    96.1   100.4   100.4   104.7   104.7
     100.4    91.9    96.1    96.1   100.4   100.4
      96.1    87.6    91.9    91.9    96.1   100.4
      91.9    83.3    87.6    87.6    91.9    96.1
      87.6    79.1    83.3    83.3    87.6    91.9
      83.3    74.8    79.1    79.1    83.3    87.6
      79.1    70.5    74.8    74.8    79.1    83.3
      74.8    66.3    70.5    74.8    74.8    79.1
      70.5    62.0    66.3    70.5    70.5    74.8
      66.3    57.7    62.0    66.3    66.3    70.5
      62.0    53.4    57.7    62.0    62.0    66.3
      57.7    49.2    53.4    57.7    57.7    62.0
      53.4    49.2    49.2    53.4    53.4    57.7
      49.2    44.9    44.9    49.2    49.2    53.4
      44.9    40.6    40.6    44.9    44.9    49.2
      40.6    36.4    36.4    40.6    40.6    44.9
      36.4    32.1    32.1    36.4    40.6    40.6
      32.1    27.8    27.8    32.1    36.4    36.4
      27.8    23.5    27.8    27.8    32.1    32.1
      23.5    19.3    23.5    23.5    27.8    27.8
      19.3    15.0    19.3    19.3    23.5    23.5
      15.0    15.0    15.0    15.0    19.3    23.5
```

final storage volume

policy table for October

Table D.3 Statistical details file (continued)

```
PERIOD       3
FLOW         1.8       6.0      10.0      15.9      21.4      27.6
   117.5   113.2     117.5     117.5     117.5     117.5     117.5
   113.2   109.0     113.2     117.5     117.5     117.5     117.5
   109.0   104.7     109.0     113.2     117.5     117.5     117.5
   104.7   100.4     104.7     109.0     113.2     117.5     117.5
   100.4    96.1     100.4     104.7     109.0     113.2     117.5
    96.1    91.9      96.1     100.4     104.7     109.0     117.5
    91.9    87.6      91.9      96.1     100.4     104.7     113.2
    87.6    83.3      87.6      91.9      96.1     104.7     109.0
    83.3    79.1      83.3      87.6      91.9     100.4     104.7
    79.1    74.8      79.1      83.3      87.6      96.1     100.4
    74.8    70.5      74.8      79.1      83.3      91.9      96.1
    70.5    66.3      70.5      74.8      83.3      87.6      91.9
    66.3    62.0      66.3      70.5      79.1      83.3      87.6      policy table for November
    62.0    62.0      62.0      66.3      74.8      79.1      83.3
    57.7    57.7      62.0      62.0      70.5      74.8      79.1
    53.4    53.4      57.7      57.7      66.3      70.5      74.8
    49.2    49.2      53.4      53.4      62.0      66.3      70.5
    44.9    44.9      49.2      53.4      57.7      62.0      66.3
    40.6    40.6      44.9      49.2      53.4      57.7      62.0
    36.4    36.4      40.6      44.9      49.2      53.4      62.0
    32.1    32.1      36.4      40.6      44.9      49.2      57.7
    27.8    27.8      32.1      36.4      40.6      44.9      53.4
    23.5    23.5      27.8      32.1      36.4      40.6      49.2
    19.3    19.3      23.5      27.8      32.1      36.4      44.9
    15.0    15.0      19.3      23.5      27.8      32.1      40.6
PERIOD       4
FLOW         3.7      14.6      25.0      33.1      51.3     141.0
   117.5   117.5     117.5     117.5     117.5     117.5     117.5
   113.2   113.2     117.5     117.5     117.5     117.5     117.5
   109.0   109.0     117.5     117.5     117.5     117.5     117.5
   104.7   104.7     117.5     117.5     117.5     117.5     117.5
   100.4   100.4     113.2     117.5     117.5     117.5     117.5
    96.1    96.1     109.0     117.5     117.5     117.5     117.5
    91.9    91.9     104.7     113.2     117.5     117.5     117.5
    87.6    87.6     100.4     109.0     117.5     117.5     117.5
    83.3    83.3      96.1     104.7     113.2     117.5     117.5
    79.1    79.1      91.9     100.4     109.0     117.5     117.5
    74.8    74.8      87.6      96.1     104.7     117.5     117.5
    70.5    70.5      83.3      91.9     100.4     117.5     117.5
    66.3    66.3      79.1      87.6      96.1     113.2     117.5      policy table for December
    62.0    62.0      74.8      83.3      91.9     109.0     117.5
    57.7    57.7      70.5      79.1      87.6     104.7     117.5
    53.4    53.4      66.3      74.8      83.3     100.4     117.5
    49.2    49.2      62.0      70.5      79.1      96.1     117.5
    44.9    44.9      57.7      66.3      74.8      91.9     117.5
    40.6    40.6      53.4      62.0      70.5      87.6     117.5
    36.4    36.4      49.2      57.7      66.3      83.3     117.5
    32.1    32.1      44.9      53.4      62.0      79.1     117.5
    27.8    27.8      40.6      49.2      57.7      74.8     117.5
    23.5    23.5      36.4      44.9      53.4      70.5     117.5
    19.3    19.3      32.1      40.6      49.2      66.3     117.5
    15.0    15.0      27.8      36.4      44.9      62.0     117.5
```

Table D.3 Statistical details file (continued)

```
PERIOD        5
FLOW             4.3      13.1      20.8      28.4      36.3      47.8      55.2      92.9
     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5             p
     113.2     113.2     117.5     117.5     117.5     117.5     117.5     117.5     117.5             o
     109.0     109.0     117.5     117.5     117.5     117.5     117.5     117.5     117.5             l
     104.7     104.7     113.2     117.5     117.5     117.5     117.5     117.5     117.5             i
     100.4     100.4     109.0     117.5     117.5     117.5     117.5     117.5     117.5             c
      96.1      96.1     104.7     113.2     117.5     117.5     117.5     117.5     117.5             y
      91.9      91.9     100.4     109.0     117.5     117.5     117.5     117.5     117.5
      87.6      87.6      96.1     104.7     113.2     117.5     117.5     117.5     117.5             t
      83.3      83.3      91.9     100.4     109.0     113.2     117.5     117.5     117.5             a
      79.1      79.1      87.6      96.1     104.7     113.2     117.5     117.5     117.5             b
      74.8      74.8      87.6      91.9     100.4     109.0     117.5     117.5     117.5             l
      70.5      70.5      83.3      87.6      96.1     104.7     113.2     117.5     117.5             e
      66.3      66.3      79.1      83.3      91.9     100.4     109.0     117.5     117.5
      62.0      62.0      74.8      79.1      87.6      96.1     104.7     113.2     117.5             f
      57.7      57.7      70.5      74.8      83.3      91.9     100.4     109.0     117.5             o
      53.4      53.4      66.3      70.5      79.1      87.6      96.1     104.7     117.5             r
      49.2      49.2      62.0      66.3      74.8      83.3      96.1     100.4     117.5
      44.9      44.9      57.7      62.0      70.5      79.1      91.9      96.1     117.5             J
      40.6      40.6      53.4      57.7      66.3      74.8      87.6      91.9     117.5             a
      36.4      36.4      49.2      53.4      62.0      70.5      83.3      87.6     117.5             n
      32.1      32.1      44.9      49.2      57.7      66.3      79.1      83.3     117.5             u
      27.8      27.8      40.6      44.9      53.4      62.0      74.8      79.1     117.5             a
      23.5      23.5      36.4      40.6      49.2      57.7      70.5      74.8     113.2             r
      19.3      19.3      32.1      36.4      44.9      53.4      66.3      70.5     109.0             y
      15.0      15.0      27.8      32.1      40.6      49.2      62.0      66.3     104.7
PERIOD        6
FLOW             4.9      14.2      22.1      31.1      43.1      46.6      78.2      81.4      98.3
     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5   p
     113.2     113.2     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5   o
     109.0     109.0     117.5     117.5     117.5     117.5     117.5     117.5     117.5     117.5   l
     104.7     104.7     113.2     117.5     117.5     117.5     117.5     117.5     117.5     117.5   i
     100.4     100.4     109.0     117.5     117.5     117.5     117.5     117.5     117.5     117.5   c
      96.1      96.1     104.7     113.2     117.5     117.5     117.5     117.5     117.5     117.5   y
      91.9      91.9     100.4     109.0     117.5     117.5     117.5     117.5     117.5     117.5
      87.6      87.6      96.1     104.7     113.2     117.5     117.5     117.5     117.5     117.5   t
      83.3      83.3      91.9     100.4     109.0     117.5     117.5     117.5     117.5     117.5   a
      79.1      79.1      87.6      96.1     104.7     117.5     117.5     117.5     117.5     117.5   b
      74.8      74.8      87.6      91.9     100.4     113.2     117.5     117.5     117.5     117.5   l
      70.5      74.8      83.3      87.6      96.1     109.0     113.2     117.5     117.5     117.5   e
      66.3      70.5      79.1      83.3      91.9     104.7     109.0     117.5     117.5     117.5
      62.0      66.3      74.8      79.1      87.6     100.4     104.7     117.5     117.5     117.5   f
      57.7      62.0      70.5      74.8      83.3      96.1     100.4     117.5     117.5     117.5   o
      53.4      57.7      66.3      74.8      83.3      91.9      96.1     117.5     117.5     117.5   r
      49.2      53.4      62.0      70.5      79.1      87.6      91.9     117.5     117.5     117.5
      44.9      49.2      57.7      66.3      74.8      83.3      87.6     117.5     117.5     117.5   F
      40.6      44.9      53.4      62.0      70.5      79.1      83.3     113.2     117.5     117.5   e
      36.4      40.6      49.2      57.7      66.3      74.8      79.1     109.0     113.2     117.5   b
      32.1      36.4      44.9      53.4      62.0      70.5      74.8     104.7     109.0     117.5   r
      27.8      32.1      40.6      49.2      57.7      70.5      70.5     100.4     104.7     117.5   u
      23.5      27.8      36.4      44.9      53.4      66.3      66.3      96.1     100.4     117.5   a
      19.3      23.5      32.1      40.6      49.2      62.0      62.0      91.9      96.1     113.2   r
      15.0      19.3      27.8      36.4      44.9      57.7      57.7      87.6      91.9     109.0   y
```

Table D.3 Statistical details file (continued)

```
PERIOD          7
FLOW             4.3       11.6       19.5       27.3       34.9       41.1       50.9       74.2
     117.5      117.5      117.5      117.5      117.5      117.5      117.5      117.5      117.5
     113.2      113.2      117.5      117.5      117.5      117.5      117.5      117.5      117.5
     109.0      109.0      113.2      117.5      117.5      117.5      117.5      117.5      117.5
     104.7      104.7      113.2      117.5      117.5      117.5      117.5      117.5      117.5
     100.4      100.4      109.0      113.2      117.5      117.5      117.5      117.5      117.5
      96.1       96.1      104.7      109.0      117.5      117.5      117.5      117.5      117.5
      91.9       91.9      100.4      104.7      113.2      117.5      117.5      117.5      117.5
      87.6       87.6       96.1      100.4      109.0      117.5      117.5      117.5      117.5
      83.3       83.3       91.9      100.4      104.7      113.2      117.5      117.5      117.5
      79.1       79.1       87.6       96.1      100.4      109.0      113.2      117.5      117.5   policy
      74.8       74.8       83.3       91.9       96.1      104.7      109.0      117.5      117.5
      70.5       70.5       79.1       87.6       91.9      100.4      104.7      117.5      117.5   table
      66.3       66.3       74.8       83.3       87.6       96.1      104.7      113.2      117.5
      62.0       62.0       70.5       79.1       83.3       91.9      100.4      109.0      117.5   for March
      57.7       57.7       66.3       74.8       83.3       87.6       96.1      104.7      117.5
      53.4       53.4       62.0       70.5       79.1       83.3       91.9      100.4      117.5
      49.2       49.2       57.7       66.3       74.8       79.1       87.6       96.1      117.5
      44.9       44.9       53.4       62.0       70.5       74.8       83.3       91.9      113.2
      40.6       40.6       49.2       57.7       66.3       70.5       79.1       87.6      109.0
      36.4       36.4       44.9       53.4       62.0       70.5       74.8       83.3      104.7
      32.1       32.1       40.6       49.2       57.7       66.3       70.5       79.1      100.4
      27.8       27.8       36.4       44.9       53.4       62.0       66.3       74.8       96.1
      23.5       23.5       32.1       40.6       49.2       57.7       62.0       70.5       91.9
      19.3       19.3       27.8       36.4       44.9       53.4       57.7       66.3       87.6
      15.0       15.0       23.5       32.1       40.6       49.2       53.4       62.0       83.3
PERIOD          8
FLOW             3.2       11.6       17.7       25.4       35.8       56.0       67.2
     117.5      109.0      117.5      117.5      117.5      117.5      117.5      117.5
     113.2      104.7      113.2      117.5      117.5      117.5      117.5      117.5
     109.0      100.4      109.0      113.2      117.5      117.5      117.5      117.5
     104.7       96.1      104.7      109.0      117.5      117.5      117.5      117.5
     100.4       91.9      100.4      104.7      113.2      117.5      117.5      117.5
      96.1       87.6       96.1      100.4      109.0      117.5      117.5      117.5
      91.9       83.3       91.9       96.1      104.7      113.2      117.5      117.5
      87.6       79.1       87.6       91.9      100.4      109.0      117.5      117.5
      83.3       74.8       83.3       87.6       96.1      109.0      117.5      117.5
      79.1       70.5       79.1       87.6       91.9      104.7      117.5      117.5              policy
      74.8       66.3       74.8       83.3       87.6      100.4      117.5      117.5
      70.5       66.3       70.5       79.1       83.3       96.1      113.2      117.5              table
      66.3       62.0       66.3       74.8       79.1       91.9      109.0      117.5
      62.0       57.7       66.3       70.5       74.8       87.6      104.7      117.5              for April
      57.7       53.4       62.0       66.3       70.5       83.3      100.4      113.2
      53.4       49.2       57.7       62.0       70.5       79.1       96.1      109.0
      49.2       44.9       53.4       57.7       66.3       74.8       91.9      104.7
      44.9       40.6       49.2       53.4       62.0       70.5       87.6      100.4
      40.6       40.6       44.9       49.2       57.7       66.3       83.3       96.1
      36.4       36.4       40.6       49.2       53.4       62.0       83.3       91.9
      32.1       32.1       36.4       44.9       49.2       57.7       79.1       87.6
      27.8       27.8       36.4       40.6       44.9       53.4       74.8       83.3
      23.5       23.5       32.1       36.4       40.6       53.4       70.5       79.1
      19.3       19.3       27.8       32.1       40.6       49.2       66.3       74.8
      15.0       15.0       23.5       32.1       36.4       44.9       62.0       70.5
```

Table D.3 Statistical details file (continued)

```
PERIOD          9
FLOW            1.7       5.7      11.3      20.9
     117.5     113.2     113.2     117.5     117.5
     113.2     109.0     109.0     117.5     117.5
     109.0     104.7     109.0     113.2     117.5
     104.7     100.4     104.7     109.0     117.5
     100.4      96.1     100.4     104.7     113.2
      96.1      91.9      96.1     100.4     109.0
      91.9      87.6      91.9      96.1     104.7
      87.6      83.3      87.6      91.9     100.4
      83.3      79.1      83.3      87.6      96.1
      79.1      74.8      79.1      83.3      91.9
      74.8      70.5      74.8      79.1      87.6
      70.5      66.3      70.5      74.8      83.3
      66.3      62.0      66.3      70.5      79.1          policy table for May
      62.0      57.7      62.0      66.3      74.8
      57.7      53.4      57.7      62.0      70.5
      53.4      53.4      53.4      62.0      70.5
      49.2      49.2      53.4      57.7      66.3
      44.9      44.9      49.2      53.4      62.0
      40.6      40.6      44.9      49.2      57.7
      36.4      36.4      40.6      44.9      53.4
      32.1      32.1      36.4      40.6      49.2
      27.8      27.8      32.1      36.4      44.9
      23.5      23.5      27.8      32.1      40.6
      19.3      19.3      23.5      27.8      36.4
      15.0      15.0      19.3      23.5      32.1
PERIOD          10
FLOW             .5       1.6       2.6       3.7
     117.5     104.7     104.7     104.7     109.0
     113.2     100.4     100.4     100.4     104.7
     109.0      96.1      96.1      96.1     100.4
     104.7      91.9      91.9      91.9      96.1
     100.4      87.6      87.6      91.9      91.9
      96.1      83.3      83.3      87.6      87.6
      91.9      79.1      79.1      83.3      83.3
      87.6      74.8      74.8      79.1      79.1
      83.3      70.5      70.5      74.8      74.8
      79.1      66.3      70.5      70.5      70.5
      74.8      62.0      66.3      66.3      66.3
      70.5      57.7      62.0      62.0      62.0
      66.3      57.7      57.7      57.7      57.7          policy table for June
      62.0      53.4      53.4      53.4      53.4
      57.7      49.2      49.2      49.2      53.4
      53.4      44.9      44.9      44.9      49.2
      49.2      40.6      40.6      44.9      44.9
      44.9      40.6      40.6      40.6      40.6
      40.6      36.4      36.4      36.4      36.4
      36.4      32.1      32.1      32.1      36.4
      32.1      27.8      27.8      32.1      32.1
      27.8      27.8      27.8      27.8      27.8
      23.5      23.5      23.5      23.5      23.5
      19.3      19.3      19.3      19.3      19.3
      15.0      15.0      15.0      15.0      15.0
```

Table D.3 Statistical details file (continued)

```
PERIOD         11
FLOW             .4      1.1      2.7
     117.5    100.4    100.4    100.4
     113.2     96.1     96.1     96.1
     109.0     91.9     91.9     91.9
     104.7     87.6     87.6     87.6
     100.4     83.3     83.3     83.3
      96.1     79.1     79.1     79.1
      91.9     74.8     74.8     74.8
      87.6     70.5     70.5     70.5
      83.3     66.3     66.3     70.5
      79.1     62.0     62.0     66.3
      74.8     57.7     57.7     62.0
      70.5     53.4     53.4     57.7
      66.3     49.2     49.2     53.4
      62.0     44.9     44.9     49.2
      57.7     40.6     44.9     44.9
      53.4     40.6     40.6     40.6
      49.2     36.4     36.4     36.4
      44.9     32.1     32.1     32.1
      40.6     27.8     27.8     32.1
      36.4     27.8     27.8     27.8
      32.1     23.5     23.5     23.5
      27.8     19.3     19.3     23.5
      23.5     19.3     19.3     19.3
      19.3     15.0     15.0     19.3
      15.0     15.0     15.0     15.0
```

policy table for July

```
PERIOD         12
FLOW             .4      2.2      4.4
     117.5    104.7    109.0    109.0
     113.2    100.4    104.7    104.7
     109.0     96.1    100.4    100.4
     104.7     91.9     96.1     96.1
     100.4     87.6     91.9     91.9
      96.1     83.3     87.6     87.6
      91.9     79.1     83.3     83.3
      87.6     79.1     79.1     79.1
      83.3     74.8     74.8     74.8
      79.1     70.5     70.5     70.5
      74.8     66.3     66.3     70.5
      70.5     62.0     62.0     66.3
      66.3     57.7     57.7     62.0
      62.0     53.4     53.4     57.7
      57.7     49.2     49.2     53.4
      53.4     44.9     44.9     49.2
      49.2     40.6     40.6     44.9
      44.9     36.4     36.4     40.6
      40.6     32.1     36.4     36.4
      36.4     27.8     32.1     32.1
      32.1     27.8     27.8     27.8
      27.8     23.5     23.5     27.8
      23.5     23.5     23.5     23.5
      19.3     19.3     19.3     19.3
      15.0     15.0     15.0     15.0
```

policy table for August

APPENDIX E

The MODIFPOL program output file

Table E.1 Modified policy file BH.MPL (output)

```
MIC
        4         5         6         6         8         9         8         7         4         4         3         3
CMVAL
     .000     1.243     2.485     3.728     4.970
     .000     2.740     5.480     8.220    10.960    13.700
     .000     4.760     9.520    14.280    19.040    23.800    28.560
     .000     9.318    18.636    27.955    37.273    55.909   141.957
     .000     8.535    17.070    25.605    34.140    42.675    51.211    59.746    93.886
     .000     9.025    18.051    27.076    36.101    45.127    54.152    81.228    90.254    99.279
     .000     7.798    15.596    23.394    31.192    38.990    46.788    54.586    77.980
     .000     7.575    15.151    22.726    30.302    37.877    60.604    68.179
     .000     4.372     8.744    13.116    21.860
     .000     1.173     2.345     3.517     4.690
     .000      .973     1.945     2.918
     .000     1.355     2.710     5.420
CHFLOW
     .556     1.573     2.820     3.970
     .950     3.760     6.410     9.070    12.150
    1.799     6.042    10.030    15.907    21.393    27.560
    3.683    14.637    25.020    33.133    51.255   140.957
    4.288    13.148    20.844    28.398    36.350    47.784    55.248    92.886
    4.860    14.162    22.117    31.134    43.075    46.570    78.236    81.416    98.279
    4.267    11.599    19.520    27.253    34.880    41.100    50.886    74.235
    3.169    11.594    17.727    25.355    35.770    55.962    67.179
    1.747     5.727    11.290    20.860
     .494     1.621     2.595     3.690
     .357     1.146     2.732
     .448     2.168     4.420
O.F. = Single sided squared deviation
    117.5      15.0     429.2        25
```

Table E.1 Modified policy file (continued I)

```
 1  6  5  5  5
 2  7  6  6  6
 3  8  7  7  7
 4  9  8  8  8
 5 10  9  9  9
 6 11 10 10 10
 7 12 11 11 11
 8 13 12 12 12
 9 14 13 13 13
10 15 14 14 14
11 16 15 15 15
12 17 16 16 16
13 17 16 16 16
14 18 17 17 17
15 19 18 18 18
16 20 19 19 19
17 20 20 20 20
18 21 21 21 21
19 22 22 22 22
20 23 23 23 22
21 24 24 24 23
22 25 25 24 24
23 25 25 25 25
24 25 25 25 25
25 25 25 25 25
 1  3  3  2  2  1
 2  4  4  3  3  2
 3  5  5  4  4  3
 4  6  6  5  5  4
 5  7  7  6  6  5
 6  8  8  7  7  6
 7  9  9  8  8  7
 8 10 10  9  9  8
 9 11 11 10 10  9
10 12 12 11 11 10
11 13 13 12 12 11
12 14 14 13 13 12
13 15 14 14 14 12
14 16 15 15 15 13
15 17 16 16 16 14
16 17 17 17 17 15
17 18 18 18 18 16
18 19 19 19 19 17
19 20 20 20 20 18
20 21 21 21 21 19
21 22 22 22 22 20
22 23 23 23 23 21
23 24 24 24 24 22
24 25 25 25 25 23
25 25 25 25 25 23
```

Table E.1 Modified policy file (continued II)

```
 1  2  1  1  1  1  1
 2  3  2  1  1  1  1
 3  4  3  2  1  1  1
 4  5  4  3  2  1  1
 5  6  5  4  3  2  1
 6  7  6  5  4  3  1
 7  8  7  6  5  4  2
 8  9  8  7  6  5  3
 9 10  9  8  7  6  4
10 11 10  9  8  7  5
11 12 11 10  9  8  6
12 13 12 11 10  9  7
13 14 13 12 10  9  8
14 15 14 13 11 10  9
15 16 14 14 12 11 10
16 17 15 15 13 12 11
17 18 16 16 14 13 12
18 19 17 16 15 14 13
19 20 18 17 16 15 14
20 21 19 18 17 16 14
21 22 20 19 18 17 15
22 23 21 20 19 18 16
23 24 22 21 20 19 17
24 25 23 22 21 20 18
25 25 24 23 22 21 19
 1  1  1  1  1  1  1
 2  2  1  1  1  1  1
 3  3  1  1  1  1  1
 4  4  1  1  1  1  1
 5  5  2  1  1  1  1
 6  6  3  1  1  1  1
 7  7  4  2  1  1  1
 8  8  5  3  1  1  1
 9  9  6  4  2  1  1
10 10  7  5  3  1  1
11 11  8  6  4  1  1
12 12  9  7  5  1  1
13 13 10  8  6  2  1
14 14 11  9  7  3  1
15 15 12 10  8  4  1
16 16 13 11  9  5  1
17 17 14 12 10  6  1
18 18 15 13 11  7  1
19 19 16 14 12  8  1
20 20 17 15 13  9  1
21 21 18 16 14 10  1
22 22 19 17 15 11  1
23 23 20 18 16 12  1
24 24 21 19 17 13  1
25 25 22 20 18 14  1
```

Table E.1 Modified policy file (continued III)

1	1	1	1	1	1	1	1	1	
2	2	1	1	1	1	1	1	1	
3	3	1	1	1	1	1	1	1	
4	4	2	1	1	1	1	1	1	
5	5	3	2	1	1	1	1	1	
6	6	4	3	1	1	1	1	1	
7	7	5	4	2	1	1	1	1	
8	8	6	5	3	1	1	1	1	
9	9	7	6	4	2	1	1	1	
10	10	8	7	5	3	1	1	1	
11	11	9	8	6	4	1	1	1	
12	12	10	9	7	5	2	1	1	
13	13	10	9	7	5	3	1	1	
14	14	11	10	8	6	4	2	1	
15	15	12	11	9	7	5	3	1	
16	16	13	12	10	8	6	4	1	
17	17	14	13	11	9	6	5	1	
18	18	15	14	12	10	7	6	1	
19	19	16	15	13	11	8	7	1	
20	20	17	16	14	12	9	8	1	
21	21	18	17	15	13	10	9	1	
22	22	19	18	16	14	11	10	1	
23	23	20	19	17	15	12	11	2	
24	24	21	20	18	16	13	12	3	
25	25	22	21	19	17	14	13	4	
1	2	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1
3	4	2	1	1	1	1	1	1	1
4	5	3	1	1	1	1	1	1	1
5	6	4	2	1	1	1	1	1	1
6	7	5	3	1	1	1	1	1	1
7	8	6	4	2	1	1	1	1	1
8	9	7	5	3	1	1	1	1	1
9	10	8	6	4	1	1	1	1	1
10	11	9	7	5	2	1	1	1	1
11	12	9	8	6	3	2	1	1	1
12	13	10	9	7	4	3	1	1	1
13	14	10	9	7	4	3	1	1	1
14	15	11	10	8	5	4	1	1	1
15	16	12	11	9	6	5	1	1	1
16	17	13	11	9	7	6	1	1	1
17	18	14	12	10	8	7	1	1	1
18	19	15	13	11	9	8	1	1	1
19	20	16	14	12	10	9	2	1	1
20	21	17	15	13	11	10	3	2	1
21	22	18	16	14	12	11	4	3	1
22	23	19	17	15	12	12	5	4	1
23	24	20	18	16	13	13	6	5	1
24	25	21	19	17	14	14	7	6	2
25	25	22	20	18	15	15	8	7	3

Table E.1 Modified policy file (continued IV)

1	2	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1
3	4	2	1	1	1	1	1	1
4	5	3	2	1	1	1	1	1
5	6	4	3	1	1	1	1	1
6	7	5	4	2	1	1	1	1
7	8	6	5	3	1	1	1	1
8	9	7	6	4	2	1	1	1
9	10	8	6	5	3	2	1	1
10	11	9	7	6	4	3	1	1
11	12	10	8	7	5	4	1	1
12	13	11	9	8	6	5	2	1
13	14	11	9	8	6	4	2	1
14	15	12	10	9	7	5	3	1
15	16	13	11	9	8	6	4	1
16	17	14	12	10	9	7	5	1
17	18	15	13	11	10	8	6	1
18	19	16	14	12	11	9	7	2
19	20	17	15	13	12	10	8	3
20	21	18	16	14	12	11	9	4
21	22	19	17	15	13	12	10	5
22	23	20	18	16	14	13	11	6
23	24	21	19	17	15	14	12	7
24	25	22	20	18	16	15	13	8
25	25	23	21	19	17	16	14	9
1	4	2	1	1	1	1	1	
2	5	3	2	1	1	1	1	
3	6	4	3	1	1	1	1	
4	7	5	4	2	1	1	1	
5	8	6	5	3	1	1	1	
6	9	7	6	4	1	1	1	
7	10	8	7	5	2	1	1	
8	11	9	8	6	3	1	1	
9	12	10	9	7	4	1	1	
10	13	11	9	8	5	1	1	
11	14	12	10	9	6	2	1	
12	14	13	11	10	7	3	1	
13	14	14	11	10	7	3	1	
14	15	15	12	11	8	4	1	
15	16	16	13	12	9	5	2	
16	17	17	14	12	10	6	3	
17	18	18	15	13	11	7	4	
18	19	19	16	14	12	8	5	
19	20	20	17	15	13	9	6	
20	21	21	17	16	14	9	7	
21	22	22	18	17	15	10	8	
22	23	23	19	18	16	11	9	
23	24	24	20	19	16	12	10	
24	25	25	21	19	17	13	11	
25	25	25	21	20	18	14	12	

Table E.1 Modified policy file (continued V)

```
 1  3  2  1  1
 2  4  3  2  1
 3  5  4  3  1
 4  6  5  4  2
 5  7  6  5  3
 6  8  7  6  4
 7  9  8  7  5
 8 10  9  8  6
 9 11 10  9  7
10 12 11 10  8
11 13 12 11  9
12 14 13 12 10
13 14 14 12 10
14 15 15 13 11
15 16 16 14 12
16 17 17 14 12
17 18 18 15 13
18 19 19 16 14
19 20 20 17 15
20 21 21 18 16
21 22 22 19 17
22 23 23 20 18
23 24 24 21 19
24 25 25 22 20
25 25 25 23 21
 1  5  5  4  4
 2  6  6  5  5
 3  7  7  6  6
 4  8  8  7  7
 5  9  9  8  8
 6 10 10  9  9
 7 11 11 10 10
 8 12 12 11 11
 9 13 13 12 12
10 14 13 13 13
11 15 14 14 14
12 16 15 15 15
13 15 15 15 15
14 16 16 16 16
15 17 17 17 16
16 18 18 18 17
17 19 19 18 18
18 19 19 19 19
19 20 20 20 20
20 21 21 21 21
21 22 22 22 22
22 23 23 23 23
23 24 24 24 24
24 25 25 25 25
25 25 25 25 25
```

Table E.1 Modified policy file (continued VI)

```
 1  6  6  5
 2  7  7  6
 3  8  8  7
 4  9  9  8
 5 10 10  9
 6 11 11 10
 7 12 12 11
 8 13 13 12
 9 14 14 13
10 15 15 14
11 16 16 15
12 17 17 16
13 17 17 16
14 18 18 17
15 19 18 18
16 19 19 19
17 20 20 20
18 21 21 21
19 22 22 21
20 22 22 22
21 23 23 23
22 24 24 23
23 24 24 24
24 25 25 25
25 25 25 25
 1  4  4  3
 2  5  5  4
 3  6  6  5
 4  7  7  6
 5  8  8  7
 6  9  9  8
 7 10 10  9
 8 11 11 10
 9 12 12 11
10 13 13 12
11 14 14 13
12 15 15 14
13 15 15 14
14 16 16 15
15 17 17 16
16 18 18 17
17 19 19 18
18 20 20 19
19 21 20 20
20 22 21 21
21 22 22 22
22 23 23 23
23 24 24 24
24 25 25 25
25 25 25 25
```

APPENDIX F

The SIMULATE program output files

Table F.1 Simulation output file BH.SIM (output)

```
O.F. = Single sided squared deviation ---- objective function used in optimization

Simulation according to the policy. ---- message on the simulation mode that was performed

Operation of  RESERVOIR BH 1991 -------- reservoir name

 Year 46 --------------------------------- year

   month (September - August)
   |      initial reservoir storage volume [10^6m^3]
   |      |        inflow during the current month [10^6m^3]
   |      |        |        evaporation losses during the month [10^6m^3]
   |      |        |        |        final reservoir storage volume [10^6m^3]
   |      |        |        |        |        distributed demand [10^6m^3]
   |      |        |        |        |        |        own demand [10^6m^3]
   |      |        |        |        |        |        |        total reservoir
   |      |        |        |        |        |        |        release [10^6m^3]
   |      |        |        |        |        |        |        |        spillage
   |      |        |        |        |        |        |        |        [10^6m^3]
   |      |        |        |        |        |        |        |        |
Month Ini.Sto.    Inflow   Evapo.   Fin.Sto.    Demand  Own Demand   Release      Spil

  1    117.50      1.015     .663     98.07     18.059        .000    19.779        .0   OK
  2     98.07      1.450     .403     89.53      9.213        .000     9.589        .0   OK
  3     89.53      3.960     .191     87.44      5.545        .000     5.865        .0   OK
  4     87.44    140.957     .180    117.50       .127        .000   110.713        .0   OK
  5    117.50     20.840     .179    117.50      3.970        .000    20.661        .0   OK
  6    117.50      8.472     .177    114.89      5.905        .000    10.908        .0   OK
  7    114.89      6.110     .277    112.35      6.947        .000     8.374        .0   OK
  8    112.35      5.670     .276    102.07     14.178        .000    15.671        .0   OK
  9    102.07      1.320     .490     93.53      9.396        .000     9.372        .0   DEFI
 10     93.53       .610     .739     76.45     14.708        .000    16.954        .0   OK
 11     76.45       .630     .838     55.09     19.284        .000    21.147        .0   OK
 12     55.09       .900     .672     46.55     12.079        .000     8.769        .0   DEFI
                                                                                       |
                                               demand fulfilment  ---------------------

 Year 47

Month Ini.Sto.    Inflow   Evapo.   Fin.Sto.    Demand  Own Demand   Release      Spil

  1     46.55       .320     .360     33.74     18.059        .000    12.772        .0   DEFI
  2     33.74      3.900     .193     29.47      9.213        .000     7.978        .0   DEFI
  3     29.47      2.970     .087     27.55      5.545        .000     4.796        .0   DEFI
  4     27.55     11.680     .088     39.14       .127        .000      .000        .0   DEFI
  5     39.14     15.210     .101     53.10      3.970        .000     1.152        .0   DEFI
  6     53.10      7.290     .111     53.29      5.905        .000     6.987        .0   OK
  7     53.29      6.840     .178     53.52      6.947        .000     6.437        .0   DEFI
  8     53.52      4.820     .179     49.17     14.178        .000     8.993        .0   DEFI
  9     49.17      1.470     .312     44.90      9.396        .000     5.429        .0   DEFI
 10     44.90       .680     .474     40.62     14.708        .000     4.477        .0   DEFI
 11     40.62       .330     .529     27.81     19.284        .000    12.614        .0   DEFI
 12     27.81       .310     .401     23.54     12.079        .000     4.179        .0   DEFI
```

Table F.1 Simulation output file (continued)

```
 Year 48

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand      Release        Spil

  1      23.54        .370      .194      15.00      18.059        .000        8.718          .0    DEFI
  2      15.00        .320      .099      15.00       9.213        .000         .221          .0    DEFI
  3      15.00      23.250      .078      34.66       5.545        .000        3.517          .0    DEFI
  4      34.66      17.040      .104      49.44        .127        .000        2.147          .0    OK
  5      49.44      57.650      .140     102.16       3.970        .000        4.796          .0    OK
  6     102.16      30.129      .169     117.50       5.905        .000       14.618          .0    OK
  7     117.50      48.480      .286     117.50       6.947        .000       48.194          .0    OK
  8     117.50       4.590      .282     106.13      14.178        .000       15.680          .0    OK
  9     106.13       1.700      .499      97.59       9.396        .000        9.743          .0    OK
 10      97.59       1.490      .760      80.50      14.708        .000       17.814          .0    OK
 11      80.50       1.140      .873      59.15      19.284        .000       21.621          .0    OK
 12      59.15       1.000      .707      50.61      12.079        .000        8.834          .0    DEFI

 Year 49

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand      Release        Spil

  1      50.61        .880      .385      36.81      18.059        .000       14.289          .0    DEFI
  2      36.81        .860      .208      32.54       9.213        .000        4.923          .0    DEFI
  3      32.54       4.180      .098      33.06       5.545        .000        3.560          .0    DEFI
  4      33.06       2.010      .086      33.06        .127        .000        1.924          .0    OK
  5      33.06      12.990      .090      45.88       3.970        .000         .087          .0    DEFI
  6      45.88      17.370      .112      62.13       5.905        .000        1.001          .0    DEFI
  7      62.13      36.330      .228      94.02       6.947        .000        4.215          .0    DEFI
  8      94.02      25.170      .266     102.56      14.178        .000       16.363          .0    OK
  9     102.56       1.800      .491      94.02       9.396        .000        9.850          .0    OK
 10      94.02       1.460      .742      76.94      14.708        .000       17.802          .0    OK
 11      76.94       1.090      .842      55.58      19.284        .000       21.602          .0    OK
 12      55.58        .920      .677      47.04      12.079        .000        8.785          .0    DEFI

 Year 50

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand      Release        Spil

  1      47.04       1.395      .364      34.23      18.059        .000       13.844          .0    DEFI
  2      34.23       1.430      .195      29.96       9.213        .000        5.505          .0    DEFI
  3      29.96       5.190      .096      34.23       5.545        .000         .823          .0    DEFI
  4      34.23       4.170      .089      34.80        .127        .000        3.511          .0    OK
  5      34.80      11.650      .093      46.36       3.970        .000         .000          .0    DEFI
  6      46.36      25.140      .118      70.57       5.905        .000         .804          .0    DEFI
  7      70.57       8.420      .219      74.79       6.947        .000        3.984          .0    DEFI
  8      74.79       2.720      .217      61.98      14.178        .000       15.316          .0    OK
  9      61.98       1.350      .366      57.71       9.396        .000        5.255          .0    DEFI
 10      57.71       1.090      .551      49.17      14.708        .000        9.081          .0    DEFI
 11      49.17        .950      .627      36.35      19.284        .000       13.135          .0    DEFI
 12      36.35        .860      .485      28.84      12.079        .000        7.894          .0    DEFI

 Year 51

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand      Release        Spil

  1      28.84        .820      .223      16.02      18.059        .000       13.409          .0    DEFI
  2      16.02       6.410      .102      15.00       9.213        .000        7.331          .0    DEFI
  3      15.00      14.880      .068      27.81       5.545        .000        2.000          .0    DEFI
  4      27.81      18.300      .092      43.64        .127        .000        2.382          .0    OK
  5      43.64      21.480      .110      61.44       3.970        .000        3.568          .0    DEFI
  6      61.44      42.170      .145      99.88       5.905        .000        3.588          .0    DEFI
  7      99.88      12.750      .262     104.77       6.947        .000        7.596          .0    OK
  8     104.77      13.590      .272     101.81      14.178        .000       16.282          .0    OK
  9     101.81       2.670      .491      94.26       9.396        .000        9.731          .0    OK
 10      94.26       1.410      .743      77.17      14.708        .000       17.751          .0    OK
 11      77.17        .890      .844      55.82      19.284        .000       21.400          .0    OK
 12      55.82        .850      .679      47.28      12.079        .000        8.713          .0    DEFI
```

Table F.1 Simulation output file (continued)

```
  Year 52

 Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

   1     47.28     1.126     .365     34.46     18.059       .000      13.573        .0    DEFI
   2     34.46      .880     .197     30.19      9.213       .000       4.954        .0    DEFI
   3     30.19    10.060     .102     38.73      5.545       .000       1.417        .0    DEFI
   4     38.73    47.910     .135     85.71       .127       .000        .795        .0    OK
   5     85.71    31.713     .161    110.63      3.970       .000       6.637        .0    OK
   6    110.63    16.719     .173    115.74      5.905       .000      11.440        .0    OK
   7    115.74    14.190     .284    117.50      6.947       .000      12.141        .0    OK
   8    117.50     4.040     .281    105.57     14.178       .000      15.688        .0    OK
   9    105.57     3.580     .500     99.00      9.396       .000       9.655        .0    OK
  10     99.00     1.850     .769     82.92     14.708       .000      17.160        .0    OK
  11     82.92     1.210     .893     61.56     19.284       .000      21.672        .0    OK
  12     61.56     1.700     .728     53.02     12.079       .000       9.514        .0    DEFI

  Year 53

 Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

   1     53.02     1.218     .398     38.86     18.059       .000      14.978        .0    DEFI
   2     38.86    11.600     .236     43.13      9.213       .000       7.093        .0    DEFI
   3     43.13    17.300     .133     57.03      5.545       .000       3.270        .0    DEFI
   4     57.03    10.220     .137     67.11       .127       .000        .000        .0    DEFI
   5     67.11    36.350     .148    100.42      3.970       .000       2.899        .0    DEFI
   6    100.42    78.236     .169    117.50      5.905       .000      60.984        .0    OK
   7    117.50    15.360     .286    117.50      6.947       .000      15.074        .0    OK
   8    117.50    16.219     .295    117.50     14.178       .000      15.924        .0    OK
   9    117.50     3.490     .531    110.83      9.396       .000       9.631        .0    OK
  10    110.83     1.420     .811     93.75     14.708       .000      17.692        .0    OK
  11     93.75     1.220     .965     72.39     19.284       .000      21.609        .0    OK
  12     72.39     1.050     .801     59.58     12.079       .000      13.061        .0    OK

  Year 54

 Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

   1     59.58     1.508     .438     46.77     18.059       .000      13.883        .0    DEFI
   2     46.77     2.160     .252     42.50      9.213       .000       6.178        .0    DEFI
   3     42.50     4.520     .120     43.70      5.545       .000       3.193        .0    DEFI
   4     43.70    17.810     .119     59.13       .127       .000       2.268        .0    OK
   5     59.13     9.830     .128     68.83      3.970       .000        .000        .0    DEFI
   6     68.83    17.170     .139     80.68      5.905       .000       5.181        .0    DEFI
   7     80.68    10.880     .235     84.95      6.947       .000       6.374        .0    DEFI
   8     84.95     4.750     .237     73.74     14.178       .000      15.723        .0    OK
   9     73.74     1.490     .405     65.20      9.396       .000       9.626        .0    OK
  10     65.20     1.150     .601     56.66     14.708       .000       9.091        .0    DEFI
  11     56.66      .990     .699     43.84     19.284       .000      13.103        .0    DEFI
  12     43.84      .870     .566     35.56     12.079       .000       8.588        .0    DEFI

  Year 55

 Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

   1     35.56     2.140     .280     22.75     18.059       .000      14.672        .0    DEFI
   2     22.75     4.700     .133     18.48      9.213       .000       8.838        .0    DEFI
   3     18.48     6.150     .065     22.86      5.545       .000       1.698        .0    DEFI
   4     22.86    16.570     .080     37.27       .127       .000       2.087        .0    OK
   5     37.27    14.180     .098     50.65      3.970       .000        .697        .0    DEFI
   6     50.65    81.416     .148    117.50      5.905       .000      14.418        .0    OK
   7    117.50    11.710     .286    117.50      6.947       .000      11.424        .0    OK
   8    117.50     5.190     .282    106.74     14.178       .000      15.671        .0    OK
   9    106.74     3.040     .502     99.58      9.396       .000       9.692        .0    OK
  10     99.58     2.100     .775     84.60     14.708       .000      16.308        .0    OK
  11     84.60     1.270     .904     63.25     19.284       .000      21.720        .0    OK
  12     63.25     1.000     .742     54.70     12.079       .000       8.800        .0    DEFI
```

Table F.1 Simulation output file (continued)

```
 Year 56

Month Ini.Sto.     Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     54.70       .907       .403     39.09       18.059       .000       16.113        .0     DEFI
  2     39.09      1.250       .219     34.82        9.213       .000        5.302        .0     DEFI
  3     34.82      2.370       .099     31.70        5.545       .000        5.393        .0     DEFI
  4     31.70     27.350       .107     55.51         .127       .000        3.436        .0     OK
  5     55.51     29.260       .132     82.06        3.970       .000        2.577        .0     DEFI
  6     82.06      7.350       .145     80.08        5.905       .000        9.189        .0     OK
  7     80.08      5.530       .229     77.28        6.947       .000        8.101        .0     OK
  8     77.28      8.410       .230     73.01       14.178       .000       12.451        .0     DEFI
  9     73.01      2.450       .404     65.22        9.396       .000        9.834        .0     OK
 10     65.22      2.420       .601     56.68       14.708       .000       10.361        .0     DEFI
 11     56.68      1.130       .700     43.86       19.284       .000       13.243        .0     DEFI
 12     43.86       .990       .566     35.65       12.079       .000        8.640        .0     DEFI

 Year 57

Month Ini.Sto.     Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     35.65       .550       .281     22.84       18.059       .000       13.082        .0     DEFI
  2     22.84      3.200       .134     18.56        9.213       .000        7.337        .0     DEFI
  3     18.56      4.050       .060     19.16        5.545       .000        3.397        .0     DEFI
  4     19.16     27.930       .083     43.57         .127       .000        3.429        .0     OK
  5     43.57     48.070       .130     90.72        3.970       .000         .797        .0     DEFI
  6     90.72      2.830       .153     86.45        5.905       .000        6.948        .0     OK
  7     86.45     20.130       .250     96.73        6.947       .000        9.599        .0     OK
  8     96.73      3.940       .256     84.70       14.178       .000       15.715        .0     OK
  9     84.70       .910       .441     76.16        9.396       .000        9.010        .0     DEFI
 10     76.16       .690       .648     59.82       14.708       .000       16.383        .0     OK
 11     59.82       .000       .709     42.73       19.284       .000       16.375        .0     DEFI
 12     42.73       .700       .554     34.51       12.079       .000        8.371        .0     DEFI

 Year 58

Month Ini.Sto.     Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     34.51       .160       .272     21.69       18.059       .000       12.700        .0     DEFI
  2     21.69      1.400       .127     17.42        9.213       .000        5.544        .0     DEFI
  3     17.42     14.600       .075     30.24        5.545       .000        1.713        .0     DEFI
  4     30.24      8.660       .087     36.06         .127       .000        2.752        .0     OK
  5     36.06     24.590       .102     57.38        3.970       .000        3.169        .0     DEFI
  6     57.38      3.980       .114     53.11        5.905       .000        8.137        .0     OK
  7     53.11     76.980       .239    117.50        6.947       .000       12.347        .0     OK
  8    117.50     55.962       .295    117.50       14.178       .000       55.667        .0     OK
  9    117.50      1.480       .526    108.96        9.396       .000        9.495        .0     OK
 10    108.96      2.230       .809     94.55       14.708       .000       15.834        .0     OK
 11     94.55       .840       .971     73.19       19.284       .000       21.224        .0     OK
 12     73.19       .000       .808     60.38       12.079       .000       12.005        .0     DEFI

 Year 59

Month Ini.Sto.     Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     60.38      1.142       .437     45.76       18.059       .000       15.327        .0     DEFI
  2     45.76       .860       .248     41.49        9.213       .000        4.883        .0     DEFI
  3     41.49      5.760       .122     45.76        5.545       .000        1.368        .0     DEFI
  4     45.76     15.900       .121     59.61         .127       .000        1.927        .0     OK
  5     59.61     25.750       .136     85.22        3.970       .000         .000        .0     DEFI
  6     85.22      3.250       .147     80.95        5.905       .000        7.373        .0     OK
  7     80.95      5.190       .230     77.75        6.947       .000        8.156        .0     OK
  8     77.75      8.330       .231     73.48       14.178       .000       12.370        .0     DEFI
  9     73.48     20.860       .433     82.03        9.396       .000       11.886        .0     OK
 10     82.03       .590       .681     64.94       14.708       .000       16.993        .0     OK
 11     64.94       .240       .755     47.86       19.284       .000       16.569        .0     DEFI
 12     47.86       .330       .608     39.32       12.079       .000        8.264        .0     DEFI
```

Table F.1 Simulation output file (continued)

```
 Year 60

Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

  1     39.32        .000     .309     26.50    18.059        .000     12.504        .0    DEFI
  2     26.50        .220     .156     22.23     9.213        .000      4.335        .0    DEFI
  3     22.23        .260     .064     17.96     5.545        .000      4.467        .0    DEFI
  4     17.96       8.280     .058     23.34      .127        .000      2.846        .0    OK
  5     23.34      26.210     .084     48.97     3.970        .000       .501        .0    DEFI
  6     48.97       3.760     .102     44.69     5.905        .000      7.929        .0    OK
  7     44.69       2.450     .153     40.42     6.947        .000      6.568        .0    DEFI
  8     40.42        .420     .145     36.15    14.178        .000      4.546        .0    DEFI
  9     36.15       1.510     .245     31.88     9.396        .000      5.536        .0    DEFI
 10     31.88        .840     .357     27.61    14.708        .000      4.754        .0    DEFI
 11     27.61        .630     .386     19.27    19.284        .000      8.584        .0    DEFI
 12     19.27        .130     .275     15.00    12.079        .000      4.126        .0    DEFI

 Year 61

Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

  1     15.00        .200     .153     15.00    18.059        .000       .047        .0    DEFI
  2     15.00        .960     .099     15.00     9.213        .000       .861        .0    DEFI
  3     15.00       1.340     .048     15.00     5.545        .000      1.292        .0    DEFI
  4     15.00       1.190     .043     15.00      .127        .000      1.147        .0    OK
  5     15.00       4.260     .039     15.00     3.970        .000      4.221        .0    OK
  6     15.00      18.410     .064     33.35     5.905        .000       .000        .0    DEFI
  7     33.35       4.860     .121     30.11     6.947        .000      7.973        .0    OK
  8     30.11      10.920     .113     25.84    14.178        .000     15.077        .0    OK
  9     25.84       1.060     .182     21.57     9.396        .000      5.149        .0    DEFI
 10     21.57        .480     .245     17.30    14.708        .000      4.506        .0    DEFI
 11     17.30        .470     .272     15.00    19.284        .000      2.496        .0    DEFI
 12     15.00        .250     .242     15.00    12.079        .000       .008        .0    DEFI

 Year 62

Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

  1     15.00        .460     .153     15.00    18.059        .000       .307        .0    DEFI
  2     15.00      12.700     .130     25.07     9.213        .000      2.503        .0    DEFI
  3     25.07      10.000     .089     33.61     5.545        .000      1.369        .0    DEFI
  4     33.61      28.700     .115     62.19      .127        .000       .000        .0    DEFI
  5     62.19      13.600     .132     75.26     3.970        .000       .405        .0    DEFI
  6     75.26      29.300     .150     96.61     5.905        .000      7.796        .0    OK
  7     96.61       2.960     .253     92.34     6.947        .000      6.977        .0    OK
  8     92.34      13.420     .256     89.34    14.178        .000     16.163        .0    OK
  9     89.34        .370     .456     80.80     9.396        .000      8.456        .0    DEFI
 10     80.80        .290     .675     63.72    14.708        .000     16.699        .0    OK
 11     63.72       2.766     .763     50.90    19.284        .000     14.816        .0    DEFI
 12     50.90       4.420     .655     46.63    12.079        .000      8.036        .0    DEFI

 Year 63

Month Ini.Sto.     Inflow    Evapo.  Fin.Sto.    Demand  Own Demand    Release      Spil

  1     46.63       2.550     .361     33.82    18.059        .000     15.002        .0    DEFI
  2     33.82       2.060     .193     29.55     9.213        .000      6.137        .0    DEFI
  3     29.55       2.800     .087     27.29     5.545        .000      4.969        .0    DEFI
  4     27.29       9.740     .088     36.95      .127        .000       .000        .0    DEFI
  5     36.95      20.100     .100     54.03     3.970        .000      2.916        .0    DEFI
  6     54.03      22.710     .126     75.35     5.905        .000      1.260        .0    DEFI
  7     75.35       5.670     .221     72.72     6.947        .000      8.085        .0    OK
  8     72.72       3.410     .215     62.16    14.178        .000     13.748        .0    DEFI
  9     62.16       1.730     .366     57.89     9.396        .000      5.634        .0    DEFI
 10     57.89        .550     .552     49.35    14.708        .000      8.540        .0    DEFI
 11     49.35        .490     .629     36.54    19.284        .000     12.673        .0    DEFI
 12     36.54        .720     .485     28.67    12.079        .000      8.101        .0    DEFI
```

Table F.1 Simulation output file (continued)

```
  Year 64

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.       Demand  Own Demand        Release        Spil

  1     28.67      1.250       .222      15.86       18.059        .000         13.841          .0    DEFI
  2     15.86      1.460       .102      15.00        9.213        .000          2.219          .0    DEFI
  3     15.00      4.010       .052      17.23        5.545        .000          1.733          .0    DEFI
  4     17.23      2.230       .049      17.23         .127        .000          2.181          .0    OK
  5     17.23     28.300       .073      42.85        3.970        .000          2.602          .0    DEFI
  6     42.85     46.570       .126      85.56        5.905        .000          3.736          .0    DEFI
  7     85.56     16.400       .249      96.15        6.947        .000          5.564          .0    DEFI
  8     96.15      2.690       .254      83.33       14.178        .000         15.248          .0    OK
  9     83.33      1.730       .437      74.79        9.396        .000          9.835          .0    OK
 10     74.79      1.110       .644      60.04       14.708        .000         15.215          .0    OK
 11     60.04       .770       .715      43.97       19.284        .000         16.124          .0    DEFI
 12     43.97       .510       .566      35.43       12.079        .000          8.486          .0    DEFI

  Year 65

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.       Demand  Own Demand        Release        Spil

  1     35.43       .330       .279      22.62       18.059        .000         12.863          .0    DEFI
  2     22.62       .230       .132      18.35        9.213        .000          4.368          .0    DEFI
  3     18.35       .150       .054      15.00        5.545        .000          3.444          .0    DEFI
  4     15.00      2.050       .043      15.00         .127        .000          2.007          .0    OK
  5     15.00      4.940       .040      15.94        3.970        .000          3.957          .0    DEFI
  6     15.94      2.910       .040      15.00        5.905        .000          3.813          .0    DEFI
  7     15.00     12.600       .080      24.62        6.947        .000          2.898          .0    DEFI
  8     24.62     35.770       .147      53.44       14.178        .000          6.806          .0    DEFI
  9     53.44      6.870       .336      51.80        9.396        .000          8.173          .0    DEFI
 10     51.80      1.510       .510      43.26       14.708        .000          9.542          .0    DEFI
 11     43.26       .880       .560      30.45       19.284        .000         13.132          .0    DEFI
 12     30.45       .810       .433      26.17       12.079        .000          4.647          .0    DEFI

  Year 66

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.       Demand  Own Demand        Release        Spil

  1     26.17      3.970       .218      17.63       18.059        .000         12.293          .0    DEFI
  2     17.63       .790       .107      15.00        9.213        .000          3.316          .0    DEFI
  3     15.00      1.970       .049      15.17        5.545        .000          1.749          .0    DEFI
  4     15.17      8.340       .050      20.62         .127        .000          2.843          .0    OK
  5     20.62     13.600       .067      33.68        3.970        .000           .470          .0    DEFI
  6     33.68     19.050       .099      52.63        5.905        .000           .000          .0    DEFI
  7     52.63      3.950       .171      48.36        6.947        .000          8.049          .0    OK
  8     48.36      2.490       .167      44.09       14.178        .000          6.594          .0    DEFI
  9     44.09      2.010       .288      39.82        9.396        .000          5.993          .0    DEFI
 10     39.82      1.330       .431      35.55       14.708        .000          5.170          .0    DEFI
 11     35.55       .620       .492      27.01       19.284        .000          8.670          .0    DEFI
 12     27.01       .780       .390      22.74       12.079        .000          4.661          .0    DEFI

  Year 67

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.       Demand  Own Demand        Release        Spil

  1     22.74       .740       .190      15.00       18.059        .000          8.288          .0    DEFI
  2     15.00       .680       .099      15.00        9.213        .000           .581          .0    DEFI
  3     15.00       .770       .048      15.00        5.545        .000           .721          .0    DEFI
  4     15.00      3.930       .043      15.29         .127        .000          3.598          .0    OK
  5     15.29     15.800       .057      29.57        3.970        .000          1.459          .0    DEFI
  6     29.57      4.640       .068      25.30        5.905        .000          8.843          .0    OK
  7     25.30      1.760       .093      21.03        6.947        .000          5.938          .0    DEFI
  8     21.03       .690       .079      16.76       14.178        .000          4.881          .0    DEFI
  9     16.76       .680       .125      15.00        9.396        .000          2.316          .0    DEFI
 10     15.00      1.470       .192      15.00       14.708        .000          1.278          .0    DEFI
 11     15.00       .420       .254      15.00       19.284        .000           .166          .0    DEFI
 12     15.00       .290       .242      15.00       12.079        .000           .048          .0    DEFI
```

Table F.1 Simulation output file (continued)

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 Year 68

Month Ini.Sto.     Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release      Spil

  1     15.00       .410       .153     15.00      18.059        .000         .257        .0     DEFI
  2     15.00       .640       .099     15.00       9.213        .000         .541        .0     DEFI
  3     15.00       .950       .048     15.00       5.545        .000         .901        .0     DEFI
  4     15.00      5.370       .045     16.97        .127        .000        3.351        .0     OK
  5     16.97     13.600       .059     30.04       3.970        .000         .478        .0     DEFI
  6     30.04      4.880       .069     25.77       5.905        .000        9.082        .0     OK
  7     25.77      2.570       .095     21.49       6.947        .000        6.746        .0     DEFI
  8     21.49      3.720       .081     17.22      14.178        .000        7.910        .0     DEFI
  9     17.22       .730       .126     15.00       9.396        .000        2.828        .0     DEFI
 10     15.00       .470       .192     15.00      14.708        .000         .278        .0     DEFI
 11     15.00       .300       .254     15.00      19.284        .000         .046        .0     DEFI
 12     15.00       .440       .242     15.00      12.079        .000         .198        .0     DEFI

 Year 69

Month Ini.Sto.     Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release      Spil

  1     15.00       .840       .153     15.00      18.059        .000         .687        .0     DEFI
  2     15.00      9.070       .099     15.00       9.213        .000        8.971        .0     DEFI
  3     15.00      1.730       .048     15.00       5.545        .000        1.682        .0     DEFI
  4     15.00     54.600       .100     65.13        .127        .000        4.367        .0     OK
  5     65.13      9.010       .136     74.01       3.970        .000         .000        .0     DEFI
  6     74.01      9.530       .142     82.55       5.905        .000         .846        .0     DEFI
  7     82.55     23.730       .249     99.63       6.947        .000        6.398        .0     DEFI
  8     99.63      3.140       .260     86.82      14.178        .000       15.693        .0     OK
  9     86.82      1.620       .448     78.28       9.396        .000        9.714        .0     OK
 10     78.28       .910       .665     62.77      14.708        .000       15.752        .0     OK
 11     62.77       .730       .736     45.69      19.284        .000       17.078        .0     DEFI
 12     45.69       .240       .584     37.15      12.079        .000        8.198        .0     DEFI

 Year 70

Month Ini.Sto.     Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release      Spil

  1     37.15       .090       .292     24.33      18.059        .000       12.610        .0     DEFI
  2     24.33       .370       .143     20.06       9.213        .000        4.498        .0     DEFI
  3     20.06       .070       .057     15.79       5.545        .000        4.284        .0     DEFI
  4     15.79     15.650       .063     29.44        .127        .000        1.941        .0     OK
  5     29.44     30.780       .097     57.62       3.970        .000        2.499        .0     DEFI
  6     57.62     32.350       .135     84.49       5.905        .000        5.351        .0     DEFI
  7     84.49     16.650       .248     96.15       6.947        .000        4.742        .0     DEFI
  8     96.15     18.640       .264     97.17      14.178        .000       17.354        .0     OK
  9     97.17      2.070       .480     88.97       9.396        .000        9.785        .0     OK
 10     88.97       .000       .716     71.89      14.708        .000       16.367        .0     OK
 11     71.89       .350       .797     50.54      19.284        .000       20.907        .0     OK
 12     50.54       .000       .633     41.99      12.079        .000        7.909        .0     DEFI

 Year 71

Month Ini.Sto.     Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release      Spil

  1     41.99       .480       .329     29.18      18.059        .000       12.963        .0     DEFI
  2     29.18      3.240       .171     24.91       9.213        .000        7.340        .0     DEFI
  3     24.91       .840       .072     20.64       5.545        .000        5.039        .0     DEFI
  4     20.64      1.680       .058     20.64        .127        .000        1.622        .0     OK
  5     20.64     17.210       .071     37.72       3.970        .000         .056        .0     DEFI
  6     37.72     20.220       .104     57.84       5.905        .000         .000        .0     DEFI
  7     57.84      7.130       .188     58.57       6.947        .000        6.210        .0     DEFI
  8     58.57     19.580       .206     68.15      14.178        .000        9.795        .0     DEFI
  9     68.15      3.340       .389     62.74       9.396        .000        8.362        .0     DEFI
 10     62.74       .670       .584     54.20      14.708        .000        8.627        .0     DEFI
 11     54.20       .000       .674     40.62      19.284        .000       12.899        .0     DEFI
 12     40.62       .000       .529     32.08      12.079        .000        8.012        .0     DEFI
```

Table F.1 Simulation output file (continued)

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 Year 72

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     32.08        .550       .254      19.27      18.059        .000      13.109        .0     DEFI
  2     19.27        .340       .112      15.00       9.213        .000       4.499        .0     DEFI
  3     15.00        .080       .048      15.00       5.545        .000        .032        .0     DEFI
  4     15.00        .470       .043      15.00        .127        .000        .427        .0     OK
  5     15.00      26.770       .068      40.62       3.970        .000       1.077        .0     DEFI
  6     40.62      22.610       .109      62.51       5.905        .000        .618        .0     DEFI
  7     62.51      71.490       .247     117.50       6.947        .000      16.251        .0     OK
  8    117.50       5.740       .283     107.29      14.178        .000      15.663        .0     OK
  9    107.29        .740       .501      98.75       9.396        .000       8.780        .0     DEFI
 10     98.75        .100       .766      81.67      14.708        .000      16.418        .0     OK
 11     81.67        .230       .884      60.31      19.284        .000      20.700        .0     OK
 12     60.31        .180       .717      51.77      12.079        .000       8.004        .0     DEFI

 Year 73

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     51.77        .000       .387      36.35      18.059        .000      15.032        .0     DEFI
  2     36.35       2.660       .206      32.08       9.213        .000       6.725        .0     DEFI
  3     32.08        .000       .091      27.81       5.545        .000       4.180        .0     DEFI
  4     27.81       2.620       .075      27.81        .127        .000       2.545        .0     OK
  5     27.81        .620       .068      27.81       3.970        .000        .552        .0     DEFI
  6     27.81       6.480       .067      26.52       5.905        .000       7.709        .0     OK
  7     26.52       4.520       .099      22.69       6.947        .000       8.250        .0     OK
  8     22.69      13.320       .095      23.23      14.178        .000      12.688        .0     DEFI
  9     23.23       1.170       .163      18.95       9.396        .000       5.278        .0     DEFI
 10     18.95        .020       .216      15.00      14.708        .000       3.759        .0     DEFI
 11     15.00        .000       .254      14.75      19.284        .000        .000        .0     DEFI
 12     14.75        .000       .241      14.51      12.079        .000        .000        .0     FAIL

 Year 74

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     14.51        .190       .151      14.54      18.059        .000        .000        .0     FAIL
  2     14.54       1.330       .098      15.00       9.213        .000        .777        .0     FAIL
  3     15.00      27.560       .085      40.62       5.545        .000       1.850        .0     DEFI
  4     40.62       8.460       .107      46.21        .127        .000       2.766        .0     OK
  5     46.21       3.250       .101      46.21       3.970        .000       3.149        .0     DEFI
  6     46.21      26.680       .119      71.89       5.905        .000        .885        .0     DEFI
  7     71.89       9.530       .221      76.16       6.947        .000       5.038        .0     DEFI
  8     76.16       3.290       .220      63.47      14.178        .000      15.760        .0     OK
  9     63.47      12.410       .393      69.46       9.396        .000       6.027        .0     DEFI
 10     69.46        .420       .608      54.50      14.708        .000      14.775        .0     OK
 11     54.50        .260       .675      40.62      19.284        .000      13.458        .0     DEFI
 12     40.62        .310       .529      32.08      12.079        .000       8.322        .0     DEFI

 Year 75

Month Ini.Sto.      Inflow     Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

  1     32.08        .480       .254      19.27      18.059        .000      13.039        .0     DEFI
  2     19.27        .160       .112      15.00       9.213        .000       4.319        .0     DEFI
  3     15.00       3.610       .051      16.82       5.545        .000       1.736        .0     DEFI
  4     16.82       7.590       .054      21.39        .127        .000       2.967        .0     OK
  5     21.39       3.700       .054      21.39       3.970        .000       3.646        .0     DEFI
  6     21.39      10.570       .068      31.89       5.905        .000        .000        .0     DEFI
  7     31.89      27.000       .159      57.52       6.947        .000       1.216        .0     DEFI
  8     57.52       4.320       .188      53.25      14.178        .000       8.403        .0     DEFI
  9     53.25      10.170       .356      61.79       9.396        .000       1.272        .0     DEFI
 10     61.79        .780       .578      53.25      14.708        .000       8.744        .0     DEFI
 11     53.25        .430       .668      40.44      19.284        .000      12.574        .0     DEFI
 12     40.44        .190       .527      31.89      12.079        .000       8.204        .0     DEFI
```

Table F.1 Simulation output file (continued)

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 Year 76

Month Ini.Sto.      Inflow      Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

   1     31.89       3.360       .260      21.19      18.059        .000      13.806        .0     DEFI
   2     21.19       1.850       .124      16.92       9.213        .000       5.997        .0     DEFI
   3     16.92      20.720       .080      34.00       5.545        .000       3.557        .0     DEFI
   4     34.00      13.720       .101      46.81        .127        .000        .807        .0     OK
   5     46.81       8.130       .106      52.37       3.970        .000       2.468        .0     DEFI
   6     52.37       4.430       .107      48.10       5.905        .000       8.594        .0     OK
   7     48.10       1.250       .161      43.83       6.947        .000       5.360        .0     DEFI
   8     43.83       1.990       .155      39.56      14.178        .000       6.106        .0     DEFI
   9     39.56       1.400       .264      35.29       9.396        .000       5.407        .0     DEFI
  10     35.29       1.540       .389      31.01      14.708        .000       5.421        .0     DEFI
  11     31.01        .980       .434      22.47      19.284        .000       9.087        .0     DEFI
  12     22.47       2.350       .322      18.20      12.079        .000       6.299        .0     DEFI

 Year 77

Month Ini.Sto.      Inflow      Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

   1     18.20       1.170       .168      15.00      18.059        .000       4.203        .0     DEFI
   2     15.00        .220       .099      15.00       9.213        .000        .121        .0     DEFI
   3     15.00       7.900       .058      21.26       5.545        .000       1.582        .0     DEFI
   4     21.26       1.190       .059      21.26        .127        .000       1.131        .0     OK
   5     21.26       5.740       .056      23.36       3.970        .000       3.584        .0     DEFI
   6     23.36      29.600       .088      52.87       5.905        .000        .000        .0     DEFI
   7     52.87       4.240       .172      48.60       6.947        .000       8.339        .0     OK
   8     48.60      13.170       .171      47.62      14.178        .000      13.977        .0     DEFI
   9     47.62       3.480       .306      43.35       9.396        .000       7.445        .0     DEFI
  10     43.35       2.770       .461      39.08      14.708        .000       6.580        .0     DEFI
  11     39.08       2.540       .536      30.54      19.284        .000      10.545        .0     DEFI
  12     30.54       2.270       .434      26.27      12.079        .000       6.106        .0     DEFI

 Year 78

Month Ini.Sto.      Inflow      Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

   1     26.27        .000       .206      15.00      18.059        .000      11.062        .0     DEFI
   2     15.00        .270       .099      15.00       9.213        .000        .171        .0     DEFI
   3     15.00       5.300       .055      19.27       5.545        .000        .974        .0     DEFI
   4     19.27       4.150       .055      19.82        .127        .000       3.549        .0     OK
   5     19.82       4.980       .052      20.82       3.970        .000       3.928        .0     DEFI
   6     20.82       8.880       .056      23.93       5.905        .000       5.712        .0     DEFI
   7     23.93       2.840       .088      19.66       6.947        .000       7.023        .0     OK
   8     19.66      25.540       .121      40.82      14.178        .000       4.256        .0     DEFI
   9     40.82       3.640       .271      36.55       9.396        .000       7.640        .0     DEFI
  10     36.55       2.040       .401      32.28      14.708        .000       5.909        .0     DEFI
  11     32.28       2.890       .450      23.74      19.284        .000      10.981        .0     DEFI
  12     23.74       2.350       .341      19.47      12.079        .000       6.280        .0     DEFI

 Year 79

Month Ini.Sto.      Inflow      Evapo.   Fin.Sto.      Demand  Own Demand     Release      Spil

   1     19.47        .000       .174      15.00      18.059        .000       4.294        .0     DEFI
   2     15.00        .000       .099      14.90       9.213        .000        .000        .0     DEFI
   3     14.90      20.210       .074      32.08       5.545        .000       2.954        .0     FAIL
   4     32.08       2.450       .084      32.08        .127        .000       2.366        .0     OK
   5     32.08       5.310       .078      33.56       3.970        .000       3.754        .0     DEFI
   6     33.56      11.640       .091      45.11       5.905        .000        .000        .0     DEFI
   7     45.11      21.620       .181      64.51       6.947        .000       2.036        .0     DEFI
   8     64.51       5.260       .203      60.24      14.178        .000       9.327        .0     DEFI
   9     60.24       4.210       .358      55.97       9.396        .000       8.122        .0     DEFI
  10     55.97        .050       .539      47.43      14.708        .000       8.053        .0     DEFI
  11     47.43        .000       .608      34.62      19.284        .000      12.205        .0     DEFI
  12     34.62        .000       .468      27.81      12.079        .000       6.337        .0     DEFI
```

Table F.1 Simulation output file (continued)

```
 Year 80

Month Ini.Sto.      Inflow    Evapo.  Fin.Sto.     Demand  Own Demand     Release      Spil

  1     27.81       .490      .214     15.00      18.059        .000      13.089        .0    DEFI
  2     15.00       .900      .099     15.00       9.213        .000        .801        .0    DEFI
  3     15.00      1.110      .048     15.00       5.545        .000       1.062        .0    DEFI
  4     15.00     19.780      .071     34.71        .127        .000        .000        .0    DEFI
  5     34.71     52.846      .121     85.96       3.970        .000       1.475        .0    DEFI
  6     85.96     13.339      .152     90.23       5.905        .000       8.916        .0    OK
  7     90.23     41.100      .264    117.50       6.947        .000      13.566        .0    OK
  8    117.50      4.220      .281    105.75      14.178        .000      15.686        .0    OK
  9    105.75      1.770      .498     97.21       9.396        .000       9.814        .0    OK
 10     97.21       .870      .758     80.13      14.708        .000      17.196        .0    OK
 11     80.13       .000      .870     58.77      19.284        .000      20.484        .0    OK
 12     58.77       .000      .704     50.23      12.079        .000       7.837        .0    DEFI

 Year 81

Month Ini.Sto.      Inflow    Evapo.  Fin.Sto.     Demand  Own Demand     Release      Spil

  1     50.23       .210      .382     36.35      18.059        .000      13.706        .0    DEFI
  2     36.35       .210      .206     32.08       9.213        .000       4.275        .0    DEFI
  3     32.08       .930      .091     27.81       5.545        .000       5.110        .0    DEFI
  4     27.81      3.610      .075     27.81        .127        .000       3.535        .0    OK
  5     27.81      7.940      .073     33.09       3.970        .000       2.585        .0    DEFI
  6     33.09     14.750      .091     46.54       5.905        .000       1.215        .0    DEFI
  7     46.54     22.800      .185     67.24       6.947        .000       1.908        .0    DEFI
  8     67.24     16.470      .223     74.79      14.178        .000       8.700        .0    DEFI
  9     74.79      6.550      .418     71.15       9.396        .000       9.771        .0    OK
 10     71.15       .000      .612     54.07      14.708        .000      16.471        .0    OK
 11     54.07       .000      .673     40.62      19.284        .000      12.771        .0    DEFI
 12     40.62       .140      .529     32.08      12.079        .000       8.152        .0    DEFI

 Year 82

Month Ini.Sto.      Inflow    Evapo.  Fin.Sto.     Demand  Own Demand     Release      Spil

  1     32.08       .521      .254     19.27      18.059        .000      13.080        .0    DEFI
  2     19.27       .410      .112     15.00       9.213        .000       4.569        .0    DEFI
  3     15.00     16.850      .069     28.55       5.545        .000       3.235        .0    DEFI
  4     28.55     35.880      .109     61.33        .127        .000       2.983        .0    OK
  5     61.33     15.550      .131     75.48       3.970        .000       1.273        .0    DEFI
  6     75.48      3.670      .137     71.21       5.905        .000       7.803        .0    OK
  7     71.21      9.960      .220     75.48       6.947        .000       5.469        .0    DEFI
  8     75.48      3.800      .219     63.31      14.178        .000      15.754        .0    OK
  9     63.31      1.140      .371     59.04       9.396        .000       5.040        .0    DEFI
 10     59.04       .290      .560     50.49      14.708        .000       8.272        .0    DEFI
 11     50.49       .000      .642     37.68      19.284        .000      12.170        .0    DEFI
 12     37.68       .000      .495     29.14      12.079        .000       8.047        .0    DEFI

 Year 83

Month Ini.Sto.      Inflow    Evapo.  Fin.Sto.     Demand  Own Demand     Release      Spil

  1     29.14       .420      .226     16.33      18.059        .000      13.006        .0    DEFI
  2     16.33       .510      .103     15.00       9.213        .000       1.735        .0    DEFI
  3     15.00      5.950      .055     19.27       5.545        .000       1.624        .0    DEFI
  4     19.27     11.010      .071     30.21        .127        .000        .000        .0    DEFI
  5     30.21     15.460      .086     44.31       3.970        .000       1.278        .0    DEFI
  6     44.31     43.980      .126     83.85       5.905        .000       4.311        .0    DEFI
  7     83.85     53.292      .260    117.50       6.947        .000      19.381        .0    OK
  8    117.50      2.950      .281    104.69      14.178        .000      15.482        .0    OK
  9    104.69       .000      .496     96.15       9.396        .000       8.046        .0    DEFI
 10     96.15       .120      .752     79.06      14.708        .000      16.451        .0    OK
 11     79.06       .000      .861     57.71      19.284        .000      20.493        .0    OK
 12     57.71       .020      .695     49.17      12.079        .000       7.867        .0    DEFI
```

Table F.1 Simulation output file (continued)

```
 Year 84

Month Ini.Sto.      Inflow     Evapo.    Fin.Sto.      Demand  Own Demand     Release       Spil

  1     49.17        .350       .378       36.35      18.059        .000      12.784         .0    DEFI
  2     36.35        .300       .206       32.08       9.213        .000       4.365         .0    DEFI
  3     32.08        .670       .091       27.81       5.545        .000       4.850         .0    DEFI
  4     27.81      34.820       .107       59.48        .127        .000       3.041         .0    OK
  5     59.48      92.886       .153      117.50       3.970        .000      34.718         .0    OK
  6    117.50      34.289       .179      117.50       5.905        .000      34.110         .0    OK
  7    117.50       6.210       .282      114.36       6.947        .000       9.067         .0    OK
  8    114.36        .020       .277      101.55      14.178        .000      12.555         .0    DEFI
  9    101.55        .030       .489       93.01       9.396        .000       8.083         .0    DEFI
 10     93.01        .000       .736       75.92      14.708        .000      16.347         .0    OK
 11     75.92        .000       .833       54.57      19.284        .000      20.521         .0    OK
 12     54.57        .000       .668       46.03      12.079        .000       7.874         .0    DEFI

 Year 85

Month Ini.Sto.      Inflow     Evapo.    Fin.Sto.      Demand  Own Demand     Release       Spil

  1     46.03        .680       .357       33.22      18.059        .000      13.136         .0    DEFI
  2     33.22        .060       .190       28.94       9.213        .000       4.140         .0    DEFI
  3     28.94        .230       .083       24.67       5.545        .000       4.418         .0    DEFI
  4     24.67        .250       .068       24.67        .127        .000        .182         .0    OK
  5     24.67      10.450       .075       35.05       3.970        .000        .000         .0    DEFI
  6     35.05      16.370       .096       50.23       5.905        .000       1.091         .0    DEFI
  7     50.23      10.590       .180       58.77       6.947        .000       1.868         .0    DEFI
  8     58.77       1.530       .191       54.50      14.178        .000       5.610         .0    DEFI
  9     54.50       4.480       .335       50.23       9.396        .000       8.416         .0    DEFI
 10     50.23        .070       .499       41.69      14.708        .000       8.113         .0    DEFI
 11     41.69       1.280       .542       28.88      19.284        .000      13.550         .0    DEFI
 12     28.88        .150       .414       24.61      12.079        .000       4.006         .0    DEFI

 Year 86

Month Ini.Sto.      Inflow     Evapo.    Fin.Sto.      Demand  Own Demand     Release       Spil

  1     24.61       2.550       .204       16.07      18.059        .000      10.888         .0    DEFI
  2     16.07       1.810       .102       15.00       9.213        .000       2.773         .0    DEFI
  3     15.00       3.680       .051       16.89       5.545        .000       1.735         .0    DEFI
  4     16.89      18.000       .068       32.47        .127        .000       2.353         .0    OK
  5     32.47      47.498       .115       79.45       3.970        .000        .404         .0    DEFI
  6     79.45      98.279       .161      117.50       5.905        .000      60.069         .0    OK
  7    117.50      31.030       .286      117.50       6.947        .000      30.744         .0    OK
  8    117.50      67.179       .295      117.50      14.178        .000      66.884         .0    OK
  9    117.50       5.010       .536      113.23       9.396        .000       8.745         .0    DEFI
 10    113.23       3.690       .827      100.42      14.708        .000      15.675         .0    OK
 11    100.42        .010      1.010       79.06      19.284        .000      20.354         .0    OK
 12     79.06        .220       .854       66.25      12.079        .000      12.178         .0    OK

 Year 87

Month Ini.Sto.      Inflow     Evapo.    Fin.Sto.      Demand  Own Demand     Release       Spil

  1     66.25       1.120       .468       51.54      18.059        .000      15.366         .0    DEFI
  2     51.54       2.440       .269       47.26       9.213        .000       6.442         .0    DEFI
  3     47.26       1.980       .125       43.36       5.545        .000       5.762         .0    OK
  4     43.36       2.200       .107       43.36        .127        .000       2.093         .0    OK
  5     43.36       4.160       .097       43.36       3.970        .000       4.063         .0    OK
  6     43.36       5.790       .095       40.79       5.905        .000       8.258         .0    OK
  7     40.79      33.430       .183       70.69       6.947        .000       3.351         .0    DEFI
  8     70.69        .070       .212       61.98      14.178        .000       8.569         .0    DEFI
  9     61.98        .630       .366       57.71       9.396        .000       4.535         .0    DEFI
 10     57.71       1.220       .551       49.17      14.708        .000       9.211         .0    DEFI
 11     49.17        .110       .627       36.35      19.284        .000      12.295         .0    DEFI
 12     36.35        .940       .486       29.03      12.079        .000       7.774         .0    DEFI
```

Table F.1 **Simulation output file (continued)**

```
 Year 88

Month Ini.Sto.      Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release        Spil

  1     29.03       .730       .225     16.22      18.059        .000       13.317          .0    DEFI
  2     16.22      1.570       .103     15.00       9.213        .000        2.689          .0    DEFI
  3     15.00       .560       .048     15.00       5.545        .000         .512          .0    DEFI
  4     15.00      2.760       .043     15.00        .127        .000        2.717          .0    OK
  5     15.00      1.290       .039     15.00       3.970        .000        1.251          .0    DEFI
  6     15.00      3.260       .039     15.00       5.905        .000        3.221          .0    DEFI
  7     15.00      6.310       .067     17.38       6.947        .000        3.863          .0    DEFI
  8     17.38      2.950       .069     15.00      14.178        .000        5.261          .0    DEFI
  9     15.00      1.480       .118     15.00       9.396        .000        1.362          .0    DEFI
 10     15.00       .640       .192     15.00      14.708        .000         .448          .0    DEFI
 11     15.00       .690       .254     15.00      19.284        .000         .436          .0    DEFI
 12     15.00       .820       .242     15.00      12.079        .000         .577          .0    DEFI

 Year 89

Month Ini.Sto.      Inflow     Evapo.  Fin.Sto.      Demand  Own Demand      Release        Spil

  1     15.00      1.050       .153     15.00      18.059        .000         .897          .0    DEFI
  2     15.00      1.140       .099     15.00       9.213        .000        1.041          .0    DEFI
  3     15.00       .570       .048     15.00       5.545        .000         .521          .0    DEFI
  4     15.00      1.060       .043     15.00        .127        .000        1.017          .0    OK
  5     15.00      1.420       .039     15.00       3.970        .000        1.381          .0    DEFI
  6     15.00       .740       .039     15.00       5.905        .000         .701          .0    DEFI
  7     15.00       .680       .062     15.00       6.947        .000         .618          .0    DEFI
  8     15.00       .310       .064     15.00      14.178        .000         .246          .0    DEFI
  9     15.00      1.360       .118     15.00       9.396        .000        1.242          .0    DEFI
 10     15.00       .340       .192     15.00      14.708        .000         .148          .0    DEFI
 11     15.00       .150       .254     14.90      19.284        .000         .000          .0    DEFI
 12     14.90       .540       .242     15.00      12.079        .000         .194          .0    FAIL
```

Table F.1 Simulation output file (continued)

```
Downstream flows  -------         total reservoir releases reduced by the reservoir's own demand [10^6m^3]
 _                   year                            monthly release volumes (September - August)
|
 46     19.779     9.589     5.865   110.713    20.661    10.908     8.374    15.671     9.372    16.954    21.147     8.769
 47     12.772     7.978     4.796      .000     1.152     6.987     6.437     8.993     5.429     4.477    12.614     4.179
 48      8.718      .221     3.517     2.147     4.796    14.618    48.194    15.680     9.743    17.814    21.621     8.834
 49     14.289     4.923     3.560     1.924      .087     1.001     4.215    16.363     9.850    17.802    21.602     8.785
 50     13.844     5.505      .823     3.511      .000      .804     3.984    15.316     5.255     9.081    13.135     7.894
 51     13.409     7.331     2.000     2.382     3.568     3.588     7.596    16.282     9.731    17.751    21.400     8.713
 52     13.573     4.954     1.417      .795     6.637    11.440    12.141    15.688     9.655    17.160    21.672     9.514
 53     14.978     7.093     3.270      .000     2.899    60.984    15.074    15.924     9.631    17.692    21.609    13.061
 54     13.883     6.178     3.193     2.268      .000     5.181     6.374    15.723     9.626     9.091    13.103     8.588
 55     14.672     8.838     1.698     2.087      .697    14.418    11.424    15.671     9.692    16.308    21.720     8.800
 56     16.113     5.302     5.393     3.436     2.577     9.189     8.101    12.451     9.834    10.361    13.243     8.640
 57     13.082     7.337     3.397     3.429      .797     6.948     9.599    15.715     9.010    16.383    16.375     8.371
 58     12.700     5.544     1.713     2.752     3.169     8.137    12.347    55.667     9.495    15.834    21.224    12.005
 59     15.327     4.883     1.368     1.927      .000     7.373     8.156    12.370    11.886    16.993    16.569     8.264
 60     12.504     4.335     4.467     2.846      .501     7.929     6.568     4.546     5.536     4.754     8.584     4.126
 61       .047      .861     1.292     1.147     4.221      .000     7.973    15.077     5.149     4.506     2.496      .008
 62       .307     2.503     1.369      .000      .405     7.796     6.977    16.163     8.456    16.699    14.816     8.036
 63     15.002     6.137     4.969      .000     2.916     1.260     8.085    13.748     5.634     8.540    12.673     8.101
 64     13.841     2.219     1.733     2.181     2.602     3.736     5.564    15.248     9.835    15.215    16.124     8.486
 65     12.863     4.368     3.444     2.007     3.957     3.813     2.898     6.806     8.173     9.542    13.132     4.647
 66     12.293     3.316     1.749     2.843      .470      .000     8.049     6.594     5.993     5.170     8.670     4.661
 67      8.288      .581      .721     3.598     1.459     8.843     5.938     4.881     2.316     1.278      .166      .048
 68       .257      .541      .901     3.351      .478     9.082     6.746     7.910     2.828      .278      .046      .198
 69       .687     8.971     1.682     4.367      .000      .846     6.398    15.693     9.714    15.752    17.078     8.198
 70     12.610     4.498     4.284     1.941     2.499     5.351     4.742    17.354     9.785    16.367    20.907     7.909
 71     12.963     7.340     5.039     1.622      .056      .000     6.210     9.795     8.362     8.627    12.899     8.012
 72     13.109     4.499      .032      .427     1.077      .618    16.251    15.663     8.780    16.418    20.700     8.004
 73     15.032     6.725     4.180     2.545      .552     7.709     8.250    12.688     5.278     3.759      .000      .000
 74       .000      .777     1.850     2.766     3.149      .885     5.038    15.760     6.027    14.775    13.458     8.322
 75     13.039     4.319     1.736     2.967     3.646      .000     1.216     8.403     1.272     8.744    12.574     8.204
 76     13.806     5.997     3.557      .807     2.468     8.594     5.360     6.106     5.407     5.421     9.087     6.299
 77      4.203      .121     1.582     1.131     3.584      .000     8.339    13.977     7.445     6.580    10.545     6.106
 78     11.062      .171      .974     3.549     3.928     5.712     7.023     4.256     7.640     5.909    10.981     6.280
 79      4.294      .000     2.954     2.366     3.754      .000     2.036     9.327     8.122     8.053    12.205     6.337
 80     13.089      .801     1.062      .000     1.475     8.916    13.566    15.686     9.814    17.196    20.484     7.837
 81     13.706     4.275     5.110     3.535     2.585     1.215     1.908     8.700     9.771    16.471    12.771     8.152
 82     13.080     4.569     3.235     2.983     1.273     7.803     5.469    15.754     5.040     8.272    12.170     8.047
 83     13.006     1.735     1.624      .000     1.278     4.311    19.381    15.482     8.046    16.451    20.493     7.867
 84     12.784     4.365     4.850     3.041    34.718    34.110     9.067    12.555     8.083    16.347    20.521     7.874
 85     13.136     4.140     4.418      .182      .000     1.091     1.868     5.610     8.416     8.113    13.550     4.006
 86     10.888     2.773     1.735     2.353      .404    60.069    30.744    66.884     8.745    15.675    20.354    12.178
 87     15.366     6.442     5.762     2.093     4.063     8.258     3.351     8.569     4.535     9.211    12.295     7.774
 88     13.317     2.689      .512     2.717     1.251     3.221     3.863     5.261     1.362      .448      .436      .577
 89       .897     1.041      .521     1.017     1.381      .701      .618      .246     1.242      .148      .000      .194
```

Table F.1 Simulation output file (continued)

```
Total Reservoir Releases ———————        total reservoir releases (including spillage) [10^6m^3]
 ┌           year                                 monthly release volumes (September - August)
 │       ┌──────────────────────────────────────────────────────────────────────────────────────────┐
46    19.779     9.589     5.865   110.713    20.661    10.908     8.374    15.671     9.372    16.954    21.147     8.769
47    12.772     7.978     4.796      .000     1.152     6.987     6.437     8.993     5.429     4.477    12.614     4.179
48     8.718      .221     3.517     2.147     4.796    14.618    48.194    15.680     9.743    17.814    21.621     8.834
49    14.289     4.923     3.560     1.924      .087     1.001     4.215    16.363     9.850    17.802    21.602     8.785
50    13.844     5.505      .823     3.511      .000      .804     3.984    15.316     5.255     9.081    13.135     7.894
51    13.409     7.331     2.000     2.382     3.568     3.588     7.596    16.282     9.731    17.751    21.400     8.713
52    13.573     4.954     1.417      .795     6.637    11.440    12.141    15.688     9.655    17.160    21.672     9.514
53    14.978     7.093     3.270      .000     2.899    60.984    15.074    15.924     9.631    17.692    21.609    13.061
54    13.883     6.178     3.193     2.268      .000     5.181     6.374    15.723     9.626     9.091    13.103     8.588
55    14.672     8.838     1.698     2.087      .697    14.418    11.424    15.671     9.692    16.308    21.720     8.800
56    16.113     5.302     5.393     3.436     2.577     9.189     8.101    12.451     9.834    10.361    13.243     8.640
57    13.082     7.337     3.397     3.429      .797     6.948     9.599    15.715     9.010    16.383    16.375     8.371
58    12.700     5.544     1.713     2.752     3.169     8.137    12.347    55.667     9.495    15.834    21.224    12.005
59    15.327     4.883     1.368     1.927      .000     7.373     8.156    12.370    11.886    16.993    16.569     8.264
60    12.504     4.335     4.467     2.846      .501     7.929     6.568     4.546     5.536     4.754     8.584     4.126
61      .047      .861     1.292     1.147     4.221      .000     7.973    15.077     5.149     4.506     2.496      .008
62      .307     2.503     1.369      .000      .405     7.796     6.977    16.163     8.456    16.699    14.816     8.036
63    15.002     6.137     4.969      .000     2.916     1.260     8.085    13.748     5.634     8.540    12.673     8.101
64    13.841     2.219     1.733     2.181     2.602     3.736     5.564    15.248     9.835    15.215    16.124     8.486
65    12.863     4.368     3.444     2.007     3.957     3.813     2.898     6.806     8.173     9.542    13.132     4.647
66    12.293     3.316     1.749     2.843      .470      .000     8.049     6.594     5.993     5.170     8.670     4.661
67     8.288      .581      .721     3.598     1.459     8.843     5.938     4.881     2.316     1.278      .166      .048
68      .257      .541      .901     3.351      .478     9.082     6.746     7.910     2.828      .278      .046      .198
69      .687     8.971     1.682     4.367      .000      .846     6.398    15.693     9.714    15.752    17.078     8.198
70    12.610     4.498     4.284     1.941     2.499     5.351     4.742    17.354     9.785    16.367    20.907     7.909
71    12.963     7.340     5.039     1.622      .056      .000     6.210     9.795     8.362     8.627    12.899     8.012
72    13.109     4.499      .032      .427     1.077      .618    16.251    15.663     8.780    16.418    20.700     8.004
73    15.032     6.725     4.180     2.545      .552     7.709     8.250    12.688     5.278     3.759      .000      .000
74      .000      .777     1.850     2.766     3.149      .885     5.038    15.760     6.027    14.775    13.458     8.322
75    13.039     4.319     1.736     2.967     3.646      .000     1.216     8.403     1.272     8.744    12.574     8.204
76    13.806     5.997     3.557      .807     2.468     8.594     5.360     6.106     5.407     5.421     9.087     6.299
77     4.203      .121     1.582     1.131     3.584      .000     8.339    13.977     7.445     6.580    10.545     6.106
78    11.062      .171      .974     3.549     3.928     5.712     7.023     4.256     7.640     5.909    10.981     6.280
79     4.294      .000     2.954     2.366     3.754      .000     2.036     9.327     8.122     8.053    12.205     6.337
80    13.089      .801     1.062      .000     1.475     8.916    13.566    15.686     9.814    17.196    20.484     7.837
81    13.706     4.275     5.110     3.535     2.585     1.215     1.908     8.700     9.771    16.471    12.771     8.152
82    13.080     4.569     3.235     2.983     1.273     7.803     5.469    15.754     5.040     8.272    12.170     8.047
83    13.006     1.735     1.624      .000     1.278     4.311    19.381    15.482     8.046    16.451    20.493     7.867
84    12.784     4.365     4.850     3.041    34.718    34.110     9.067    12.555     8.083    16.347    20.521     7.874
85    13.136     4.140     4.418      .182      .000     1.091     1.868     5.610     8.416     8.113    13.550     4.006
86    10.888     2.773     1.735     2.353      .404    60.069    30.744    66.884     8.745    15.675    20.354    12.178
87    15.366     6.442     5.762     2.093     4.063     8.258     3.351     8.569     4.535     9.211    12.295     7.774
88    13.317     2.689      .512     2.717     1.251     3.221     3.863     5.261     1.362      .448      .436      .577
89      .897     1.041      .521     1.017     1.381      .701      .618      .246     1.242      .148      .000      .194
```

Table F.1 Simulation output file (continued)

```
 Month    Average      Average       Total
          shortage     Sto:deficit   deficit
 -----    --------     -----------   -------
   1        .000        85.790        85.790
   2        .000        92.278        92.278
   3        .000        91.882        91.882
   4        .000        84.879        84.879
   5        .000        71.237        71.237
   6        .000        56.847        56.847
   7        .000        46.736        46.736
   8        .000        44.851        44.851
   9        .000        49.303        49.303
  10        .000        57.035        57.035
  11        .000        69.260        69.260
  12        .000        79.483        79.483
        ---------    ----------    -----------
Annual      .000       829.579       829.579
```

reservoir shortages (summary) [$10^6 m^3$]

```
 Percentages of the months corresponding to different
 levels of demand fulfilment
 ---------------------------------------------------

 Considering each month of the year separately:-

 Month              1     2     3     4     5     6     7     8     9    10    11    12

 100%            100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 80% or more     100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 60% or more     100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 40% or more     100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 more than zero  100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
 zero               .0    .0    .0    .0    .0    .0    .0    .0    .0    .0    .0    .0

 Considering the whole time series:-

 100%            100.0
 80% or more     100.0
 60% or more     100.0
 40% or more     100.0
 more than zero  100.0
 zero               .0
```

own demand fulfilment

```
 Percentages of the months corresponding to different
 levels of active storage
 ---------------------------------------------------

 Considering each month of the year separately:-

 Month              1     2     3     4     5     6     7     8     9    10    11    12

 100%              2.3    .0    .0    .0   2.3   4.5  11.4  20.5   6.8    .0    .0    .0
 80% or more       2.3   2.3    .0    .0   2.3  11.4  18.2  29.5  31.8  18.2   2.3    .0
 60% or more       2.3   2.3   2.3   2.3   4.5  22.7  40.9  47.7  40.9  38.6  25.0   2.3
 40% or more       9.1   2.3   2.3   4.5  20.5  38.6  56.8  70.5  65.9  65.9  47.7  20.5
 more than zero   86.4  72.7  54.5  79.5  88.6  93.2  93.2  97.7  95.5  90.9  88.6  86.4
 zero             13.6  27.3  45.5  20.5  11.4   6.8   6.8   2.3   4.5   9.1  11.4  13.6

 Considering the whole time series:-

 100%              4.0
 80% or more       9.8
 60% or more      19.3
 40% or more      33.7
 more than zero   85.6
 zero             14.4
```

active storage volume

APPENDIX G

The DEFICIT program output files

Table G.1 New general demand file BH.DEM (output)

```
  TU     0.125     0.181     0.276     0.119     0.199     0.017     0.062     0.024     0.057     0.043     0.132     0.244
  MO     0.101     0.090     0.082     0.079     0.069     0.065     0.084     0.094     0.100     0.110     0.129     0.128
  NA     0.116     0.099     0.086     0.081     0.080     0.073     0.090     0.098     0.108     0.119     0.145     0.150
  SO     0.290     0.275     0.252     0.229     0.205     0.190     0.250     0.264     0.274     0.296     0.355     0.372
  SF     0.762     0.654     0.626     0.567     0.544     0.484     0.615     0.675     0.715     0.739     0.766     0.801
  JE     0.086     0.103     0.092     0.088     0.085     0.069     0.083     0.091     0.104     0.098     0.103     0.130
  BE     0.106     0.125     0.120     0.116     0.093     0.088     0.111     0.103     0.137     0.129     0.162     0.162
  MB     0.031     0.036     0.034     0.033     0.027     0.025     0.032     0.034     0.039     0.041     0.046     0.046
  TO     1.624     1.459     0.914     0.777     0.716     0.765     1.138     1.211     1.388     1.531     1.892     2.077
IAEA     2.881     2.131     1.391     0.000     0.000     0.235     2.287     4.820     7.488     9.350    10.001     7.519
 IBV     1.250     0.627     0.305     0.002     0.002     0.003     0.154     0.768     1.813     2.736     3.089     2.715
IMSC    12.784     5.420     2.258     0.606     0.505     2.020     6.586     7.675    13.132    21.709    26.502    25.250
 INE     0.204     0.079     0.060     0.000     0.000     0.000     0.070     0.119     0.224     0.487     0.654     0.585
 IBH     8.958     6.124     3.570     0.000     2.367     2.471     1.735     3.980     3.301     5.699     7.892     6.331
----------------------------------------------------------------
 DSS     0.368     0.101     0.018     0.020     0.135     0.052     0.059     0.081     0.018     0.043     0.220     0.556
 DKA     0.493     0.282     0.294     0.263     0.347     0.116     0.166     0.118     0.076     0.095     0.353     0.800
 DME     0.102     0.000     0.056     0.000     0.036     0.028     0.098     0.008     0.092     0.007     0.000     0.063
 DBH     9.326     6.225     3.588     0.020     2.502     2.523     1.794     4.062     3.319     5.742     8.113     6.887
 DBM     9.965     7.304     6.202     3.361     4.419     3.855     3.525     5.136     5.552     7.305     9.896     9.016
 DXX     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table G.2 Free downstream flow file BH.FDF (output)

```
46  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
47  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
48  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
49  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
50  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
51  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
52  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
53  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
54  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
55  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
56  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
57  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
58  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
59  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
60  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
61  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
62  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
63  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
64  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
65  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
66  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
67  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
68  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
69  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
70  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
71  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
72  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
73  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
74  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
75  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
76  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
77  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
78  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
79  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
80  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
81  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
82  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
83  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
84  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
85  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
86  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
87  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
88  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
89  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
```

Table G.3 Interim results file BH.INT (output)

```
PROGRAM DEFICIT

Flag: strictly following the policy

Simulation Data File       : C:\CU\BH.SIM
Demand Input File          : C:\CU\KA.DEM
Demand Allocation File     : C:\SY\BH.DAF
Demand Output File         : C:\CU\BH.DEM
Free Flow Output File      : C:\CU\BH.FDF
This file (debug file)     : C:\CU\BH.INT
Reservoir Deficit Name     : DBH
Downstream Reservoir Name  : DSS
Allocated Supply for
the Downstream Reservoir   : C:\CU\BH.DRS
Available Additional Supply
for the Downstream Reservoir: C:\CU\BH.DRE
The Capacity of the Water
Transfer Structure Towards
the Downstream Reservoir   : 1000000000000000.000

SIMULATION DATA
Note: The data is the Total Reservoir Release
        46  19.779   9.589   5.865 110.713  20.661  10.908   8.374  15.671   9.372  16.954  21.147   8.769
        47  12.772   7.978   4.796   0.000   1.152   6.987   6.437   8.993   5.429   4.477  12.614   4.179
        48   8.718   0.221   3.517   2.147   4.796  14.618  48.194  15.680   9.743  17.814  21.621   8.834
        49  14.289   4.923   3.560   1.924   0.087   1.001   4.215  16.363   9.850  17.802  21.602   8.785
        50  13.844   5.505   0.823   3.511   0.000   0.804   3.984  15.316   5.255   9.081  13.135   7.894
        51  13.409   7.331   2.000   2.382   3.568   3.588   7.596  16.282   9.731  17.751  21.400   8.713
        52  13.573   4.954   1.417   0.795   6.637  11.440  12.141  15.688   9.655  17.160  21.672   9.514
        53  14.978   7.093   3.270   0.000   2.899  60.984  15.074  15.924   9.631  17.692  21.609  13.061
        54  13.883   6.178   3.193   2.268   0.000   5.181   6.374  15.723   9.626   9.091  13.103   8.588
        55  14.672   8.838   1.698   2.087   0.697  14.418  11.424  15.671   9.692  16.308  21.720   8.800
        56  16.113   5.302   5.393   3.436   2.577   9.189   8.101  12.451   9.834  10.361  13.243   8.640
        57  13.082   7.337   3.397   3.429   0.797   6.948   9.599  15.715   9.010  16.383  16.375   8.371
        58  12.700   5.544   1.713   2.752   3.169   8.137  12.347  55.667   9.495  15.834  21.224  12.005
        59  15.327   4.883   1.368   1.927   0.000   7.373   8.156  12.370  11.886  16.993  16.569   8.264
        60  12.504   4.335   4.467   2.846   0.501   7.929   6.568   4.546   5.536   4.754   8.584   4.126
        61   0.047   0.861   1.292   1.147   4.221   0.000   7.973  15.077   5.149   4.506   2.496   0.008
        62   0.307   2.503   1.369   0.000   0.405   7.796   6.977  16.163   8.456  16.699  14.816   8.036
```

Table G.3 Interim results file (continued)

```
63    15.002     6.137     4.969     0.000     2.916     1.260     8.085    13.748     5.634     8.540    12.673     8.101
64    13.841     2.219     1.733     2.181     2.602     3.736     5.564    15.248     9.835    15.215    16.124     8.486
65    12.863     4.368     3.444     2.007     3.957     3.813     2.898     6.806     8.173     9.542    13.132     4.647
66    12.293     3.316     1.749     2.843     0.470     0.000     8.049     6.594     5.993     5.170     8.670     4.661
67     8.288     0.581     0.721     3.598     1.459     8.843     5.938     4.881     2.316     1.278     0.166     0.048
68     0.257     0.541     0.901     3.351     0.478     9.082     6.746     7.910     2.828     0.278     0.046     0.198
69     0.687     8.971     1.682     4.367     0.000     0.846     6.398    15.693     9.714    15.752    17.078     8.198
70    12.610     4.498     4.284     1.941     2.499     5.351     4.742    17.354     9.785    16.367    20.907     7.909
71    12.963     7.340     5.039     1.622     0.056     0.000     6.210     9.795     8.362     8.627    12.899     8.012
72    13.109     4.499     0.032     0.427     1.077     0.618    16.251    15.663     8.780    16.418    20.700     8.004
73    15.032     6.725     4.180     2.545     0.552     7.709     8.250    12.688     5.278     3.759     0.000     0.000
74     0.000     0.777     1.850     2.766     3.149     0.885     5.038    15.760     6.027    14.775    13.458     8.322
75    13.039     4.319     1.736     2.967     3.646     0.000     1.216     8.403     1.272     8.744    12.574     8.204
76    13.806     5.997     3.557     0.807     2.468     8.594     5.360     6.106     5.407     5.421     9.087     6.299
77     4.203     0.121     1.582     1.131     3.584     0.000     8.339    13.977     7.445     6.580    10.545     6.106
78    11.062     0.171     0.974     3.549     3.928     5.712     7.023     4.256     7.640     5.909    10.981     6.280
79     4.294     0.000     2.954     2.366     3.754     0.000     2.036     9.327     8.122     8.053    12.205     6.337
80    13.089     0.801     1.062     0.000     1.475     8.916    13.566    15.686     9.814    17.196    20.484     7.837
81    13.706     4.275     5.110     3.535     2.585     1.215     1.908     8.700     9.771    16.471    12.771     8.152
82    13.080     4.569     3.235     2.983     1.273     7.803     5.469    15.754     5.040     8.272    12.170     8.047
83    13.006     1.735     1.624     0.000     1.278     4.311    19.381    15.482     8.046    16.451    20.493     7.867
84    12.784     4.365     4.850     3.041    34.718    34.110     9.067    12.555     8.083    16.347    20.521     7.874
85    13.136     4.140     4.418     0.182     0.000     1.091     1.868     5.610     8.416     8.113    13.550     4.006
86    10.888     2.773     1.735     2.353     0.404    60.069    30.744    66.884     8.745    15.675    20.354    12.178
87    15.366     6.442     5.762     2.093     4.063     8.258     3.351     8.569     4.535     9.211    12.295     7.774
88    13.317     2.689     0.512     2.717     1.251     3.221     3.863     5.261     1.362     0.448     0.436     0.577
89     0.897     1.041     0.521     1.017     1.381     0.701     0.618     0.246     1.242     0.148     0.000     0.194

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DEMAND: IBH
      20.154    10.369     6.283     0.000     4.363     6.611     7.790    16.018    10.660    16.661    21.693    13.170

CALCULATION OF DEMAND AFTER ALLOCATION OF AVAILABLE FLOW
Average monthly useful flow
(only positive flow values reduce the demand)
Useful flow: If flow[y,m] > demand[m] :  Useful_Flow [y,m]= demand[m]
             If flow[y,m] <=demand[m] :  Useful_Flow [y,m]= Flow[y,m]
```

Table G.3 Interim results file (continued)

```
meeting the condition that:
        if a demand is a downstream reservoir deficit
        Useful_Flow [y,m] <= Water_Transfer_Capacity
         11.196     4.245     2.713     0.000     1.996     4.140     6.055    12.038     7.359    10.962    13.801     6.839

New_Demand[m] := Demand[m] - Average_Useful_Flow[m]  :
Note: Negative New_Demand values are set to zero
          8.958     6.124     3.570     0.000     2.367     2.471     1.735     3.980     3.301     5.699     7.892     6.331

Demand is not Downstream_Reservoir_Deficit
The remaining available flow is:
Available_Flow[y,m]:= Available_Flow[y,m] - Demand[m]
      46    -0.375    -0.780    -0.418   110.713    16.298     4.297     0.584    -0.347    -1.288     0.293    -0.546    -4.401
      47    -7.382    -2.391    -1.487     0.000    -3.211     0.376    -1.353    -7.025    -5.231   -12.184    -9.079    -8.991
      48   -11.436   -10.148    -2.766     2.147     0.433     8.007    40.404    -0.338    -0.917     1.153    -0.072    -4.336
      49    -5.865    -5.446    -2.723     1.924    -4.276    -5.610    -3.575     0.345    -0.810     1.141    -0.091    -4.385
      50    -6.310    -4.864    -5.460     3.511    -4.363    -5.807    -3.806    -0.702    -5.405    -7.580    -8.558    -5.276
      51    -6.745    -3.038    -4.283     2.382    -0.795    -3.023    -0.194     0.264    -0.929     1.090    -0.293    -4.457
      52    -6.581    -5.415    -4.866     0.795     2.274     4.829     4.351    -0.330    -1.005     0.499    -0.021    -3.656
      53    -5.176    -3.276    -3.013     0.000    -1.464    54.373     7.284    -0.094    -1.029     1.031    -0.084    -0.109
      54    -6.271    -4.191    -3.090     2.268    -4.363    -1.430    -1.416    -0.295    -1.034    -7.570    -8.590    -4.582
      55    -5.482    -1.531    -4.585     2.087    -3.666     7.807     3.634    -0.347    -0.968    -0.353     0.027    -4.370
      56    -4.041    -5.067    -0.890     3.436    -1.786     2.578     0.311    -3.567    -0.826    -6.300    -8.450    -4.530
      57    -7.072    -3.032    -2.886     3.429    -3.566     0.337     1.809    -0.303    -1.650    -0.278    -5.318    -4.799
      58    -7.454    -4.825    -4.570     2.752    -1.194     1.526     4.557    39.649    -1.165    -0.827    -0.469    -1.165
      59    -4.827    -5.486    -4.915     1.927    -4.363     0.762     0.366    -3.648     1.226     0.332    -5.124    -4.906
      60    -7.650    -6.034    -1.816     2.846    -3.862     1.318    -1.222   -11.472    -5.124   -11.907   -13.109    -9.044
      61   -20.107    -9.508    -4.991     1.147    -0.142    -6.611     0.183    -0.941    -5.511   -12.155   -19.197   -13.162
      62   -19.847    -7.866    -4.914     0.000    -3.958     1.185    -0.813     0.145    -2.204     0.038    -6.877    -5.134
      63    -5.152    -4.232    -1.314     0.000    -1.447    -5.351     0.295    -2.270    -5.026    -8.121    -9.020    -5.069
      64    -6.313    -8.150    -4.550     2.181    -1.761    -2.875    -2.226    -0.770    -0.825    -1.446    -5.569    -4.684
      65    -7.291    -6.001    -2.839     2.007    -0.406    -2.798    -4.892    -9.212    -2.487    -7.119    -8.561    -8.523
      66    -7.861    -7.053    -4.534     2.843    -3.893    -6.611     0.259    -9.424    -4.667   -11.491   -13.023    -8.509
      67   -11.866    -9.788    -5.562     3.598    -2.904     2.232    -1.852   -11.137    -8.344   -15.383   -21.527   -13.122
      68   -19.897    -9.828    -5.382     3.351    -3.885     2.471    -1.044    -8.108    -7.832   -16.383   -21.647   -12.972
      69   -19.467    -1.398    -4.601     4.367    -4.363    -5.765    -1.392    -0.325    -0.946    -0.909    -4.615    -4.972
      70    -7.544    -5.871    -1.999     1.941    -1.864    -1.260    -3.048     1.336    -0.875    -0.294    -0.786    -5.261
      71    -7.191    -3.029    -1.244     1.622    -4.307    -6.611    -1.580    -6.223    -2.298    -8.034    -8.794    -5.158
      72    -7.045    -5.870    -6.251     0.427    -3.286    -5.993     8.461    -0.355    -1.880    -0.243    -0.993    -5.166
      73    -5.122    -3.644    -2.103     2.545    -3.811     1.098     0.460    -3.330    -5.382   -12.902   -21.693   -13.170
      74   -20.154    -9.592    -4.433     2.766    -1.214    -5.726    -2.752    -0.258    -4.633    -1.886    -8.235    -4.848
```

Table G.3 Interim results file (continued)

```
     75   -7.115   -6.050   -4.547    2.967   -0.717   -6.611   -6.574   -7.615   -9.388   -7.917   -9.119   -4.966
     76   -6.348   -4.372   -2.726    0.807   -1.895    1.983   -2.430   -9.912   -5.253  -11.240  -12.606   -6.871
     77  -15.951  -10.248   -4.701    1.131   -0.779   -6.611    0.549   -2.041   -3.215  -10.081  -11.148   -7.064
     78   -9.092  -10.198   -5.309    3.549   -0.435   -0.899   -0.767  -11.762   -3.020  -10.752  -10.712   -6.890
     79  -15.860  -10.369   -3.329    2.366   -0.609   -6.611   -5.754   -6.691   -2.538   -8.608   -9.488   -6.833
     80   -7.065   -9.568   -5.221    0.000   -2.888    2.305    5.776   -0.332   -0.846    0.535   -1.209   -5.333
     81   -6.448   -6.094   -1.173    3.535   -1.778   -5.396   -5.882   -7.318   -0.889   -0.190   -8.922   -5.018
     82   -7.074   -5.800   -3.048    2.983   -3.090    1.192   -2.321   -0.264   -5.620   -8.389   -9.523   -5.123
     83   -7.148   -8.634   -4.659    0.000   -3.085   -2.300   11.591   -0.536   -2.614   -0.210   -1.200   -5.303
     84   -7.370   -6.004   -1.433    3.041   30.355   27.499    1.277   -3.463   -2.577   -0.314   -1.172   -5.296
     85   -7.018   -6.229   -1.865    0.182   -4.363   -5.520   -5.922  -10.408   -2.244   -8.548   -8.143   -9.164
     86   -9.266   -7.596   -4.548    2.353   -3.959   53.458   22.954   50.866   -1.915   -0.986   -1.339   -0.992
     87   -4.788   -3.927   -0.521    2.093   -0.300    1.647   -4.439   -7.449   -6.125   -7.450   -9.398   -5.396
     88   -6.837   -7.680   -5.771    2.717   -3.112   -3.390   -3.927  -10.757   -9.298  -16.213  -21.257  -12.593
     89  -19.257   -9.328   -5.762    1.017   -2.982   -5.910   -7.172  -15.772   -9.418  -16.513  -21.693  -12.976
----------------------


DEMAND: DSS
          0.368    0.101    0.018    0.144    0.149    0.099    0.104    0.094    0.018    0.053    0.221    0.556

CALCULATION OF DEMAND AFTER ALLOCATION OF AVAILABLE FLOW
Average monthly useful flow
(only positive flow values reduce the demand)
Useful flow: If flow[y,m] > demand[m]  :  Useful_Flow [y,m]= demand[m]
             If flow[y,m] <=demand[m]  :  Useful_Flow [y,m]= Flow[y,m]
meeting the condition that:
             if a demand is a downstream reservoir deficit
             Useful_Flow [y,m] <= Water_Transfer_Capacity
          0.000    0.000    0.000    0.124    0.014    0.047    0.045    0.013    0.000    0.011    0.001    0.000

New_Demand[m] := Demand[m] - Average_Useful_Flow[m]  :
Note: Negative New_Demand values are set to zero
          0.368    0.101    0.018    0.020    0.135    0.052    0.059    0.081    0.018    0.043    0.220    0.556

Demand is Downstream_Reservoir_Deficit:
If Available_Flow[y,m] <= 0
  Downstream_Reservoir_Supply[y,m]:= 0
  Downstream_Reservoir_Extra[y,m]:= 0
```

Table G.3 Interim results file (continued)

```
  Free_Flow[y,m]:= 0
  If Demand[m] <= Water_Transfer_Capacity
    Flow[y,m]:= Flow[y,m] - Demand[m]
  If Demand[m] > Water_Transfer_Capacity
    Flow[y,m]:= Flow[y,m] - Water_Transfer_Capacity
If 0 < Available_Flow[y,m] <= Demand[m] <= Water_Transfer_Capacity
  Downstream_Reservoir_Supply[y,m]:= Available_Flow[y,m]
  Downstream_Reservoir_Extra[y,m]:= 0
  Free_Flow[y,m]:= 0
  Flow[y,m]:= Flow[y,m] - Demand[m]
If 0 < Available_Flow[y,m] <= Water_Transfer_Capacity <= Demand[m]
  Downstream_Reservoir_Supply[y,m]:= Available_Flow[y,m]
  Downstream_Reservoir_Extra[y,m]:= 0
  Free_Flow[y,m]:= 0
  Flow[y,m]:= Flow[y,m] - Water_Transfer_Capacity
If Demand[m] <= Available_Flow[y,m] <= Water_Transfer_Capacity
  Downstream_Reservoir_Supply[y,m]:= Demand[m]
  Downstream_Reservoir_Extra[y,m]:= Available_Flow[y,m] - Demand[m]
  Free_Flow[y,m]:= 0
  Flow[y,m]:= Flow[y,m] - Demand[m]
If Demand[m] <= Water_Transfer_Capacity <= Available_Flow[y,m]
  Downstream_Reservoir_Supply[y,m]:= Demand[m]
  Downstream_Reservoir_Extra[y,m]:= Water_Transfer_Capacity - Demand[m]
  Free_Flow[y,m]:= Available_Flow[y,m] - Water_Transfer_Capacity
  Flow[y,m]:= Flow[y,m] - Demand[m]
If Water_Transfer_Capacity <= Available_Flow[y,m] <= Demand[m]
  Downstream_Reservoir_Supply[y,m]:= Water_Transfer_Capacity
  Downstream_Reservoir_Extra[y,m]:= 0
  Free_Flow[y,m]:= Available_Flow[y,m] - Water_Transfer_Capacity
  Flow[y,m]:= Flow[y,m] - Water_Transfer_Capacity
If Water_Transfer_Capacity <= Demand[m] <= Available_Flow[y,m]
  Downstream_Reservoir_Supply[y,m]:= Water_Transfer_Capacity
  Downstream_Reservoir_Extra[y,m]:= 0
  Free_Flow[y,m]:= Available_Flow[y,m] - Water_Transfer_Capacity
  Flow[y,m]:= Flow[y,m] - Water_Transfer_Capacity

Downstream_Reservoir_Supply
     46   0.000    0.000    0.000    0.144    0.149    0.099    0.104    0.000    0.000    0.053    0.000    0.000
     47   0.000    0.000    0.000    0.000    0.000    0.099    0.000    0.000    0.000    0.000    0.000    0.000
```

Table G.3 Interim results file (continued)

48	0.000	0.000	0.000	0.144	0.149	0.099	0.104	0.000	0.000	0.053	0.000	0.000
49	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.094	0.000	0.053	0.000	0.000
50	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
51	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.094	0.000	0.053	0.000	0.000
52	0.000	0.000	0.000	0.144	0.149	0.099	0.104	0.000	0.000	0.053	0.000	0.000
53	0.000	0.000	0.000	0.000	0.000	0.099	0.104	0.000	0.000	0.053	0.000	0.000
54	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
55	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.000	0.000	0.000	0.027	0.000
56	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.000	0.000	0.000	0.000	0.000
57	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.000	0.000	0.000	0.000	0.000
58	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.094	0.000	0.000	0.000	0.000
59	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.000	0.018	0.053	0.000	0.000
60	0.000	0.000	0.000	0.144	0.000	0.099	0.000	0.000	0.000	0.000	0.000	0.000
61	0.000	0.000	0.000	0.144	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
62	0.000	0.000	0.000	0.000	0.000	0.099	0.000	0.094	0.000	0.038	0.000	0.000
63	0.000	0.000	0.000	0.000	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
64	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
65	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
66	0.000	0.000	0.000	0.144	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
67	0.000	0.000	0.000	0.144	0.000	0.099	0.000	0.000	0.000	0.000	0.000	0.000
68	0.000	0.000	0.000	0.144	0.000	0.099	0.000	0.000	0.000	0.000	0.000	0.000
69	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.094	0.000	0.000	0.000	0.000
71	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
72	0.000	0.000	0.000	0.144	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
73	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.000	0.000	0.000	0.000	0.000
74	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
76	0.000	0.000	0.000	0.144	0.000	0.099	0.000	0.000	0.000	0.000	0.000	0.000
77	0.000	0.000	0.000	0.144	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
78	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
79	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	0.000	0.099	0.104	0.000	0.000	0.053	0.000	0.000
81	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
82	0.000	0.000	0.000	0.144	0.000	0.099	0.000	0.000	0.000	0.000	0.000	0.000
83	0.000	0.000	0.000	0.000	0.000	0.000	0.104	0.000	0.000	0.000	0.000	0.000
84	0.000	0.000	0.000	0.144	0.149	0.099	0.104	0.000	0.000	0.000	0.000	0.000
85	0.000	0.000	0.000	0.144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	0.000	0.000	0.000	0.144	0.000	0.099	0.104	0.094	0.000	0.000	0.000	0.000

Table G.3 Interim results file (continued)

```
      87    0.000     0.000     0.000     0.144     0.000     0.099     0.000     0.000     0.000     0.000     0.000     0.000
      88    0.000     0.000     0.000     0.144     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      89    0.000     0.000     0.000     0.144     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000

Downstream_Reservoir_Extra_Inflow
      46    0.000     0.000     0.000   110.569    16.149     4.198     0.480     0.000     0.000     0.240     0.000     0.000
      47    0.000     0.000     0.000     0.000     0.000     0.277     0.000     0.000     0.000     0.000     0.000     0.000
      48    0.000     0.000     0.000     2.003     0.284     7.908    40.300     0.000     0.000     1.100     0.000     0.000
      49    0.000     0.000     0.000     1.780     0.000     0.000     0.000     0.251     0.000     1.088     0.000     0.000
      50    0.000     0.000     0.000     3.367     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      51    0.000     0.000     0.000     2.238     0.000     0.000     0.000     0.170     0.000     1.037     0.000     0.000
      52    0.000     0.000     0.000     0.651     2.125     4.730     4.247     0.000     0.000     0.446     0.000     0.000
      53    0.000     0.000     0.000     0.000     0.000    54.274     7.180     0.000     0.000     0.978     0.000     0.000
      54    0.000     0.000     0.000     2.124     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      55    0.000     0.000     0.000     1.943     0.000     7.708     3.530     0.000     0.000     0.000     0.000     0.000
      56    0.000     0.000     0.000     3.292     0.000     2.479     0.207     0.000     0.000     0.000     0.000     0.000
      57    0.000     0.000     0.000     3.285     0.000     0.238     1.705     0.000     0.000     0.000     0.000     0.000
      58    0.000     0.000     0.000     2.608     0.000     1.427     4.453    39.555     0.000     0.000     0.000     0.000
      59    0.000     0.000     0.000     1.783     0.000     0.663     0.262     0.000     1.208     0.279     0.000     0.000
      60    0.000     0.000     0.000     2.702     0.000     1.219     0.000     0.000     0.000     0.000     0.000     0.000
      61    0.000     0.000     0.000     1.003     0.000     0.000     0.079     0.000     0.000     0.000     0.000     0.000
      62    0.000     0.000     0.000     0.000     0.000     1.086     0.000     0.051     0.000     0.000     0.000     0.000
      63    0.000     0.000     0.000     0.000     0.000     0.000     0.191     0.000     0.000     0.000     0.000     0.000
      64    0.000     0.000     0.000     2.037     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      65    0.000     0.000     0.000     1.863     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      66    0.000     0.000     0.000     2.699     0.000     0.000     0.155     0.000     0.000     0.000     0.000     0.000
      67    0.000     0.000     0.000     3.454     0.000     2.133     0.000     0.000     0.000     0.000     0.000     0.000
      68    0.000     0.000     0.000     3.207     0.000     2.372     0.000     0.000     0.000     0.000     0.000     0.000
      69    0.000     0.000     0.000     4.223     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      70    0.000     0.000     0.000     1.797     0.000     0.000     0.000     1.242     0.000     0.000     0.000     0.000
      71    0.000     0.000     0.000     1.478     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      72    0.000     0.000     0.000     0.283     0.000     0.000     8.357     0.000     0.000     0.000     0.000     0.000
      73    0.000     0.000     0.000     2.401     0.000     0.999     0.356     0.000     0.000     0.000     0.000     0.000
      74    0.000     0.000     0.000     2.622     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      75    0.000     0.000     0.000     2.823     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      76    0.000     0.000     0.000     0.663     0.000     1.884     0.000     0.000     0.000     0.000     0.000     0.000
      77    0.000     0.000     0.000     0.987     0.000     0.000     0.445     0.000     0.000     0.000     0.000     0.000
      78    0.000     0.000     0.000     3.405     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
      79    0.000     0.000     0.000     2.222     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table G.3 Interim results file (continued)

```
      80   0.000   0.000   0.000   0.000   0.000   2.206   5.672   0.000   0.000   0.482   0.000   0.000
      81   0.000   0.000   0.000   3.391   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      82   0.000   0.000   0.000   2.839   0.000   1.093   0.000   0.000   0.000   0.000   0.000   0.000
      83   0.000   0.000   0.000   0.000   0.000   0.000  11.487   0.000   0.000   0.000   0.000   0.000
      84   0.000   0.000   0.000   2.897  30.206  27.400   1.173   0.000   0.000   0.000   0.000   0.000
      85   0.000   0.000   0.000   0.038   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      86   0.000   0.000   0.000   2.209   0.000  53.359  22.850  50.772   0.000   0.000   0.000   0.000
      87   0.000   0.000   0.000   1.949   0.000   1.548   0.000   0.000   0.000   0.000   0.000   0.000
      88   0.000   0.000   0.000   2.573   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      89   0.000   0.000   0.000   0.873   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000

Downstream_Free_Flows
      46   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      47   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      48   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      49   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      50   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      51   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      52   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      53   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      54   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      55   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      56   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      57   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      58   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      59   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      60   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      61   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      62   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      63   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      64   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      65   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      66   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      67   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      68   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      69   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      70   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      71   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      72   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
```

Table G.3 Interim results file (continued)

```
      73   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      74   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      75   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      76   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      77   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      78   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      79   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      80   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      81   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      82   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      83   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      84   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      85   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      86   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      87   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      88   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
      89   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
----------------------

AVERAGE SUPPLY DEFICIT OF THE RESERVOIR
Average_Supply_Deficit[m]:= Flow[y,m] (only if < 0) / Number_Of_Years in data
          -9.326  -6.225  -3.588  -0.020  -2.502  -2.523  -1.794  -4.062  -3.319  -5.742  -8.113  -6.887
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```

Table G.3 Interim results file (continued)

```
THE OLD DEMAND FILE  C:\CU\KA.DEM  :
  TU     0.125      0.181      0.276      0.119      0.199      0.017      0.062      0.024      0.057      0.043      0.132      0.244
  MO     0.101      0.090      0.082      0.079      0.069      0.065      0.084      0.094      0.100      0.110      0.129      0.128
  NA     0.116      0.099      0.086      0.081      0.080      0.073      0.090      0.098      0.108      0.119      0.145      0.150
  SO     0.290      0.275      0.252      0.229      0.205      0.190      0.250      0.264      0.274      0.296      0.355      0.372
  SF     0.762      0.654      0.626      0.567      0.544      0.484      0.615      0.675      0.715      0.739      0.766      0.801
  JE     0.086      0.103      0.092      0.088      0.085      0.069      0.083      0.091      0.104      0.098      0.103      0.130
  BE     0.106      0.125      0.120      0.116      0.093      0.088      0.111      0.103      0.137      0.129      0.162      0.162
  MB     0.031      0.036      0.034      0.033      0.027      0.025      0.032      0.034      0.039      0.041      0.046      0.046
  TO     1.624      1.459      0.914      0.777      0.716      0.765      1.138      1.211      1.388      1.531      1.892      2.077
IAEA     2.881      2.131      1.391      0.000      0.000      0.235      2.287      4.820      7.488      9.350     10.001      7.519
 IBV     1.250      0.627      0.305      0.002      0.002      0.003      0.154      0.768      1.813      2.736      3.089      2.715
IMSC    12.784      5.420      2.258      0.606      0.505      2.020      6.586      7.675     13.132     21.709     26.502     25.250
 INE     0.204      0.079      0.060      0.000      0.000      0.000      0.070      0.119      0.224      0.487      0.654      0.585
 IBH    20.154     10.369      6.283      0.000      4.363      6.611      7.790     16.018     10.660     16.661     21.693     13.170
--------------------------------------------------------------
 DSS     0.368      0.101      0.018      0.144      0.149      0.099      0.104      0.094      0.018      0.053      0.221      0.556
 DKA     0.493      0.282      0.294      0.263      0.347      0.116      0.166      0.118      0.076      0.095      0.353      0.800
 DME     0.102      0.000      0.056      0.000      0.036      0.028      0.098      0.008      0.092      0.007      0.000      0.063
 DBH     8.706      5.844      3.585      0.000      2.339      2.131      1.621      3.676      3.304      5.691      7.968      6.681
 DBM     9.965      7.304      6.202      3.361      4.419      3.855      3.525      5.136      5.552      7.305      9.896      9.016
 DXX     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000

THE NEW DEMAND FILE C:\CU\BH.DEM  :
  TU     0.125      0.181      0.276      0.119      0.199      0.017      0.062      0.024      0.057      0.043      0.132      0.244
  MO     0.101      0.090      0.082      0.079      0.069      0.065      0.084      0.094      0.100      0.110      0.129      0.128
  NA     0.116      0.099      0.086      0.081      0.080      0.073      0.090      0.098      0.108      0.119      0.145      0.150
  SO     0.290      0.275      0.252      0.229      0.205      0.190      0.250      0.264      0.274      0.296      0.355      0.372
  SF     0.762      0.654      0.626      0.567      0.544      0.484      0.615      0.675      0.715      0.739      0.766      0.801
  JE     0.086      0.103      0.092      0.088      0.085      0.069      0.083      0.091      0.104      0.098      0.103      0.130
  BE     0.106      0.125      0.120      0.116      0.093      0.088      0.111      0.103      0.137      0.129      0.162      0.162
  MB     0.031      0.036      0.034      0.033      0.027      0.025      0.032      0.034      0.039      0.041      0.046      0.046
  TO     1.624      1.459      0.914      0.777      0.716      0.765      1.138      1.211      1.388      1.531      1.892      2.077
IAEA     2.881      2.131      1.391      0.000      0.000      0.235      2.287      4.820      7.488      9.350     10.001      7.519
 IBV     1.250      0.627      0.305      0.002      0.002      0.003      0.154      0.768      1.813      2.736      3.089      2.715
IMSC    12.784      5.420      2.258      0.606      0.505      2.020      6.586      7.675     13.132     21.709     26.502     25.250
 INE     0.204      0.079      0.060      0.000      0.000      0.000      0.070      0.119      0.224      0.487      0.654      0.585
 IBH     8.958      6.124      3.570      0.000      2.367      2.471      1.735      3.980      3.301      5.699      7.892      6.331
--------------------------------------------------------------
 DSS     0.368      0.101      0.018      0.020      0.135      0.052      0.059      0.081      0.018      0.043      0.220      0.556
 DKA     0.493      0.282      0.294      0.263      0.347      0.116      0.166      0.118      0.076      0.095      0.353      0.800
 DME     0.102      0.000      0.056      0.000      0.036      0.028      0.098      0.008      0.092      0.007      0.000      0.063
 DBH     9.326      6.225      3.588      0.020      2.502      2.523      1.794      4.062      3.319      5.742      8.113      6.887
 DBM     9.965      7.304      6.202      3.361      4.419      3.855      3.525      5.136      5.552      7.305      9.896      9.016
 DXX     0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
```

Table G.4 Downstream reservoir supply file BH.DRS (output)

```
46   0.000  0.000  0.000  0.144  0.149  0.099  0.104  0.000  0.000  0.053  0.000  0.000
47   0.000  0.000  0.000  0.000  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
48   0.000  0.000  0.000  0.144  0.149  0.099  0.104  0.000  0.000  0.053  0.000  0.000
49   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.094  0.000  0.053  0.000  0.000
50   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
51   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.094  0.000  0.053  0.000  0.000
52   0.000  0.000  0.000  0.144  0.149  0.099  0.104  0.000  0.000  0.053  0.000  0.000
53   0.000  0.000  0.000  0.000  0.000  0.099  0.104  0.000  0.000  0.053  0.000  0.000
54   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
55   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.000  0.000  0.000  0.027  0.000
56   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.000  0.000  0.000  0.000  0.000
57   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.000  0.000  0.000  0.000  0.000
58   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.094  0.000  0.000  0.000  0.000
59   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.000  0.018  0.053  0.000  0.000
60   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
61   0.000  0.000  0.000  0.144  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
62   0.000  0.000  0.000  0.000  0.000  0.099  0.000  0.094  0.000  0.038  0.000  0.000
63   0.000  0.000  0.000  0.000  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
64   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
65   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
66   0.000  0.000  0.000  0.144  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
67   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
68   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
69   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
70   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.094  0.000  0.000  0.000  0.000
71   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
72   0.000  0.000  0.000  0.144  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
73   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.000  0.000  0.000  0.000  0.000
74   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
75   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
76   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
77   0.000  0.000  0.000  0.144  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
78   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
79   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
80   0.000  0.000  0.000  0.000  0.000  0.099  0.104  0.000  0.000  0.053  0.000  0.000
81   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
82   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
83   0.000  0.000  0.000  0.000  0.000  0.000  0.104  0.000  0.000  0.000  0.000  0.000
84   0.000  0.000  0.000  0.144  0.149  0.099  0.104  0.000  0.000  0.000  0.000  0.000
85   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
86   0.000  0.000  0.000  0.144  0.000  0.099  0.104  0.094  0.000  0.000  0.000  0.000
87   0.000  0.000  0.000  0.144  0.000  0.099  0.000  0.000  0.000  0.000  0.000  0.000
88   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
89   0.000  0.000  0.000  0.144  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
```

Table G.5 Downstream reservoir extra supply file BH.DRE (output)

```
46    0.000    0.000    0.000  110.569   16.149    4.198    0.480    0.000    0.000    0.240    0.000    0.000
47    0.000    0.000    0.000    0.000    0.000    0.277    0.000    0.000    0.000    0.000    0.000    0.000
48    0.000    0.000    0.000    2.003    0.284    7.908   40.300    0.000    0.000    1.100    0.000    0.000
49    0.000    0.000    0.000    1.780    0.000    0.000    0.000    0.251    0.000    1.088    0.000    0.000
50    0.000    0.000    0.000    3.367    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
51    0.000    0.000    0.000    2.238    0.000    0.000    0.000    0.170    0.000    1.037    0.000    0.000
52    0.000    0.000    0.000    0.651    2.125    4.730    4.247    0.000    0.000    0.446    0.000    0.000
53    0.000    0.000    0.000    0.000    0.000   54.274    7.180    0.000    0.000    0.978    0.000    0.000
54    0.000    0.000    0.000    2.124    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
55    0.000    0.000    0.000    1.943    0.000    7.708    3.530    0.000    0.000    0.000    0.000    0.000
56    0.000    0.000    0.000    3.292    0.000    2.479    0.207    0.000    0.000    0.000    0.000    0.000
57    0.000    0.000    0.000    3.285    0.000    0.238    1.705    0.000    0.000    0.000    0.000    0.000
58    0.000    0.000    0.000    2.608    0.000    1.427    4.453   39.555    0.000    0.000    0.000    0.000
59    0.000    0.000    0.000    1.783    0.000    0.663    0.262    0.000    1.208    0.279    0.000    0.000
60    0.000    0.000    0.000    2.702    0.000    1.219    0.000    0.000    0.000    0.000    0.000    0.000
61    0.000    0.000    0.000    1.003    0.000    0.000    0.079    0.000    0.000    0.000    0.000    0.000
62    0.000    0.000    0.000    0.000    0.000    1.086    0.000    0.051    0.000    0.000    0.000    0.000
63    0.000    0.000    0.000    0.000    0.000    0.000    0.191    0.000    0.000    0.000    0.000    0.000
64    0.000    0.000    0.000    2.037    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
65    0.000    0.000    0.000    1.863    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
66    0.000    0.000    0.000    2.699    0.000    0.000    0.155    0.000    0.000    0.000    0.000    0.000
67    0.000    0.000    0.000    3.454    0.000    2.133    0.000    0.000    0.000    0.000    0.000    0.000
68    0.000    0.000    0.000    3.207    0.000    2.372    0.000    0.000    0.000    0.000    0.000    0.000
69    0.000    0.000    0.000    4.223    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
70    0.000    0.000    0.000    1.797    0.000    0.000    0.000    1.242    0.000    0.000    0.000    0.000
71    0.000    0.000    0.000    1.478    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
72    0.000    0.000    0.000    0.283    0.000    0.000    8.357    0.000    0.000    0.000    0.000    0.000
73    0.000    0.000    0.000    2.401    0.000    0.999    0.356    0.000    0.000    0.000    0.000    0.000
74    0.000    0.000    0.000    2.622    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
75    0.000    0.000    0.000    2.823    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
76    0.000    0.000    0.000    0.663    0.000    1.884    0.000    0.000    0.000    0.000    0.000    0.000
77    0.000    0.000    0.000    0.987    0.000    0.000    0.445    0.000    0.000    0.000    0.000    0.000
78    0.000    0.000    0.000    3.405    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
79    0.000    0.000    0.000    2.222    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
80    0.000    0.000    0.000    0.000    0.000    2.206    5.672    0.000    0.000    0.482    0.000    0.000
81    0.000    0.000    0.000    3.391    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
82    0.000    0.000    0.000    2.839    0.000    1.093    0.000    0.000    0.000    0.000    0.000    0.000
83    0.000    0.000    0.000    0.000    0.000    0.000   11.487    0.000    0.000    0.000    0.000    0.000
84    0.000    0.000    0.000    2.897   30.206   27.400    1.173    0.000    0.000    0.000    0.000    0.000
85    0.000    0.000    0.000    0.038    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
86    0.000    0.000    0.000    2.209    0.000   53.359   22.850   50.772    0.000    0.000    0.000    0.000
87    0.000    0.000    0.000    1.949    0.000    1.548    0.000    0.000    0.000    0.000    0.000    0.000
88    0.000    0.000    0.000    2.573    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
89    0.000    0.000    0.000    0.873    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

APPENDIX H

The NEWDEM program input and output files

Table H.1 General demand file ORIG.DEM (input)

```
  TU   4.634   4.538   4.305   4.181   4.529   4.048   4.515   4.691   4.977   5.243   5.743   5.738
  MO   0.101   0.090   0.082   0.079   0.069   0.065   0.084   0.094   0.100   0.110   0.129   0.128
  NA   0.116   0.099   0.086   0.081   0.080   0.073   0.090   0.098   0.108   0.119   0.145   0.150
  SO   0.290   0.275   0.252   0.229   0.205   0.190   0.250   0.264   0.274   0.296   0.355   0.372
  SF   0.762   0.654   0.626   0.567   0.544   0.484   0.615   0.675   0.715   0.739   0.766   0.801
  JE   0.108   0.103   0.092   0.090   0.096   0.084   0.096   0.099   0.104   0.106   0.105   0.130
  BE   0.136   0.125   0.120   0.119   0.105   0.108   0.128   0.128   0.137   0.147   0.166   0.162
  MB   0.039   0.036   0.034   0.034   0.030   0.031   0.037   0.037   0.039   0.042   0.047   0.046
  TO   1.624   1.459   0.914   0.777   0.716   0.765   1.138   1.211   1.388   1.531   1.892   2.077
IAEA   2.881   2.131   1.391   0.000   0.000   0.235   2.287   4.820   7.488   9.350  10.001   7.519
 IBV   1.250   0.627   0.305   0.002   0.002   0.003   0.154   0.768   1.813   2.736   3.089   2.715
IMSC  12.784   5.420   2.258   0.606   0.505   2.020   6.586   7.675  13.132  21.709  26.502  25.250
 INE   0.204   0.079   0.060   0.000   0.000   0.000   0.070   0.119   0.224   0.487   0.654   0.585
 IBH  20.154  10.369   6.283   0.000   4.363   6.611   7.790  16.018  10.660  16.661  21.693  13.170
-------------------------------------------------------------------------------------------------------
 DSS   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DKA   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DME   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DBH   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DBM   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
 DXX   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
```

Table H.2 New general demand file SS.DEM (input)

```
  TU  0.000  0.000  0.000  0.033  0.027  0.002  0.011  0.001  0.000  0.000  0.000  0.000
  MO  0.000  0.002  0.000  0.023  0.011  0.009  0.015  0.002  0.000  0.000  0.000  0.000
  NA  0.000  0.002  0.000  0.024  0.011  0.010  0.016  0.002  0.000  0.000  0.000  0.000
  SO  0.000  0.006  0.000  0.072  0.033  0.026  0.045  0.006  0.000  0.000  0.000  0.000
  SF  0.004  0.015  0.008  0.180  0.101  0.068  0.112  0.029  0.000  0.000  0.000  0.000
  JE  0.086  0.103  0.092  0.088  0.085  0.069  0.083  0.091  0.104  0.098  0.103  0.130
  BE  0.106  0.125  0.120  0.116  0.093  0.088  0.111  0.103  0.137  0.129  0.162  0.162
  MB  0.031  0.036  0.034  0.033  0.027  0.025  0.032  0.034  0.039  0.041  0.046  0.046
  TO  0.000  0.012  0.000  0.230  0.098  0.104  0.207  0.028  0.000  0.000  0.000  0.000
IAEA  0.000  0.000  0.000  0.000  0.000  0.032  0.340  0.110  0.000  0.000  0.000  0.000
 IBV  0.028  0.014  0.007  0.001  0.000  0.000  0.028  0.035  0.000  0.000  0.000  0.000
IMSC  1.222  0.230  0.113  0.193  0.105  0.392  1.518  0.607  0.044  0.891  0.000  1.430
 INE  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
 IBH  0.114  0.000  0.055  0.000  0.027  0.028  0.088  0.010  0.086  0.007  0.000  0.055
-----------------------------------------------------
 DSS  1.254  0.282  0.128  0.757  0.386  0.644  2.293  0.819  0.044  0.891  0.000  1.430
 DKA  0.493  0.282  0.294  0.263  0.347  0.116  0.166  0.118  0.076  0.095  0.353  0.800
 DME  0.131  0.000  0.057  0.001  0.033  0.030  0.095  0.012  0.087  0.008  0.000  0.068
 DBH  9.326  6.225  3.588  0.020  2.502  2.523  1.794  4.062  3.319  5.742  8.113  6.887
 DBM  9.965  7.304  6.202  3.361  4.419  3.855  3.525  5.136  5.552  7.305  9.896  9.016
 DXX  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
```

Table H.3 New general demand file NEW.DEM (output)

```
  TU    4.634    4.538    4.305    4.181    4.529    4.048    4.515    4.691    4.977    5.243    5.743    5.738
  MO    0.101    0.090    0.082    0.079    0.069    0.065    0.084    0.094    0.100    0.110    0.129    0.128
  NA    0.116    0.099    0.086    0.081    0.080    0.073    0.090    0.098    0.108    0.119    0.145    0.150
  SO    0.290    0.275    0.252    0.229    0.205    0.190    0.250    0.264    0.274    0.296    0.355    0.372
  SF    0.762    0.654    0.626    0.567    0.544    0.484    0.615    0.675    0.715    0.739    0.766    0.801
  JE    0.108    0.103    0.092    0.090    0.096    0.084    0.096    0.099    0.104    0.106    0.105    0.130
  BE    0.136    0.125    0.120    0.119    0.105    0.108    0.128    0.128    0.137    0.147    0.166    0.162
  MB    0.039    0.036    0.034    0.034    0.030    0.031    0.037    0.037    0.039    0.042    0.047    0.046
  TO    1.624    1.459    0.914    0.777    0.716    0.765    1.138    1.211    1.388    1.531    1.892    2.077
IAEA    2.881    2.131    1.391    0.000    0.000    0.235    2.287    4.820    7.488    9.350   10.001    7.519
 IBV    1.250    0.627    0.305    0.002    0.002    0.003    0.154    0.768    1.813    2.736    3.089    2.715
IMSC   12.784    5.420    2.258    0.606    0.505    2.020    6.586    7.675   13.132   21.709   26.502   25.250
 INE    0.204    0.079    0.060    0.000    0.000    0.000    0.070    0.119    0.224    0.487    0.654    0.585
 IBH   20.154   10.369    6.283    0.000    4.363    6.611    7.790   16.018   10.660   16.661   21.693   13.170
-------------------------------------------------------------
 DSS    1.254    0.282    0.128    0.757    0.386    0.644    2.293    0.819    0.044    0.891    0.000    1.430
 DKA    0.493    0.282    0.294    0.263    0.347    0.116    0.166    0.118    0.076    0.095    0.353    0.800
 DME    0.131    0.000    0.057    0.001    0.033    0.030    0.095    0.012    0.087    0.008    0.000    0.068
 DBH    9.326    6.225    3.588    0.020    2.502    2.523    1.794    4.062    3.319    5.742    8.113    6.887
 DBM    9.965    7.304    6.202    3.361    4.419    3.855    3.525    5.136    5.552    7.305    9.896    9.016
 DXX    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000    0.000
```

APPENDIX I

The DEMGEN program input and output files

Table I.1 New general demand file NEW.DEM (i.e., NEWDEM4.RMD) (input)

```
  TU     4.634     4.538     4.305     4.181     4.529     4.048     4.515     4.691     4.977     5.243     5.743     5.738
  MO     0.101     0.090     0.082     0.079     0.069     0.065     0.084     0.094     0.100     0.110     0.129     0.128
  NA     0.116     0.099     0.086     0.081     0.080     0.073     0.090     0.098     0.108     0.119     0.145     0.150
  SO     0.290     0.275     0.252     0.229     0.205     0.190     0.250     0.264     0.274     0.296     0.355     0.372
  SF     0.762     0.654     0.626     0.567     0.544     0.484     0.615     0.675     0.715     0.739     0.766     0.801
  JE     0.108     0.103     0.092     0.090     0.096     0.084     0.096     0.099     0.104     0.106     0.105     0.130
  BE     0.136     0.125     0.120     0.119     0.105     0.108     0.128     0.128     0.137     0.147     0.166     0.162
  MB     0.039     0.036     0.034     0.034     0.030     0.031     0.037     0.037     0.039     0.042     0.047     0.046
  TO     1.624     1.459     0.914     0.777     0.716     0.765     1.138     1.211     1.388     1.531     1.892     2.077
IAEA     2.881     2.131     1.391     0.000     0.000     0.235     2.287     4.820     7.488     9.350    10.001     7.519
 IBV     1.250     0.627     0.305     0.002     0.002     0.003     0.154     0.768     1.813     2.736     3.089     2.715
IMSC    12.784     5.420     2.258     0.606     0.505     2.020     6.586     7.675    13.132    21.709    26.502    25.250
 INE     0.204     0.079     0.060     0.000     0.000     0.000     0.070     0.119     0.224     0.487     0.654     0.585
 IBH    20.154    10.369     6.283     0.000     4.363     6.611     7.790    16.018    10.660    16.661    21.693    13.170
----------------------------------------------------------------
 DSS     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 DKA     0.000     0.000     0.018     0.000     0.000     0.072     0.094     0.080     0.100     0.068     0.070     0.068
 DME     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.152     0.000
 DBH     7.973     5.486     2.893     0.000     1.459     1.993     1.858     4.309     2.959     5.927     7.479     6.231
 DBM     2.058     2.147     1.782     1.910     1.736     1.397     1.338     1.242     1.457     1.925     2.234     2.410
 DXX     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table I.2 Individual (consumptive) demand time series file TO.RMD (output)

1946	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1947	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1948	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1949	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1950	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1951	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1952	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1953	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1954	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1955	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1956	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1957	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1958	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1959	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1960	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1961	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1962	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1963	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1964	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1965	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1966	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1967	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1968	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1969	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1970	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1971	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1972	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1973	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1974	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1975	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1976	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1977	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1978	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1979	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1980	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1981	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1982	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1983	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1984	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1985	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1986	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1987	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1988	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077
1989	1.624	1.459	.914	.777	.716	.765	1.138	1.211	1.388	1.531	1.892	2.077

Table I.3 Individual (DRD-type) demand time series file DBH.RMD (output)

1946	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1947	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1948	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1949	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1950	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1951	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1952	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1953	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1954	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1955	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1956	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1957	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1958	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1959	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1960	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1961	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1962	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1963	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1964	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1965	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1966	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1967	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1968	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1969	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1970	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1971	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1972	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1973	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1974	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1975	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1976	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1977	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1978	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1979	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1980	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1981	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1982	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1983	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1984	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1985	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1986	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1987	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1988	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231
1989	7.973	5.486	2.893	.000	1.459	1.993	1.858	4.309	2.959	5.927	7.479	6.231

APPENDIX J

The AGGRMD program output file

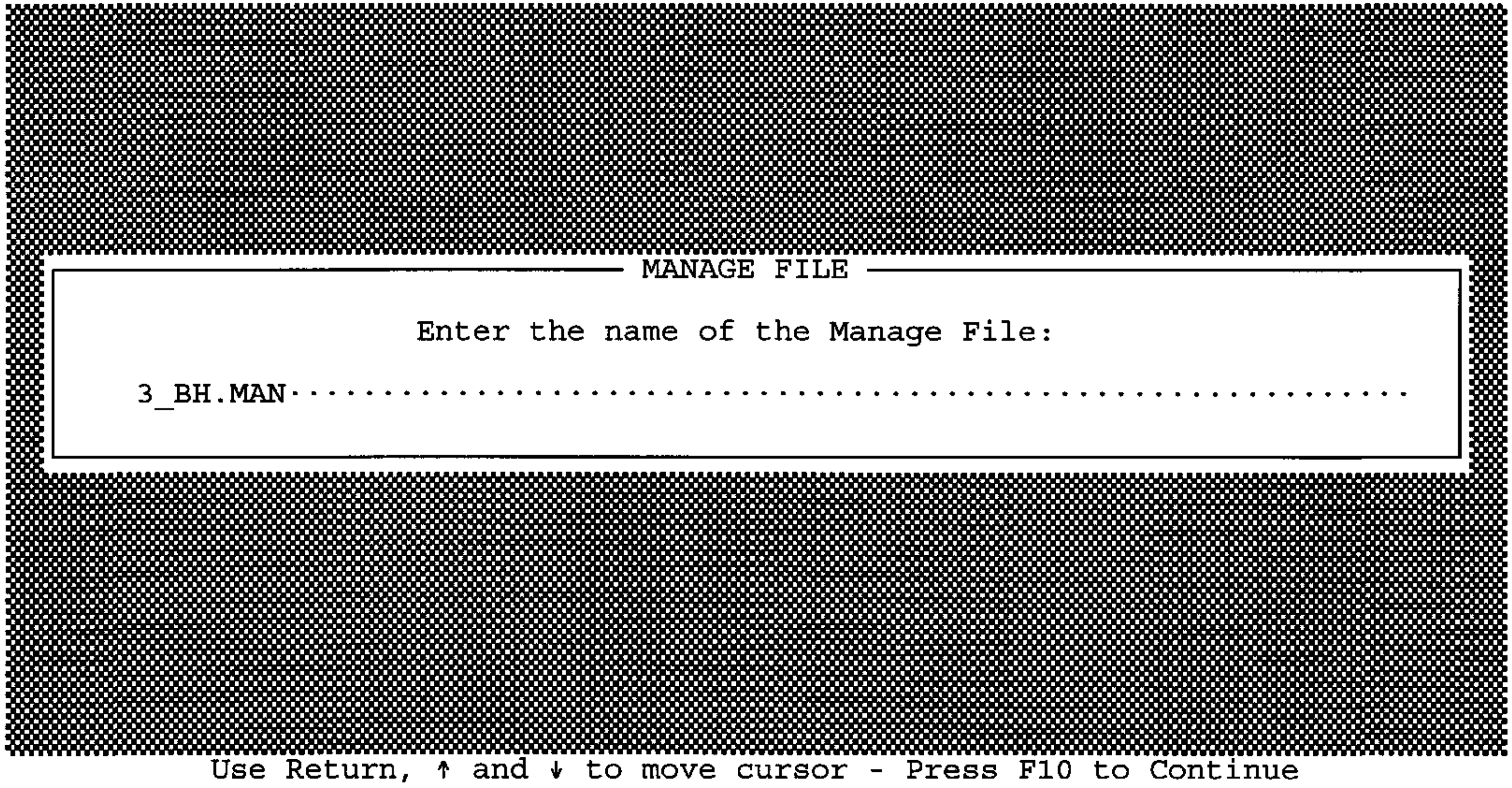
Table J.1 Aggregated demand file MEDEM.AGG (output)

```
46     .204    .079    .060    .000    .000    .000    .070    .234    .224    .487    .654   1.859
47    2.833   2.467    .060    .000   2.288    .000   1.239   7.222   5.450  12.661   9.718   9.557
48   12.870  10.227   1.538    .000    .000    .000    .070    .119    .224    .487    .654    .722
49     .409   1.242    .060    .000   3.983   6.305   3.052    .184    .224    .487    .706   3.413
50    2.115   1.322    .060    .000   4.363   6.611   7.860   9.349   5.620   8.052   7.489   8.769
51    6.855   4.137   2.967    .000    .079    .000    .070    .119    .224    .487    .996   1.690
52    2.146   1.203    .635    .000    .000    .000    .070    .119    .224    .487    .670   4.234
53    2.073    .079    .060    .000    .000    .000    .070    .119    .224    .487    .654    .739
54     .940    .079    .060    .000   2.510    .733    .070    .119   1.939   8.035   5.823   5.577
55    5.634   4.218    .540    .000   3.930    .000    .070    .119    .224    .938    .654    .700
56    2.707   1.194    .060    .000    .000   2.403    .070    .119    .867   6.773   5.658   5.378
57    7.234   4.659   2.246    .000    .000    .000    .070    .119    .224    .487   5.967   5.058
58    5.560   4.889   4.623    .000    .401    .000    .070    .119    .224    .487    .654    .585
59     .695    .404    .060    .000    .000    .000    .070    .119   3.241    .487   5.725   5.427
60    6.464   6.069   6.132    .000   3.862    .000   1.300  11.601   5.366  12.425  13.607   9.673
61   17.327   9.587   5.051    .000    .000   5.346    .402   3.733   5.769  12.704  17.946  10.426
62   20.051   2.131    .681    .000    .000    .000    .865    .119    .224    .487   7.261   5.598
63    5.282   1.653   1.917    .000   4.363   4.063   1.102   8.659   5.241   8.594   7.218   9.217
64    6.509   9.087   2.381    .000   1.761    .427    .070    .883    .224    .487   5.309   5.219
65    6.952   7.292   6.241    .000    .000   1.202   4.750   6.134    .720  10.320   9.183   9.076
66    8.040   9.757   4.421    .000   3.896   4.746    .070   9.549   4.904  11.999   9.411   9.068
67   13.820   9.867   5.622    .000   3.950    .000   1.949  11.286   6.108  11.640  20.884  13.707
68   20.101   9.907   5.442    .000   3.862    .000   1.087   8.252   6.048  12.625  22.301  13.557
69   19.671   1.477   4.661    .000   3.787    .520   1.462    .444    .224    .487   5.251   5.535
70    4.103   5.919   6.321    .000    .645    .000    .070    .119    .224    .778   1.435   5.059
71    1.891   3.075   1.287    .000   4.363   4.338   7.597   5.274    .773   4.533   5.914   5.692
72    7.209  10.207   6.311    .000   3.287   4.064    .070    .119    .224    .487    .654   1.486
73    3.010   2.025   2.151    .000    .000    .054    .070   4.662   5.592  15.337  22.347  13.755
74   20.358   9.671    .217    .000    .000   5.671   3.605    .251   5.185   2.463   5.654   5.382
75    7.279  10.387   2.782    .000    .000   4.336   6.308   7.731   9.605   8.394   5.466   7.207
76    4.399   8.697   2.780    .000   4.363    .000   2.512  10.045   5.504  11.773  10.056   7.485
77   14.260  10.327    .584    .000    .000   3.570    .070   3.746   3.421  10.538  11.758   7.604
78   12.317  10.277   1.091    .000    .000   6.333    .854   8.270   3.249  11.247  11.377   7.488
79   14.628  10.448   3.389    .000    .000   3.397   5.527   6.236   2.761   9.094   7.671   9.937
80    7.269   9.647   5.281    .000    .000    .000   2.346    .119    .224    .487    .654   1.643
81    1.126   1.863   1.205    .000   4.363   3.594   5.681   5.596    .288   1.568   5.914   5.552
82    7.163  10.137   2.572    .000    .000    .000   2.394    .119   5.854   8.892   5.909   6.243
83    7.339  10.037    .442    .000   3.914   1.189    .070    .119    .224    .487    .654   1.610
84    2.722   1.765   1.461    .000    .000    .000    .070   2.475    .224    .487    .859   1.599
85    2.427   1.984   4.151    .000   4.363   3.805   4.819  10.502    .557  13.245  10.249   9.695
86   12.208   8.737   2.711    .000    .000    .000    .070    .119   1.757    .487    .654    .613
87     .204    .079    .060    .000    .000    .000   4.513   3.466   6.339   7.921   8.084   8.997
88    7.029   8.977   5.831    .000    .398   3.390   3.955   9.409   9.522  16.700  21.911  13.178
89   19.461   9.407   5.822    .000   1.966   5.910   7.242  15.891   9.642  17.000  22.347  13.561
```

APPENDIX K

The SHELL windows

Table K.1 'Manage Files/Load Manage File' option window



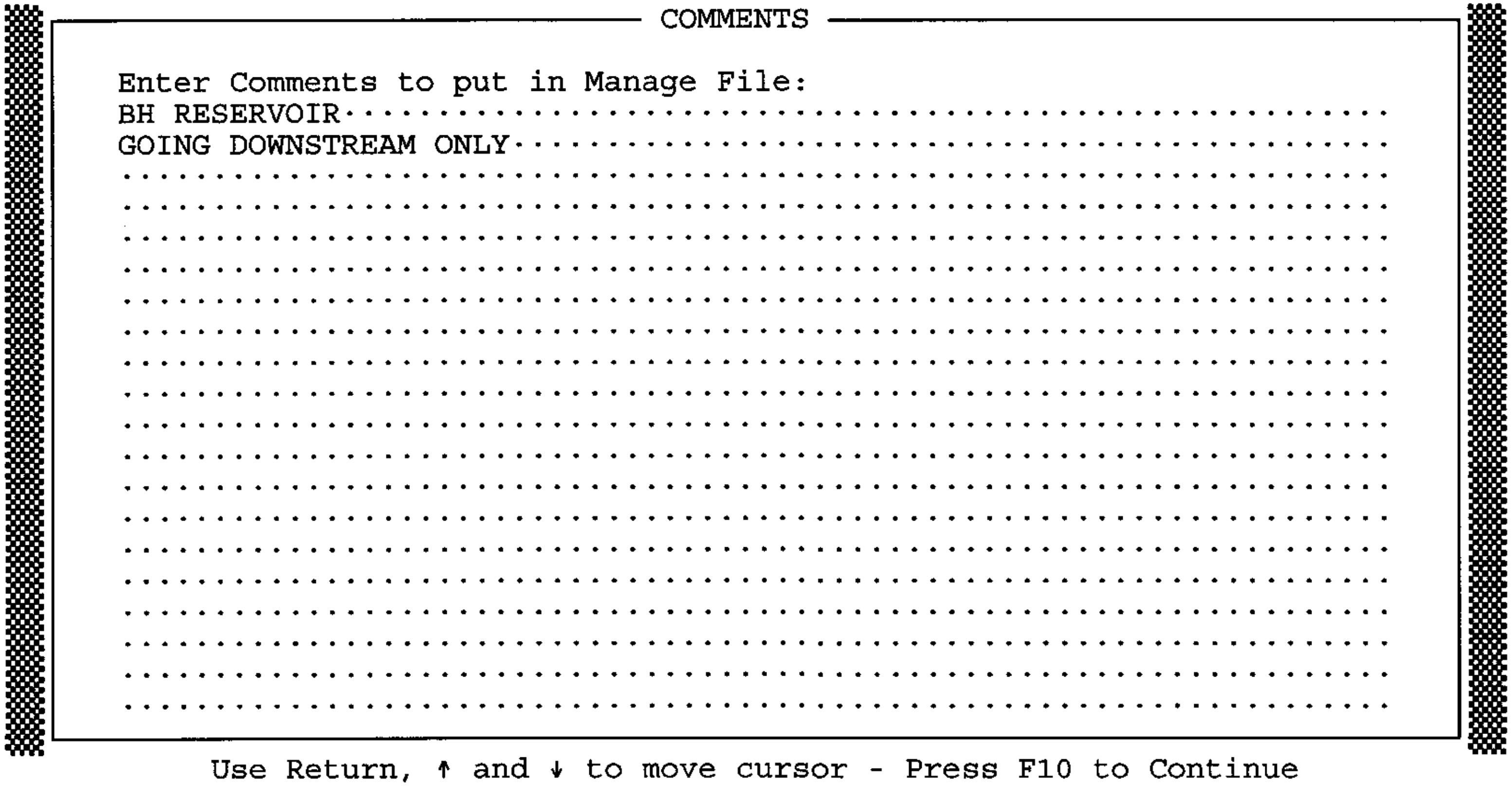
```
MANAGE FILE

Enter the name of the Manage File:

3_BH.MAN.............................................................

Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.2 'Manage Files/Edit Manage File' option window: The COMMENT section



```
                              COMMENTS
   Enter Comments to put in Manage File:
   BH RESERVOIR·······································
   GOING DOWNSTREAM ONLY······························
   ..................................................
   ..................................................
   ..................................................
   ..................................................
   ..................................................
   ..................................................
   ..................................................
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   ..................................................
   ..................................................

      Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```
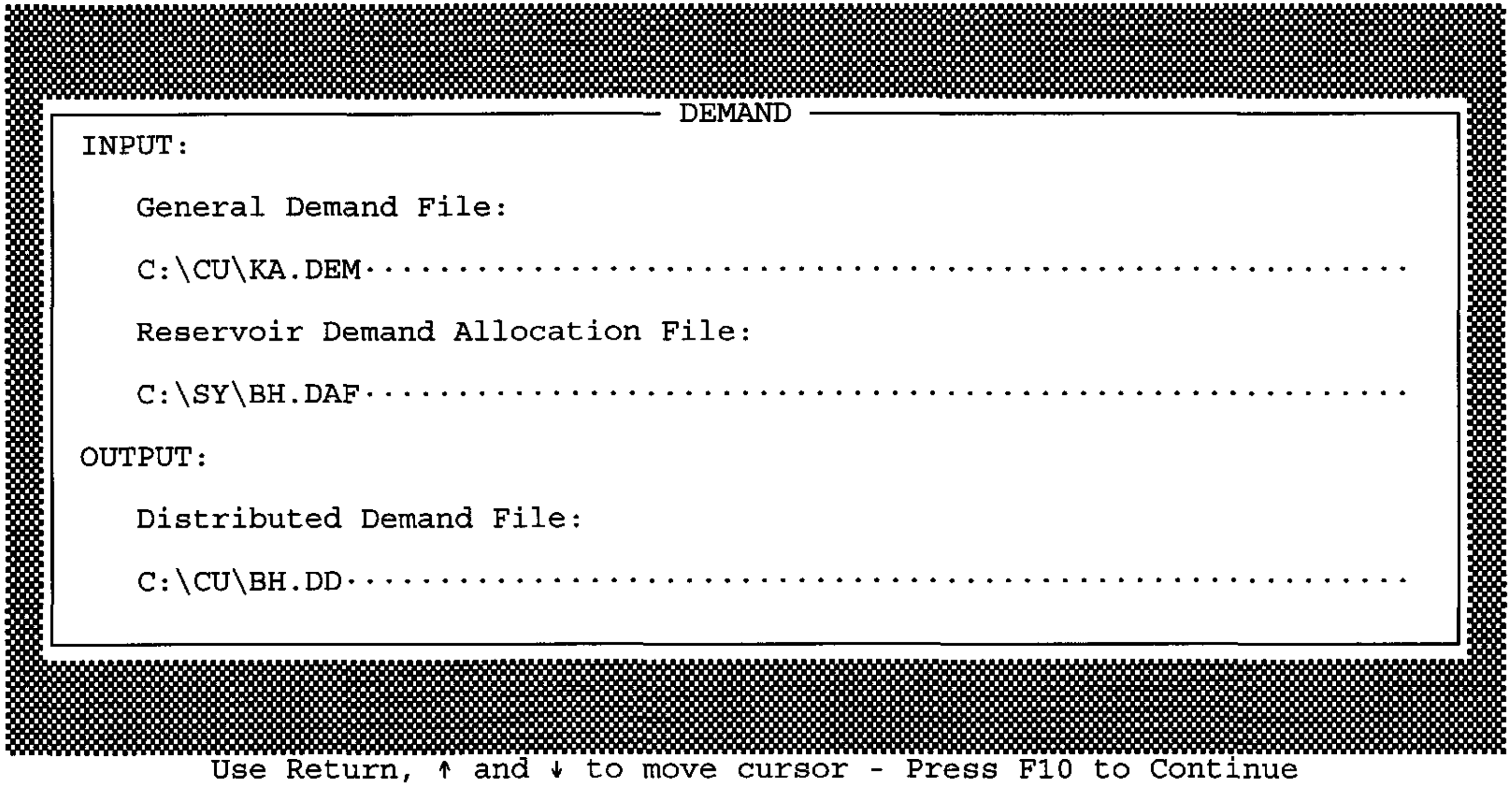
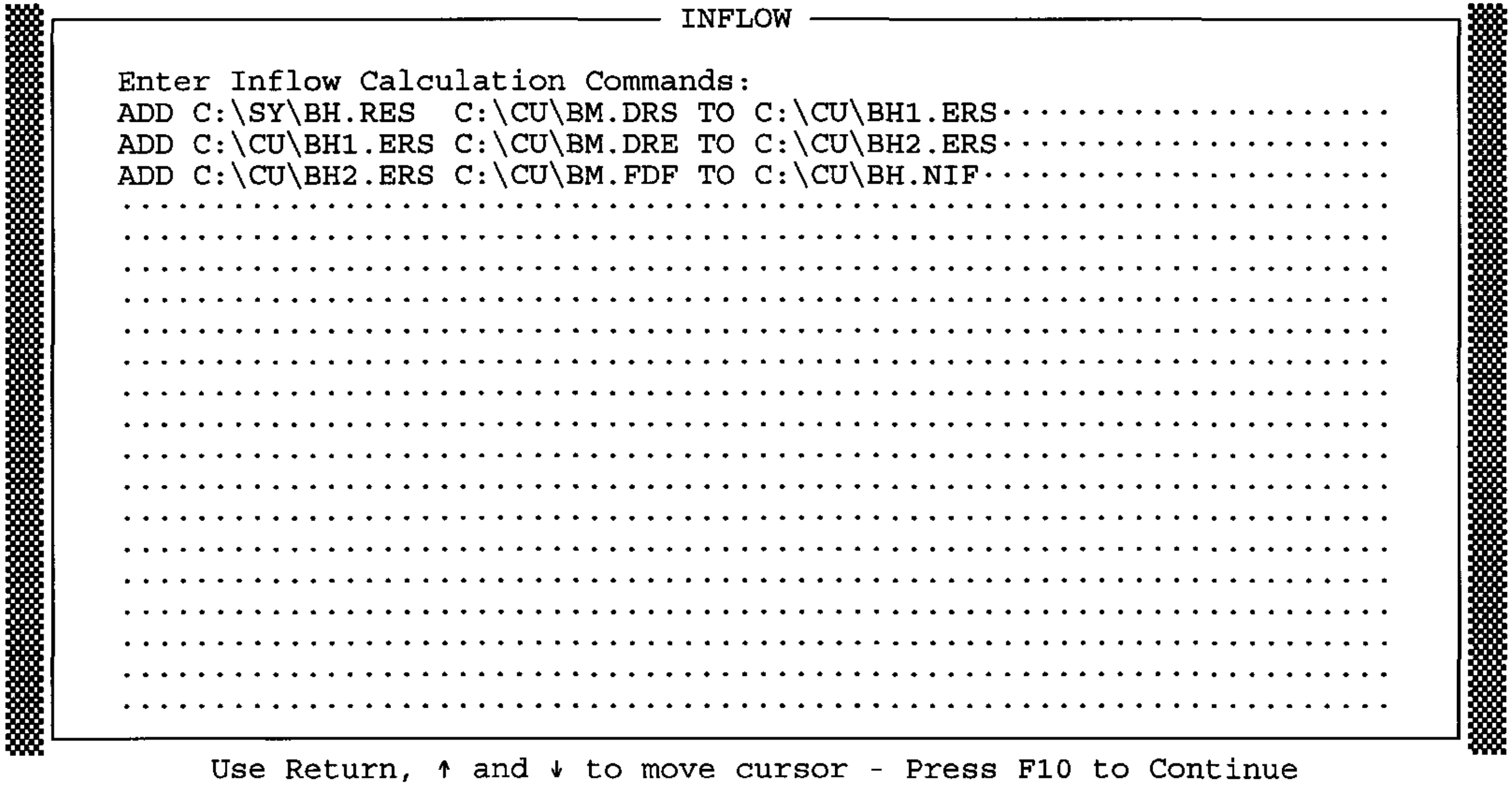

Table K.3 'Manage Files/Edit Manage File' option window: The DEMAND program section



```
                          DEMAND
INPUT:

   General Demand File:

   C:\CU\KA.DEM·························································

   Reservoir Demand Allocation File:

   C:\SY\BH.DAF·························································

OUTPUT:

   Distributed Demand File:

   C:\CU\BH.DD··························································

       Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.4 'Manage Files/Edit Manage File' option window: The INFLOW program section



```
                            INFLOW
  Enter Inflow Calculation Commands:
  ADD C:\SY\BH.RES  C:\CU\BM.DRS TO C:\CU\BH1.ERS·····················
  ADD C:\CU\BH1.ERS C:\CU\BM.DRE TO C:\CU\BH2.ERS·····················
  ADD C:\CU\BH2.ERS C:\CU\BM.FDF TO C:\CU\BH.NIF······················
  ....................................................................
  ....................................................................
  ....................................................................
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  ....................................................................
  ....................................................................
  ....................................................................

      Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```
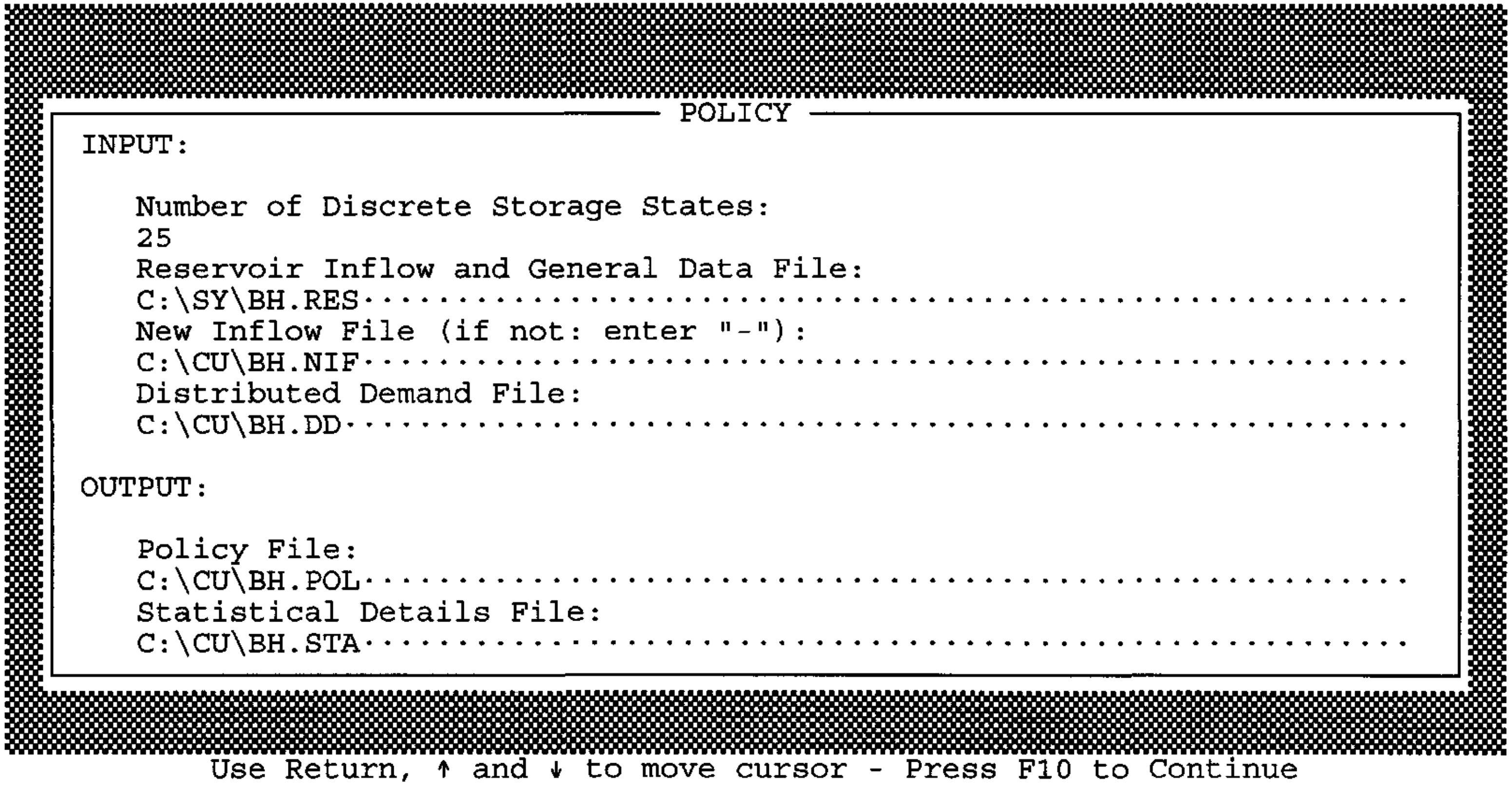
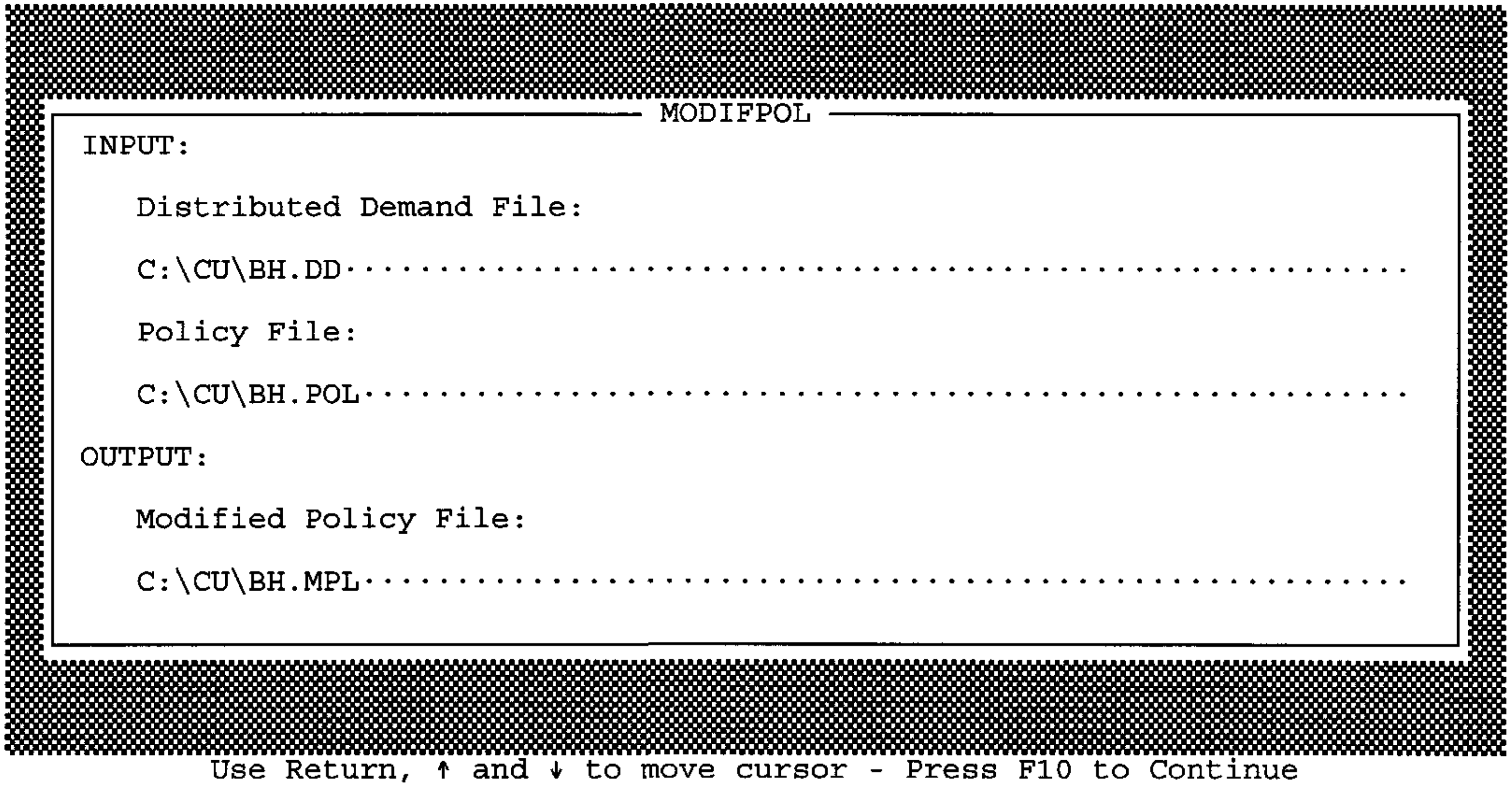

Table K.5 'Manage Files/Edit Manage File' option window: The POLICY program section



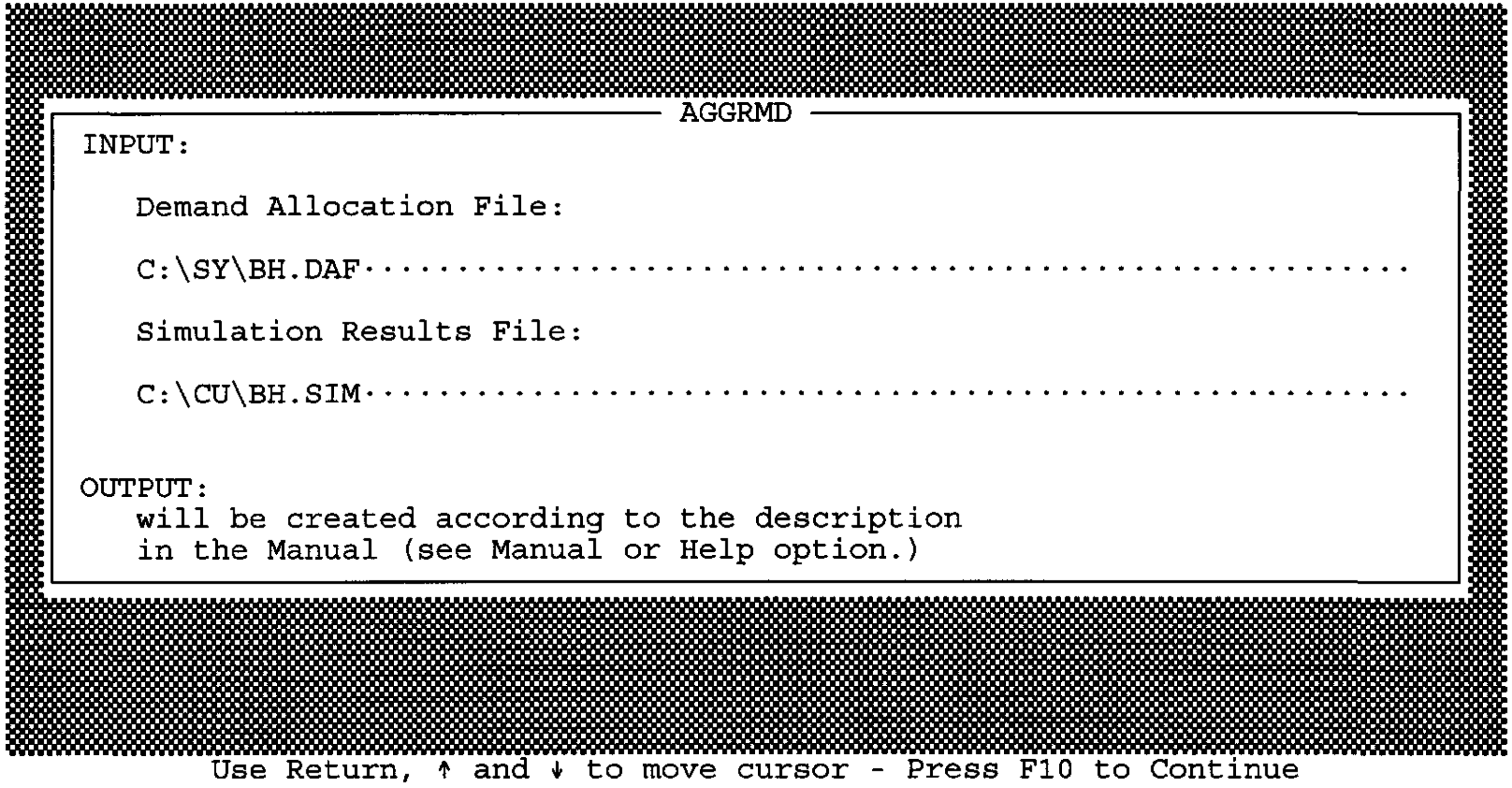
```
───────────────────────────── POLICY ─────────────────────────────
INPUT:

   Number of Discrete Storage States:
   25
   Reservoir Inflow and General Data File:
   C:\SY\BH.RES·····················································
   New Inflow File (if not: enter "-"):
   C:\CU\BH.NIF·····················································
   Distributed Demand File:
   C:\CU\BH.DD······················································

OUTPUT:

   Policy File:
   C:\CU\BH.POL·····················································
   Statistical Details File:
   C:\CU\BH.STA·····················································

          Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.6 'Manage Files/Edit Manage File' option window: The MODIFPOL program section



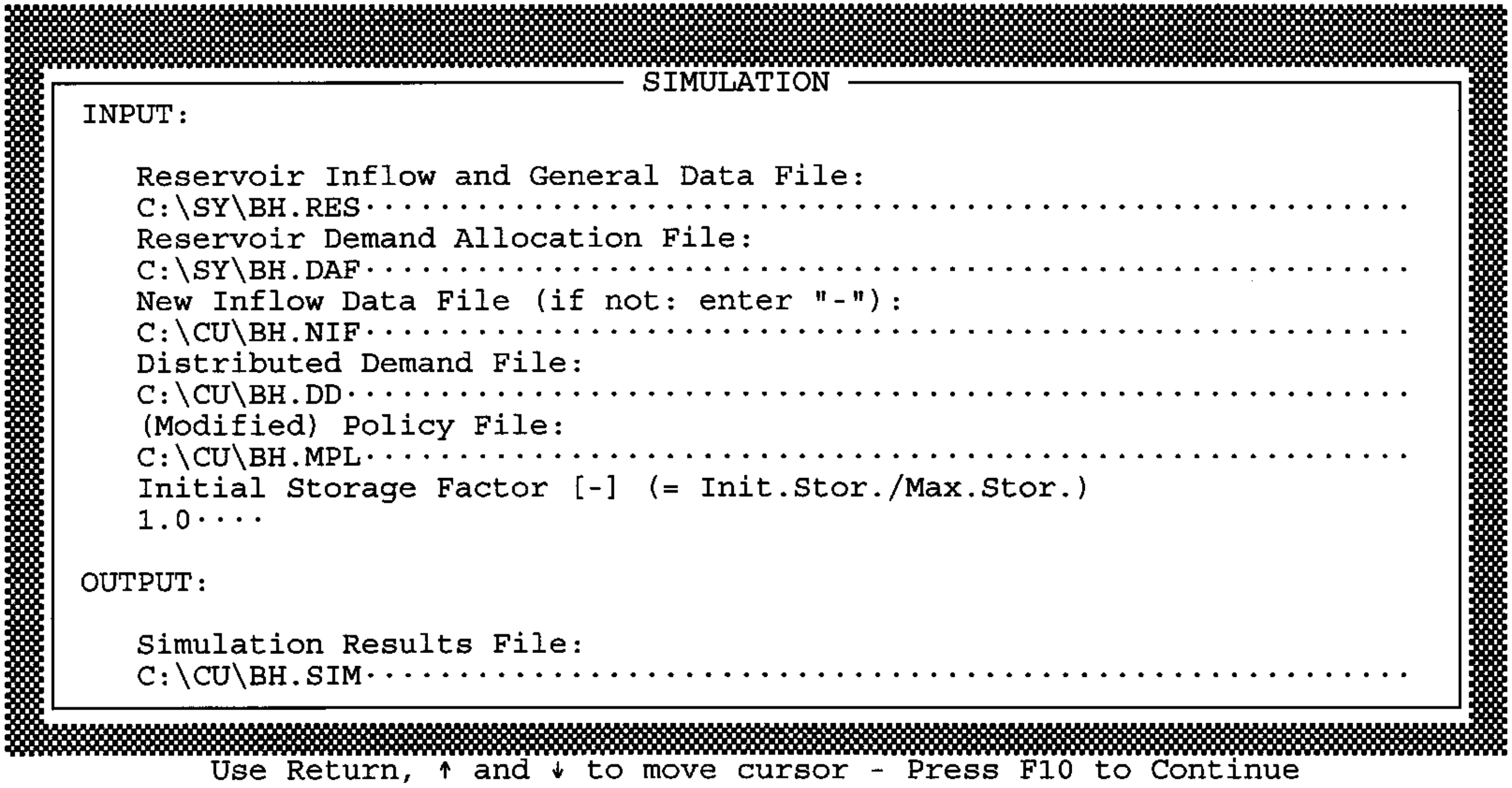
```
                              MODIFPOL
INPUT:

   Distributed Demand File:

   C:\CU\BH.DD··························································

   Policy File:

   C:\CU\BH.POL·························································

OUTPUT:

   Modified Policy File:

   C:\CU\BH.MPL·························································

            Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.7 'Manage Files/Edit Manage File' option window: The AGGRMD program section



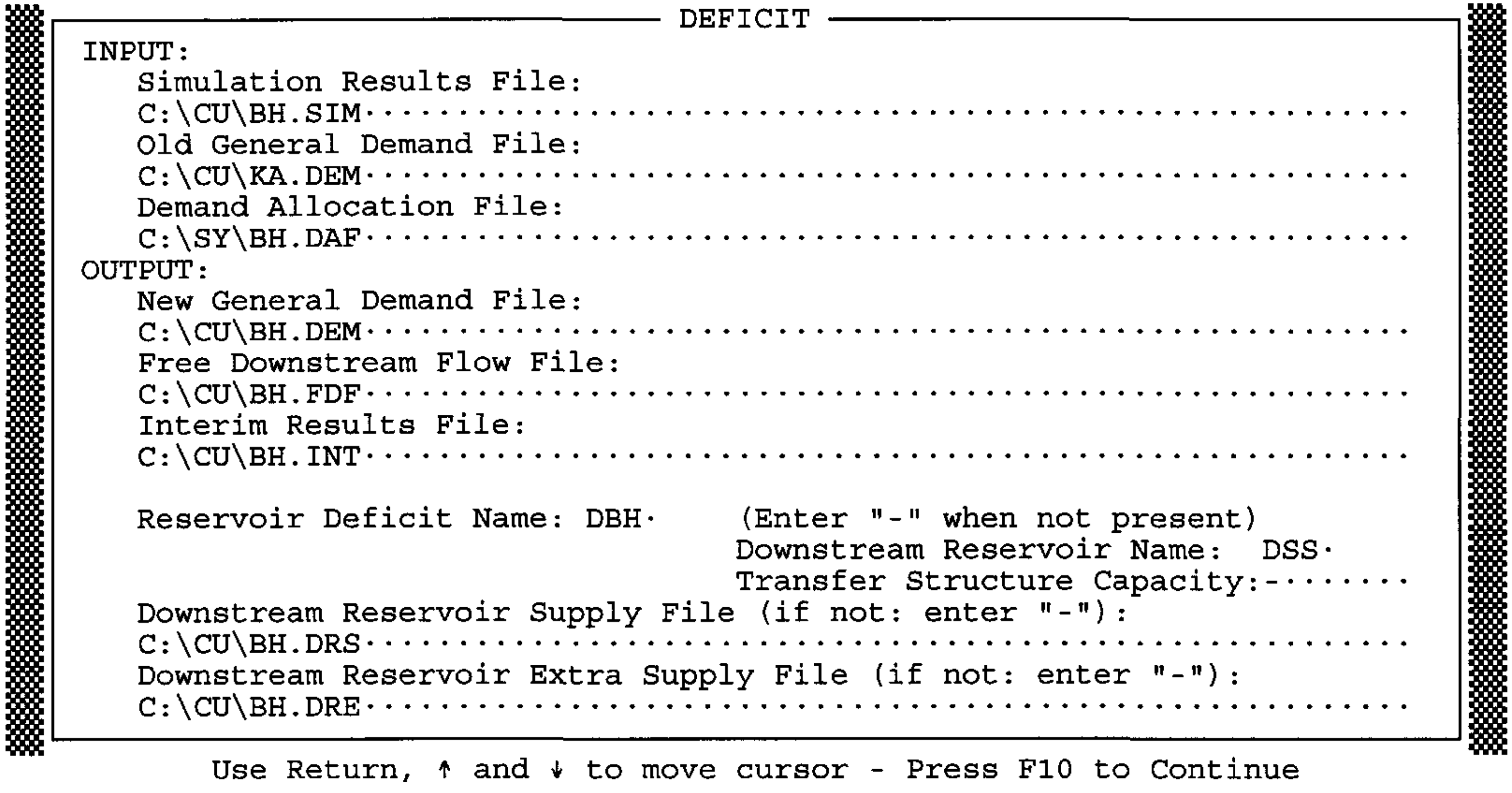
```
                              AGGRMD
 INPUT:

    Demand Allocation File:

    C:\SY\BH.DAF·······································································

    Simulation Results File:

    C:\CU\BH.SIM·······································································


 OUTPUT:
    will be created according to the description
    in the Manual (see Manual or Help option.)

      Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.8 'Manage Files/Edit Manage File' option window: The SIMULATE program section



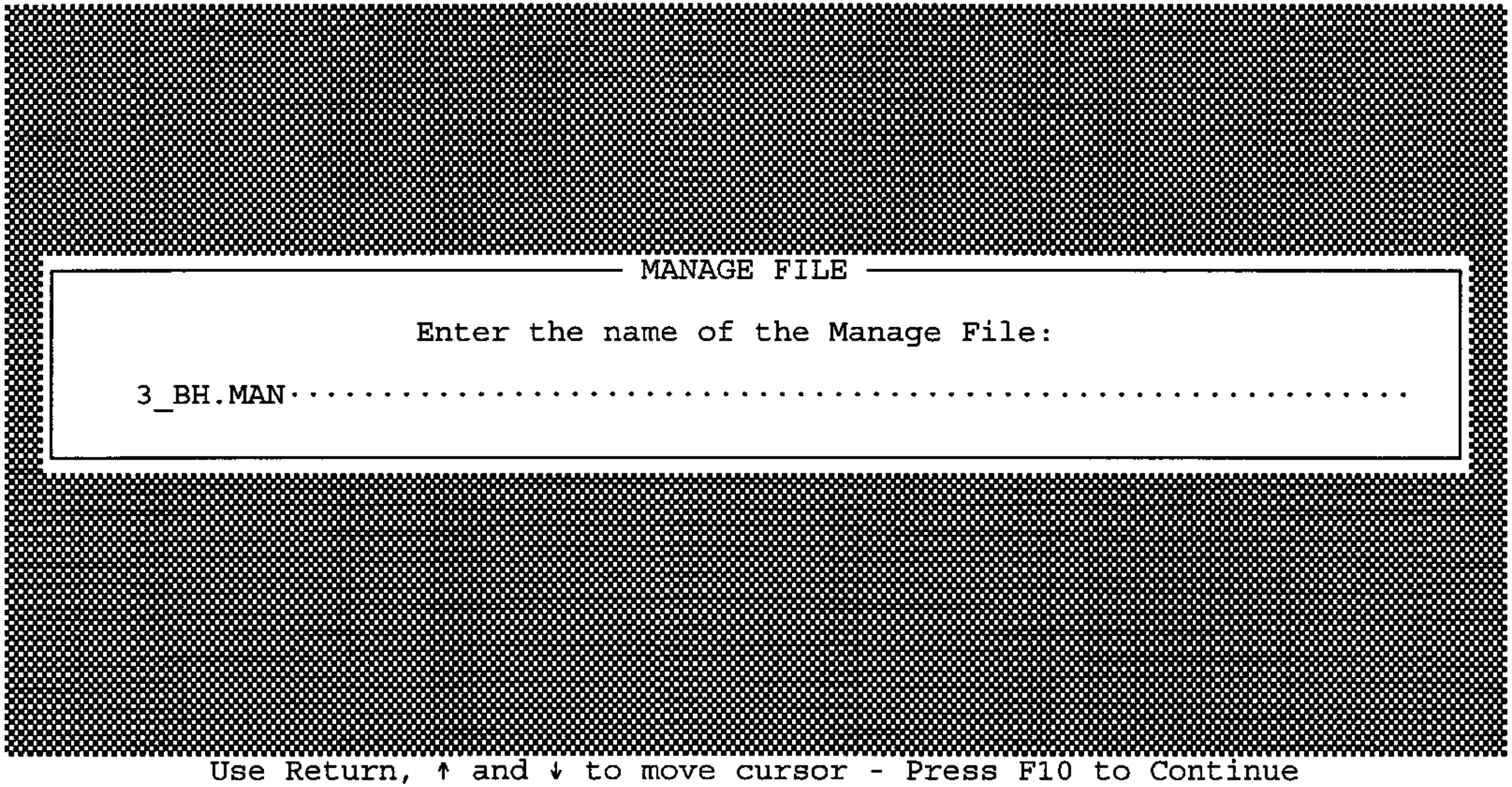
```
                          SIMULATION
INPUT:

   Reservoir Inflow and General Data File:
   C:\SY\BH.RES·························································
   Reservoir Demand Allocation File:
   C:\SY\BH.DAF·························································
   New Inflow Data File (if not: enter "-"):
   C:\CU\BH.NIF·························································
   Distributed Demand File:
   C:\CU\BH.DD··························································
   (Modified) Policy File:
   C:\CU\BH.MPL·························································
   Initial Storage Factor [-] (= Init.Stor./Max.Stor.)
   1.0····

OUTPUT:

   Simulation Results File:
   C:\CU\BH.SIM·························································
       Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.9 'Manage Files/Edit Manage File' option window: The DEFICIT program section



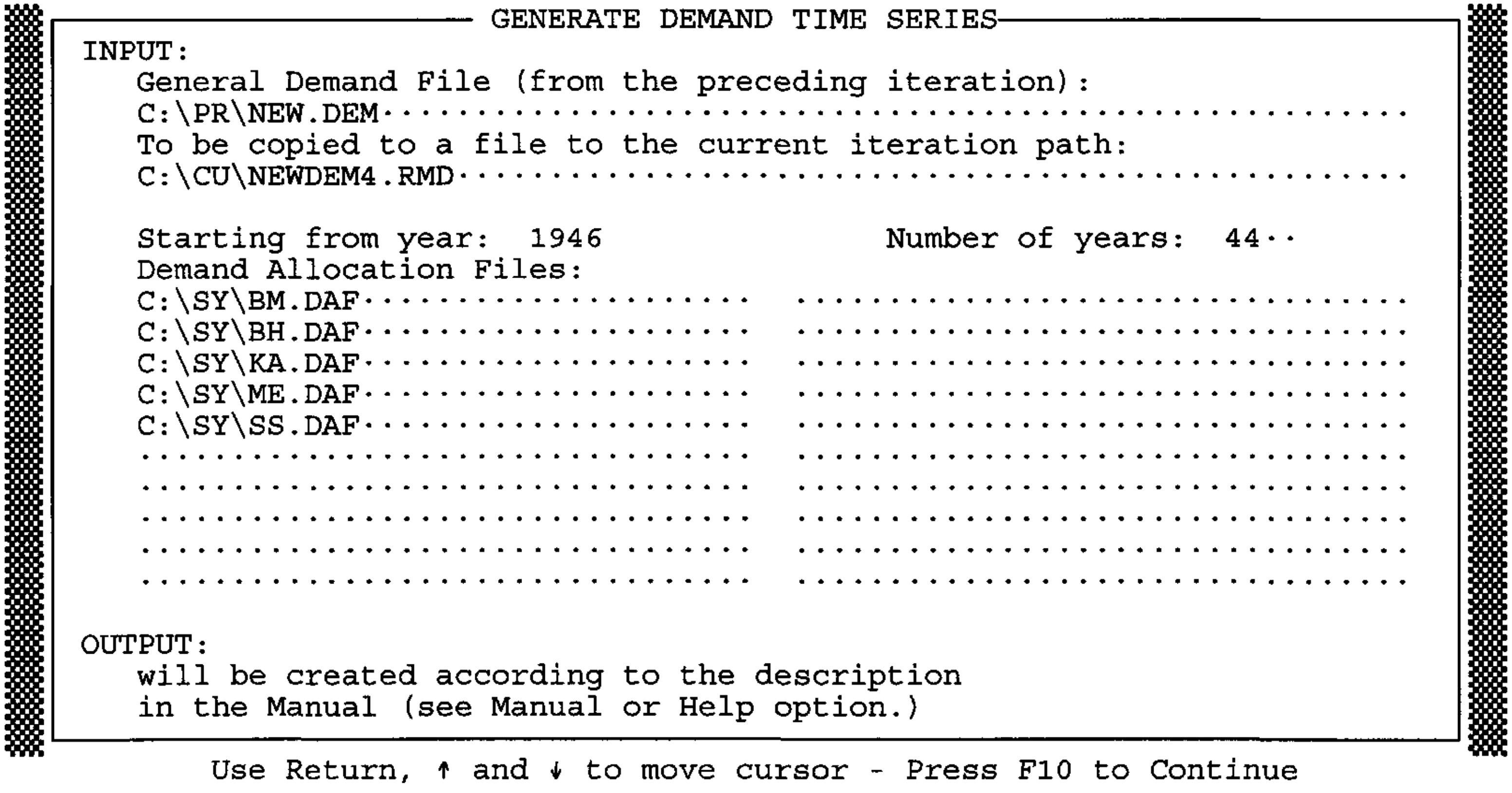
```
─────────────────────────────── DEFICIT ───────────────────────────────
INPUT:
   Simulation Results File:
   C:\CU\BH.SIM·············································
   Old General Demand File:
   C:\CU\KA.DEM·············································
   Demand Allocation File:
   C:\SY\BH.DAF·············································
OUTPUT:
   New General Demand File:
   C:\CU\BH.DEM·············································
   Free Downstream Flow File:
   C:\CU\BH.FDF·············································
   Interim Results File:
   C:\CU\BH.INT·············································

   Reservoir Deficit Name: DBH·    (Enter "-" when not present)
                                   Downstream Reservoir Name:  DSS·
                                   Transfer Structure Capacity:-·······
   Downstream Reservoir Supply File (if not: enter "-"):
   C:\CU\BH.DRS·············································
   Downstream Reservoir Extra Supply File (if not: enter "-"):
   C:\CU\BH.DRE·············································

       Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.10 'Manage Files/Save Manage File' option window



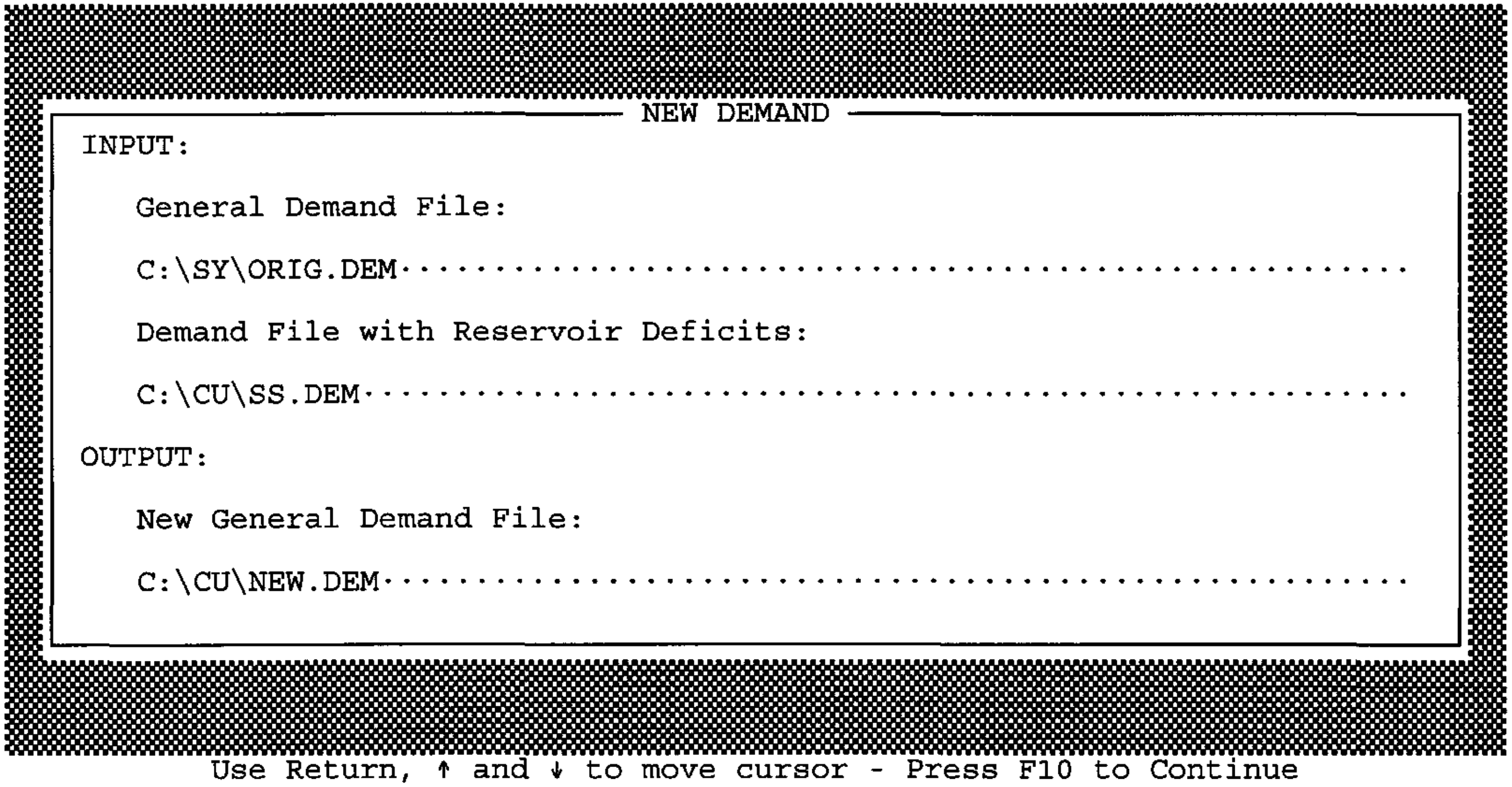
```
MANAGE FILE

Enter the name of the Manage File:

3_BH.MAN····························································

Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.11 'Files/Tools/Demgen.man' option window: The DEMGEN.MAN manage file editing window



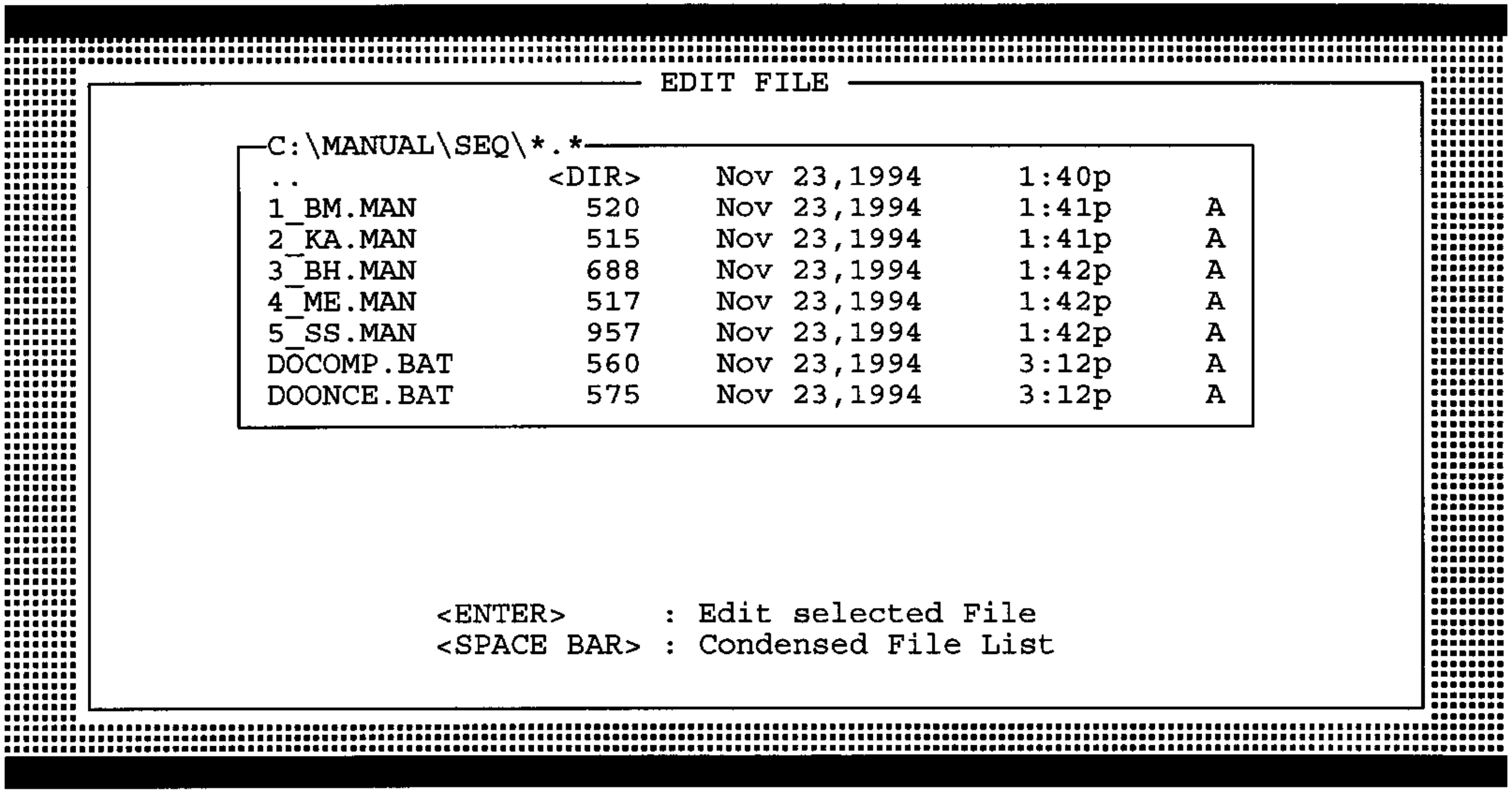
```
               ─────── GENERATE DEMAND TIME SERIES───────
INPUT:
   General Demand File (from the preceding iteration):
   C:\PR\NEW.DEM·········································
   To be copied to a file to the current iteration path:
   C:\CU\NEWDEM4.RMD·····································

   Starting from year:  1946            Number of years:  44··
   Demand Allocation Files:
   C:\SY\BM.DAF··················   ·····························
   C:\SY\BH.DAF··················   ·····························
   C:\SY\KA.DAF··················   ·····························
   C:\SY\ME.DAF··················   ·····························
   C:\SY\SS.DAF··················   ·····························
   ······························   ·····························
   ······························   ·····························
   ······························   ·····························
   ······························   ·····························
   ······························   ·····························

OUTPUT:
   will be created according to the description
   in the Manual (see Manual or Help option.)
      Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.12 'Files/Tools/Newdem.man' option window: The NEWDEM.MAN manage file editing window



```
                          NEW DEMAND
INPUT:

   General Demand File:

   C:\SY\ORIG.DEM·······················································

   Demand File with Reservoir Deficits:

   C:\CU\SS.DEM·························································

OUTPUT:

   New General Demand File:

   C:\CU\NEW.DEM························································

        Use Return, ↑ and ↓ to move cursor - Press F10 to Continue
```

Table K.13 'Edit File' sub-option window



```
                         EDIT FILE

  C:\MANUAL\SEQ\*.*
  ..               <DIR>    Nov 23,1994     1:40p
  1_BM.MAN           520    Nov 23,1994     1:41p      A
  2_KA.MAN           515    Nov 23,1994     1:41p      A
  3_BH.MAN           688    Nov 23,1994     1:42p      A
  4_ME.MAN           517    Nov 23,1994     1:42p      A
  5_SS.MAN           957    Nov 23,1994     1:42p      A
  DOCOMP.BAT         560    Nov 23,1994     3:12p      A
  DOONCE.BAT         575    Nov 23,1994     3:12p      A


          <ENTER>      : Edit selected File
          <SPACE BAR>  : Condensed File List
```

APPENDIX L

The SHELL HELP

Table L.1 The SHELL HELP

```
----------------------------------------------------------------------------
----------------------------------------------------------------------------




                      THE ShellDP PROGRAMS







 1 PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
DEMAND                                               (Manual: Section 5.2)

General Demand File    -->
                                     DEMAND.EXE      -->  Distributed
Demand Allocation File -->                                Demand File


Description: The DEMAND program calculates the DISTRIBUTED DEMAND of
             a reservoir. The distributed demand can be constituted as
             a real demand, or as the ANNUAL MEDIAN INFLOW to the reservoir
             distributed over a year according to the real monthly demands:

Distributed_Demand[month] =

       Sum_of_Demands[month] * Annual_Median_Flow / Total_Annual_Demand

 2 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
INFLOW                                               (Manual: Section 5.3)

Reservoir Data File
(General Flow File) -->
                            INFLOW.EXE      --> General Flow File
General Flow file   -->


Description: The INFLOW program can be used to manipulate flow files.
             The input for this program are two flow files in the
             'general flow file format' or 'reservoir data file format'
             (that file also contains a flow section). The output is always
             a file in the 'general flow file format'.


 3 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
----------------------------------------------------------------------------
----------------------------------------------------------------------------
INFLOW (continued)


THE INFLOW PROGRAM AVAILABLE COMMANDS:

  ADD 'flow_file_1' 'flow_file_2' TO 'flow_file_3'
     Adds two files

  SUBSTRACT 'flow_file_1' 'flow_file_2' TO 'flow_file_3'
     Subtracts 'flow_file_2' from 'flow_file_1'

  SPLIT 'flow_file' TO 'pos_flow_file' 'neg_flow_file'
     Splits the contents of the 'flow_file' into files 'pos_flow_file' and
     'neg_flow_file' containing positive and negative values respectively.

  RESIZE 'flow_file_1' TO 'flow_file_2' BY 'integer'
     Expands one-line flow file to a file with more lines.

 4 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
INFLOW (continued)


THE INFLOW PROGRAM AVAILABLE COMMANDS (continued):

  SIM2GEN 'simulation_file' TO 'flow_file' [/TOTAL] [/NOLOCAL] [/SPILLAGE]
     Extracts data from a simulation output file. The switch specified
     indicates which data are to be extracted.

  DAT2GEN 'reservoir_data_file' TO 'flow_file'
     Extracts the flow matrix from a reservoir data file.


And one additional command:

  EXTRACTDEMAND 'general_demand_file' 'demand_name' TO 'one_line_demand_file'
     Extracts a specified demand line from a general demand data file.

 5 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
POLICY                                                (Manual: Section 5.4)


Number of Storage Classes -->               --> Policy File
Reservoir Data File       -->  POLICY.EXE
[New Inflow File]         -->               --> Statistical
Distributed Demand File   -->                   Details File


Description: The POLICY program calculates the optimal operational policy
             of a reservoir using stochastic dynamic programming.



 6 PgUp/PgDn                                                 [...] -> optional
----------------------------------------------------------------------------
----------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
----------------------------------------------------------------------------
----------------------------------------------------------------------------
MODIFPOL                                                (Manual: Section 5.5)


Policy File                  -->
                                   MODIFPOL.EXE     --> Modified Policy File
Distributed Demand File      -->


Description: The MODIFPOL program performs user defined modifications
             of the operational policy derived by the POLICY program.



 7 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
AGGRMD                                                  (Manual: Section 5.6)


Demand Allocation File        -->

Individual Demand             -->
Time Series Files                    AGGRMD.EXE     -->   Aggregated
                                                          Demand File
Simulation File Name          -->

Description: The AGGRMD program reads individual demand time series
             associated with a reservoir and aggregates them into a single
             cumulative demand time series. This record is used in, so
             called, "monitored demand concept" embedded in simulation
             and release allocation models.

 8 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
AGGRMD (continued)

Note that the program assumes certain rules regarding input and output
file names. Firstly, Individual Demand Time Series Files are stored in
files named as follows (these files are initially created by DEMGEN):

           "current iteration path" + "demand code" + '.rmd'

The output file name is created by the program also automatically:

  Aggregated Demand File Name =
                     "Simulation File Path" + "Reservoir Name" + 'dem.agg'

IMPORTANT: If the "average demand" instead of "monitored demand" concept
is to be followed in simulation and release allocation AGGRMD need not be
executed. Namely, if SIMULATE and DEFICIT could not find the Aggregated
Demand File (output of AGGRMD) they would assume the "average demand concept".

 9 PgUp/PgDn
----------------------------------------------------------------------------
----------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
SIMULATE                                                (Manual: Section 5.7)


Reservoir Data File              -->
Demand Allocation File           -->
[New Inflow File]                -->
Distributed Demand File          -->  SIMULATE.EXE  --> Simulation File
[Modified] Policy File           -->
Initial Reservoir Storage Ratio -->


Description: Simulation of reservoir operation according to
             the policy derived by the POLICY program or
             the modified policy derived by the MODIFPOL program.

10 PgUp/PgDn                                                [...] -> optional
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
DEFICIT                                                 (Manual: Section 5.8)

Simulation File                -->              --> New General Demand File
General Demand File            -->              --> Free Downstream Flow File
Demand Allocation File         -->              --> Interim Results File
Reservoir Deficit Name         -->  DEFICIT.EXE --> [Downstream Reservoir
[Downstream Reservoir Name]    -->                  Supply]
[Transfer Structure Capacity] -->               --> [Downstream Reservoir
                                                    Extra Supply]


Description: The DEFICIT program carries out the allocation of
             reservoir releases derived by the SIMULATE program.


11 PgUp/PgDn                                                [...] -> optional
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
NEWDEM                                                  (Manual: Section 5.9)


General Demand File 1    -->
                               NEWDEM.EXE     --> General Demand File 2
New General Demand File  -->


Description: The NEWDEM program couples the original demand distribution
             (the upper section of the file) from the 'General Demand File 1'
             and reservoir supply deficits (the bottom section of the file)
             from the 'New General Demand File' and creates the new
             'General Demand File 2'. This program is used to transfer
             information on reservoir supply deficits from one iteration
             to the following one in sequential downstream decomposition.

12 PgUp/PgDn
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
DEMGEN                                                (Manual: Section 5.10)


General Demand File        -->
                                  DEMGEN.EXE       --> Individual Demand
Demand Allocation Files    -->                         Time Series Files

Description: The DEMGEN program creates demand time series of a specified
             length for each demand target. It simply assumes that demand
             values given in a 'General Demand File' are recurring in
             annual cycles of the whole simulation period. Similarly to
             AGGRMD, this program is used only if "monitored demand
             concept" is to be applied in simulation and release allocation.
             Note that DEMGEN creates output file names automatically
             (see Help on AGGRMD or on the respective files).

13 PgUp/PgDn
------------------------------------------------------------------------------
------------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
----------------------------------------------------------------------
----------------------------------------------------------------------





                         THE ShellDP FILES







14 PgUp/PgDn
----------------------------------------------------------------------
----------------------------------------------------------------------
GENERAL DEMAND FILE                             (Appendix A, Table A.11)

Description:  The file contains demand names and monthly demand values,
              including reservoir supply deficits (one demand name per line).
              [Format: (demand names up to A4, then 12F10.*)]
Important:    The file MUST end with a 'dummy' demand line [see Manual]!!!!!!
----------------------------------------------------------------------
----------------------------------------------------------------------
DEMAND ALLOCATION FILE                    (Appendix A, Tables A.6 to A.10)

Description:  The first record contains the value of the annual median (or
              mean, or any other user selected value) inflow to the reservoir
              (or the value '-999.999' if the real demand is to be used),
              objective function type, weight factors for the objective
              function type 3, and the code for the selected simulation
              approach. The following lines consist of the demand names that
              are to be supplied by the reservoir (one demand name per line).
              [Format: free, given a demand name up to A4]
15 PgUp/PgDn
----------------------------------------------------------------------
----------------------------------------------------------------------
RESERVOIR DATA FILE                        (Appendix A, Tables A.1 to A.5)


Description:  File containing the reservoir characteristics (such as
              minimum and maximum storage, the reservoir characteristics
              curves, evaporation data, own demand of the reservoir) and
              the own inflow of the reservoir (inflow not controlled by
              any other reservoir).


Format:

              record            1:  free

              record            2:  I10

              record            3:  3F10.*, I10, F10.*

16 PgUp/PgDn
----------------------------------------------------------------------
----------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
RESERVOIR DATA FILE (continued)

               record             4:\
               ......................  I10, 12F10.*
               record       NoY +  3:/                ! NoY - number of years
                                                              in the inflow
               record       NoY +  4:\                        time series
               ......................  3F10.*
               record NoC + NoY +  3:/                ! NoC - number of points
                                                              representing
               record NoC + NoY +  4:\                        the reservoir
               ......................  F10.*                  characteristics
               record NoC + NoY + 15:/

               record NoC + NoY + 16:  empty line

               record NoC + NoY + 17:\
               ......................  F10.*
17 PgUp/PgDn   record NoC + NoY + 28:/
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
NEW RESERVOIR INFLOW FILE                                  (Appendix C, Table C.5)

Description:   File in 'general flow file format' created by the INFLOW
               program (or even created by the user). The file contains
               reservoir inflows that will replace the flow data in
               the 'reservoir data file' for the POLICY and the SIMULATE
               programs (inflow record for one year in one line).
               [Format: I10, 12F10.*].

-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
DISTRIBUTED DEMAND FILE                                    (Appendix B, Table B.3)


Description:   File created by the DEMAND program, containing the individual
               demands of the reservoir and the distributed demand.


18 PgUp/PgDn
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
POLICY FILE                                                (Appendix D, Table D.1)


Description:   The POLICY program output file. It contains the operational
               policy of the reservoir, as well as the inflow class data.

NOTE: The MODIFIED POLICY FILE (the output of the MODIFPOL program)
      has the same structure (Appendix E, Table E.1).

-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
STATISTICAL DETAILS FILE                                   (Appendix D, Table D.3)


Description:   The POLICY program output file. It contains statistical
               details of the optimization process.


19 PgUp/PgDn
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
------------------------------------------------------------------------------
------------------------------------------------------------------------------
SIMULATION FILE                                       (Appendix F, Table F.1)

Description:   The SIMULATE program output file. Reservoir initial
               and final storage, evaporation, outflow, etc. are listed
               for each month. It is a detailed presentation of reservoir
               operation according to the operational policy.


------------------------------------------------------------------------------
------------------------------------------------------------------------------
FREE DOWNSTREAM FLOW FILE                             (Appendix G, Table G.2)

Description:   The DEFICIT program output file. It is in 'general flow
               file format' and it contains data of non-consumptive releases
               of the reservoir.

20 PgUp/PgDn
------------------------------------------------------------------------------
------------------------------------------------------------------------------
DOWNSTREAM RESERVOIR SUPPLY FILE                      (Appendix G, Table G.4)

Description:   The DEFICIT program output file. It is in 'general flow
               file format' and contains data of allocated releases towards
               the 'DRD reservoir' [see Manual: Section 3.4.6].


------------------------------------------------------------------------------
------------------------------------------------------------------------------
DOWNSTREAM RESERVOIR EXTRA SUPPLY FILE                (Appendix G, Table G.5)

Description:   The DEFICIT program output file. It is in 'general flow
               file format' and contains data of available additional releases
               towards the 'DRD reservoir' [see Manual: Section 3.4.6].

21 PgUp/PgDn
------------------------------------------------------------------------------
------------------------------------------------------------------------------
INTERIM RESULTS FILE                                  (Appendix G, Table G.3)

Description:   The DEFICIT program output file. It contains the interim
               results of the allocation of reservoir releases. A detailed
               description of release allocation is given in this file.

------------------------------------------------------------------------------
------------------------------------------------------------------------------
INDIVIDUAL DEMAND TIME SERIES FILE           (Appendix I, Tables I.2 and I.3)

Description:   The DEMGEN program output file written in 'general file format'
               for each individual demand. At the beginning of an iteration,
               it contains number-of-years-in-the-inflow-record repeated sets
               of the estimated average demands. This file is continuously
               updated as individual reservoirs take part in the optimization
               process. [see Manual: Sections 3.4.5, 3.4.6, and 5.10].
Important:     This file is needed only for the "monitored demand simulation".

22 PgUp/PgDn
------------------------------------------------------------------------------
------------------------------------------------------------------------------
```

Table L.1 The SHELL HELP (continued)

```
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
AGGREGATED DEMAND FILE                             (Appendix J, Table J.1)

Description:    The AGGRMD program output file. It is in 'general flow
                file format' and contains aggregated demand time series of a
                single reservoir given in the respective Individual Demand
                Time Series Files. [see Manual: Sections 3.4.5, 3.4.6 and
                5.10].

Important:      This file is needed only for the "monitored demand simulation".

-----------------------------------------------------------------------------
-----------------------------------------------------------------------------


                                 the end

23 PgUp
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
```

APPENDIX M

The extended reference list:
The SDP-based Applications in Water Resources Management

THE EXTENDED REFERENCE LIST

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