OPTIMIZATION OF OPERATING PROCEDURES FOR MULTI-RESERVOIR SYSTEM UNDER STOCHASTIC INFLOWS

by

Foh-Kim Tai

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
Master of Science in Civil Engineering
in
Department of Civil Engineering

Winnipeg, Manitoba, 1983

OPTIMIZATION OF OPERATING PROCEDURES FOR MULTI-RESERVOIR SYSTEM UNDER STOCHASTIC INFLOWS

by

Foh-Kim Tai

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

ABSTRACT

Recent advances in reservoir studies (water-use studies) have placed emphasis on developing optimization models, especially chance-constrained models, for multireservoir systems. While the derivation of optimal policies for serially-linked deterministic reservoir systems is relatively simple, the construction of a model that produces optimal operating policies for dendritic reservoir systems requires tramendous amount of time and effort especially when natural variability of the streamflows is taken into account.

This study uses a Markovian stochastic dynamic programming model to produce a practical overall operating policy for a four-dam two-reservoir system located in North-Western region of Manitoba. Since complete optimization for the reservoir problem was found to be highly intractable, this thesis concentrates on deriving at a model that produces a more superior overall operating policy. From this study, an overall operating policy, possibly sub-optimal, was obtained. Two major problems were encountered: 1) the 'curse of dimensionality', as reported by many researchers whose used dynamic programming, and 2) the statistical nature of reservoir problem. Since the

existing policy operates on a rule curve which requires a great deal of judgement and practical experience, no detailed comparisons can be done between the existing and the newly developed policies. Although a rough comparison shows that the existing policy is slightly better than the newly developed policy, there is ample of room for improvement in the proposed model.

ACKNOWLEDGEMENTS

The author is deeply indebted to Professor Ian Goulter of the Department of Civil Engineering, University of Manitoba for his interest, cooperation and understanding during the preparation and completion of this thesis.

The author also wishes to express thanks to Mr. D. A. Cormie, Planning Engineer, Manitoba Hydro, Winnipeg, Manitoba, for supplying the necessary data for this thesis and to Professor C. Booy, Department of Civil Engineering, University of Manitoba, for his advice on engineering statistics.

Finally, a very special thanks is due to Chris Tai for typing this thesis and Henry Chu for drawing some of the figures and diagrams.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

INTRODUCTION

The systems approach to water resources planning often involves mathematical optimization and simulation of a mathematical model. In such a mathematical model the planner can take into account multiple users, multiple purposes and multiple objectives.

However, the use of optimization models does not always guarantee the development of optimal plans for water resources development and management. Given different conflicting objectives and often-times ill-defined objectives or constraints, it is difficult, if not impossible, to produce the optimal plans for water resources development and management. Two major reasons for the difficulty of arriving at a true optimal plan are: 1) benefits derived from different sources are either intangible or cannot be expressed in common units, and 2) the problem under consideration is usually of great complexity. Nevertheless, with the aid of mathematical optimization models, one can screen out the clearly infeasible and inferior alternatives. With the remaining feasible alternatives, one can evaluate in more detail those alternatives which best fulfill the system objectives and identify trade-offs between different competing objectives.

Since the advent of Operations Research in the 1940's, a number of mathematical programming models have developed ;many of which have been used in water resources planning. A few examples of those models commonly used in water resources planning are linear programming, dynamic programming, simulation, queueing theory, and non-linear programming.

Dynamic programming (DP), in particular, is extensively used in reservoir studies. Despite its seemingly complex mathematical formulations, dynamic programming is easy to implement. It is especially useful for generating optimal policies because it is a model that is suited for making sequential decisions. Furthermore, it has an advantage over linear programming for the fact that it does not require linearization of all objective functions and constraints.

A complication of water resources planning is the uncertainty imposed by climatic variability. In order to incorporate the element of uncertainty into mathematical programming models, various stochastic models have also been developed. Examination of the literature indicates that simulation models, along with other mathematical models, are often used to account for natural variability [8,10,11,17]. Non simulation models include stochastic linear programming [2,9], and stochastic dynamic programming [2,3,5,12,13,15,28,29], and chance-constrained nonlinear programming [23].

Stochastic linear programming and stochastic dynamic programming are often applied to single multipurpose reservoir studies [3,5,9,12,15,20]. The application of these models to multipurpose multireservoir studies are rarely found in the literature. One of the reasons for this is the complexity and dimensionality of the problem. However, attempts have been made by some researchers to develop models for multireservoir multiperiod operations. Some of these models are relatively simple, e.g. the joint use of dynamic programming and simulation models [8,11], while others are highly complex and difficult to derive solutions from. Some examples of these complex models are statistical and nonlinear programming models [23], and joint use of generalized-nonlinear network flow programming, stochastic dynamic programming and regression analysis [32]. In most cases, if these models are to be applied to multipurpose multireservoir studies, drastic simplifying assumptions have to be made in order to reduce the problem to a computationally reasonable size [8,9].

In this thesis, an attempt is made to use Markovian stochastic dynamic programming to approximate an overall optimal policy for a multipurpose multireservoir system. Markovian stochastic dynamic programming is essentially (deterministic) dynamic programming which incorporates first-order Markov chain theory. Apart from the advantages of dynamic programming mentioned previously, stochastic dynamic programming also takes into account natural variability. It, therefore, lends more credibility to the solution technique. As mentioned previously, simplifying assumptions are made to reduce the complexity of the problem and justifications underlying these assumptions are also given. Since complete optimization for multireservoir problem appears to be highly intractable, this study aims at improvement rather than optimization. In another words, this study emphasizes more the practicality of the model rather than its theoretical details. As such, no detailed theoretical derivations and justifications of stochastic dynamic programming model will be given.

The proposed model is applied to an example system, the Laurie river basin, located in North-western Manitoba. This basin has been managed by Manitoba Hydro since the 1950's. The operating policies obtained using this model are compared to those of Manitoba Hydro to check for model efficiency and feasibility. Descriptions of the basin, and definition of the problem and underlying assumptions are given in later chapters.

This thesis is developed in the following fashion. Chapter 1 reviews systems approach to water resources planning. Chapters 2 and 3 introduce the methodologies of dynamic programming and Markovian processes respectively. Chapter 4 describes the physical, geographical and hydrological characteristics of the river basin under study.

Chapter 5 details model development and formulation, and discusses the results obtained from the model. Chapter 6 provides some recommendations and conclusions regarding the model and the policies.

Chapter II

DYNAMIC PROGRAMMING

2.1 INTRODUCTION

In this chapter, the basic concepts and essential features of dynamic programming are presented. No attempt will be made to provide detailed theoretical justification of the dynamic programming methodology. For detailed treatment of dynamic programming model, one can refer to any number of texts of Operations Research [e.g. 21,27].

2.2 DETERMINISTIC DYNAMIC PROGRAMMING

In dynamic programming, the problem must be decomposed into series of stages. Each stage has a set of states associated with it. The states, represented by state variables, indicate the conditions that the system may find itself at that stage. At any state, a decision is made resulting in the transition to another state within the subsequent stage. Coupled with the decision there is an associated return which indicates the value of that decision. Between any two states, there exists a certain transformation function that defines the transition from one state to the other. It determines what subsequent state results from a given decision at a given state.

To demonstrate the concept, consider a deterministic reservoir operation problem. Here, the main objective is to determine the release policy for the reservoir such that the benefits derived are a maximum. To solve the problem using dynamic programming, the problem should be viewed in stages and states. In this case, the stage can be the time (expressed in years, months, weeks, etc.) and the states can be the storage levels as shown in the schematic below:

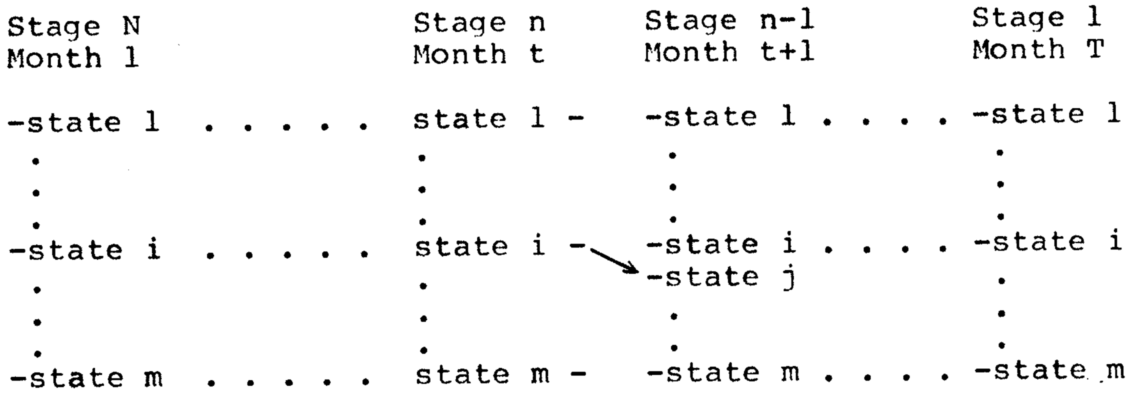


Figure 1: Schematic of deterministic reservoir operation problem

The decision would be how much water to release and the return would be the benefit derived from the water released. If one is in state i (S_i), stage n (month t), and makes a decision to release an amount (x) of water, one will end up at another state, say state j (S_j) (storage level), in the next stage (month t+1), see Figure 1. The total return would be the sum of the immediate return (i.e. benefit derived from releasing x amount of water) and the long range return which is the benefit accumulated by following the 'optimal' (to this point) path from the last stage to stage n. Inherent in the decision making process is the transformation from one state to another. This transformation may be defined by the continuity equation: Final Storage Level = Initial Storage Level + Inflow - Release. See Figure 2 for a pictorial description of the transformation function. It should be pointed out that for reservoir operation problems solved using deterministic dynamic programming technique the inflow for each stage is assumed to be the monthly average inflow. To solve the problem, it is necessary to enumerate each state starting at the last stage (an arbitrary point in time in the future) and to determine its corresponding optimal decision until the first stage is reached. By performing the above operations, it allows the development of an optimal path or trajectory which if followed gives maximum return.

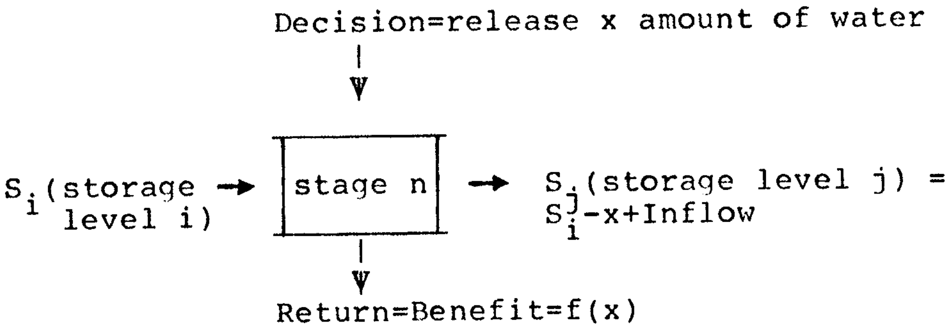


Figure 2: The transformation function

Therefore, in summary, dynamic programming is characterized by a sequence of subproblems (stages); see Figure 3.

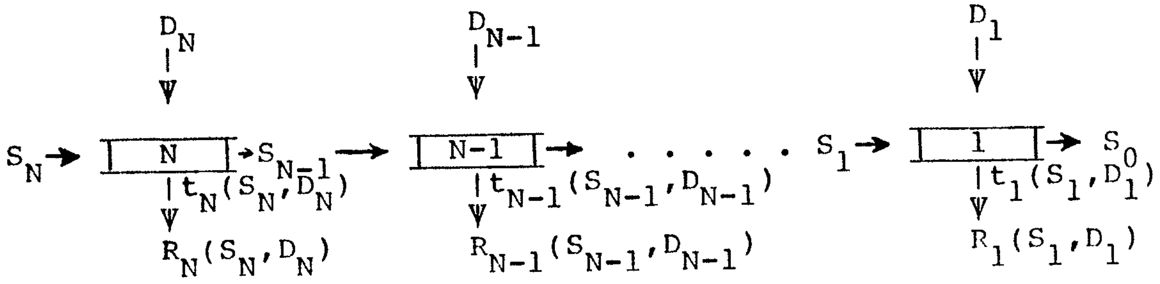


Figure 3: Problem decomposition into sequence of stages

At any stage n, a decision (D_n) is made for any state (S_n) and a short range return (R_n) is derived as a result of that decision. There is also a transformation function (t_n) that defines the relationship between the current state (S_n) and the next state (S_{n-1}). Figure 4 illustrates all the relevant model components.

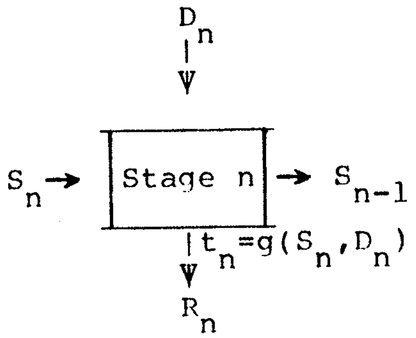


Figure 4: Symbolic representation of the model components for stage n

Note also at any stage n, the following relationships exist:

$$S_{n-1} = S_n \oplus D_n \qquad \text{where } \oplus = +, -, \text{ or } *$$

$$R_n = g(S_n, D_n)$$

$$f_n = R_n \oplus f^*_{n-1}(S_{n-1})$$

where f_n = long range return

f^*_n = optimal long range return

In general, the optimizing procedure, which makes use of recursion equation, is given by:

$$f^*_n(Sn) = \underset{D_n}{\text{opt}} \left\{ R_n \oplus f^*_{n-1}(S_{n-1}) \right\}$$

For example, the sequential optimizaton of the recursive return function for three (n=3) stages is given as follows:

Stage 1:

$$f^*_1(S_1) = \underset{D_1}{\text{opt}} \left\{ (R_1) \right\}$$

Stage 2:

$$f^*_2(S_2) = \underset{D_2}{\text{opt}} \left\{ R_2 + f^*_1(S_1) \right\}$$

Stage 3:

$$f^*_3(S_3) = \underset{D_3}{\text{opt}} \left\{ R_3 + f^*_2(S_2) \right\}$$

where each stage can be optimized individually and sequentially by making use of the transition function, such as $S_1=S_2 \oplus D_2$ and $S_2=S_3 \oplus D_3$. It can be shown that the overall system is optimized at stage 3 by a sequential imbedded optimization function of the following form:

$$f_3^*(S_3)=\underbrace{\underset{D_3}{\mathrm{opt}}\left\{ R_3+\underbrace{\underset{D_2}{\mathrm{opt}}\;[R_2+\underbrace{\underset{D_1}{\mathrm{opt}}\;(R_1)])}_{\text{Stage 1}}}_{\text{Stage 2}}\right\}}_{\text{Stage 3}}$$

It is appropriate, at this point, to quote Bellman's principle of optimality:

> An optimal policy has the property that, whatever, the initial state and the initial decision are, the remaining decision must constitute an optimal policy with regard to the state resulting from the first decision [21].

The above statements of the principle of optimality has an intuitively obvious basis. It simply means that every optimal policy consists of optimal subpolicies.

2.3 STOCHASTIC DYNAMIC PROGRAMMING

In this section the concept of stochastic dynamic programming is presented. Conceptually, it is quite similar to deterministic dynamic programming; except it embodies random phenomena which are described by probabilities. As before, an example problem is used to illustrate the fundamental concept of stochastic dynamic programming.

2.3.1 Example: The Forgetful Traveller

Consider the network in Figure 5. The problem involves a forgetful traveller who wants to travel from city 1 to city 6 or 7 at the lowest cost. Note that the problem is broken into stages and states. The fact that the traveller is forgetful is incorporated in the following fashion. When he is instructed to take certain action (A or B) he remembers to do so with a certain probability of p. There is also a probability (1-p) that he forgets and does the opposite. In Figure 5, those states that are labelled A or B are the traveller's possible actions and there are probabilities (shown in fractions) and costs (number in parentheses) attached to each of the actions. For example, in city 1 the probability of going to city 2 via plan A is 0.3.

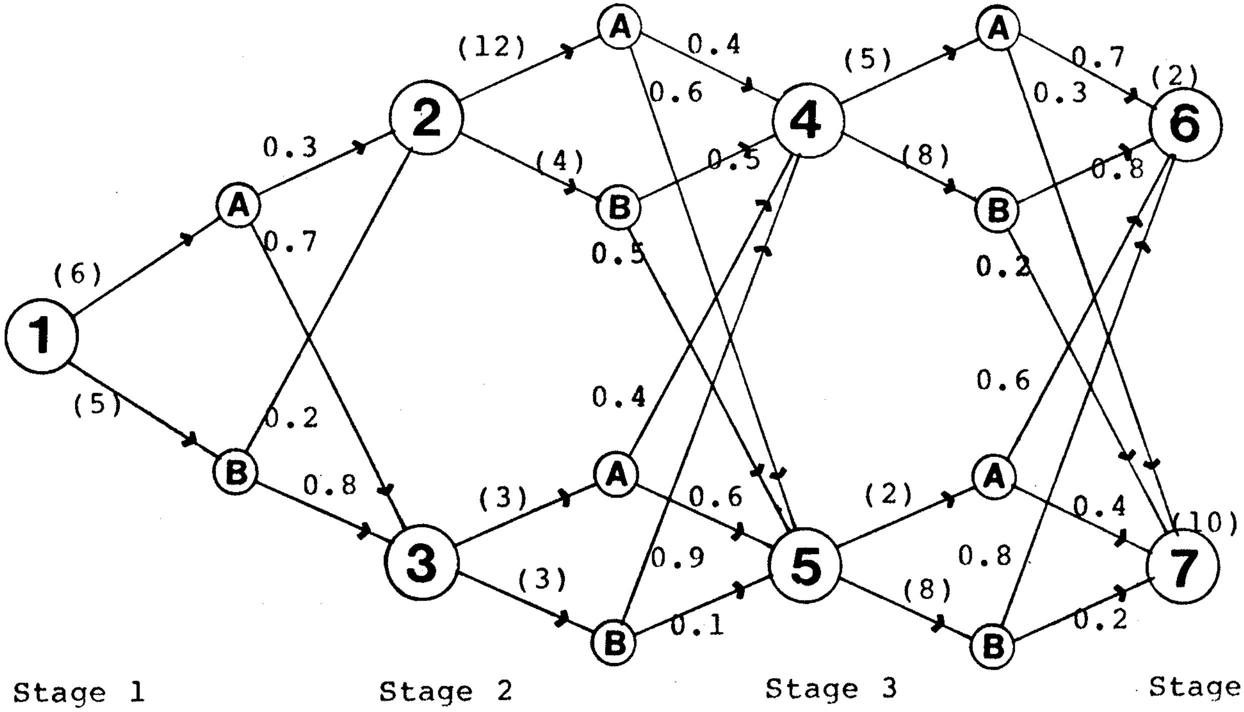


Figure 5: Probabilistic routing problem

To solve the problem, one starts again at the the last stage and works backward evaluating each state until one reaches the starting state. For each state and each action the expected cost is computed. This becomes the long range expected cost and it is added to the immediate cost. For instance, from city 4 to the last stage, the expected cost would be:

Action A: $5+(0.7)2+(0.3)10=9.4$ - optimal

Action B: $8+(0.8)2+(0.2)10=11.6$

Therefore, if the traveller is at city 4 he chooses action A. Similarly, if he is in city 5, the two possible routes and associated expected cost would be:

Action A (5-6): $2+(0.6)2+(0.4)10 = 7.2$ -optimal

Action B (5-7): $8+(0.8)2+(0.2)10 =11.6$

and he will choose plan A.

By employing the recursive relation:

$$f(S_n)=\min_{S_n} \left\{R_n+P_{n,n+1}\cdot f^*(S_{n+1})\right\} \qquad \text{for all stages}$$

where $P_{n,n+1}$= probability of transforming from one state to the next.

the minimum expected cost can be computed. The final results are shown in Figure 6. Note that the long range expected costs are given in square brackets and the short range expected costs are shown on each stochastic state i.e. the cost associated with actions A or B.

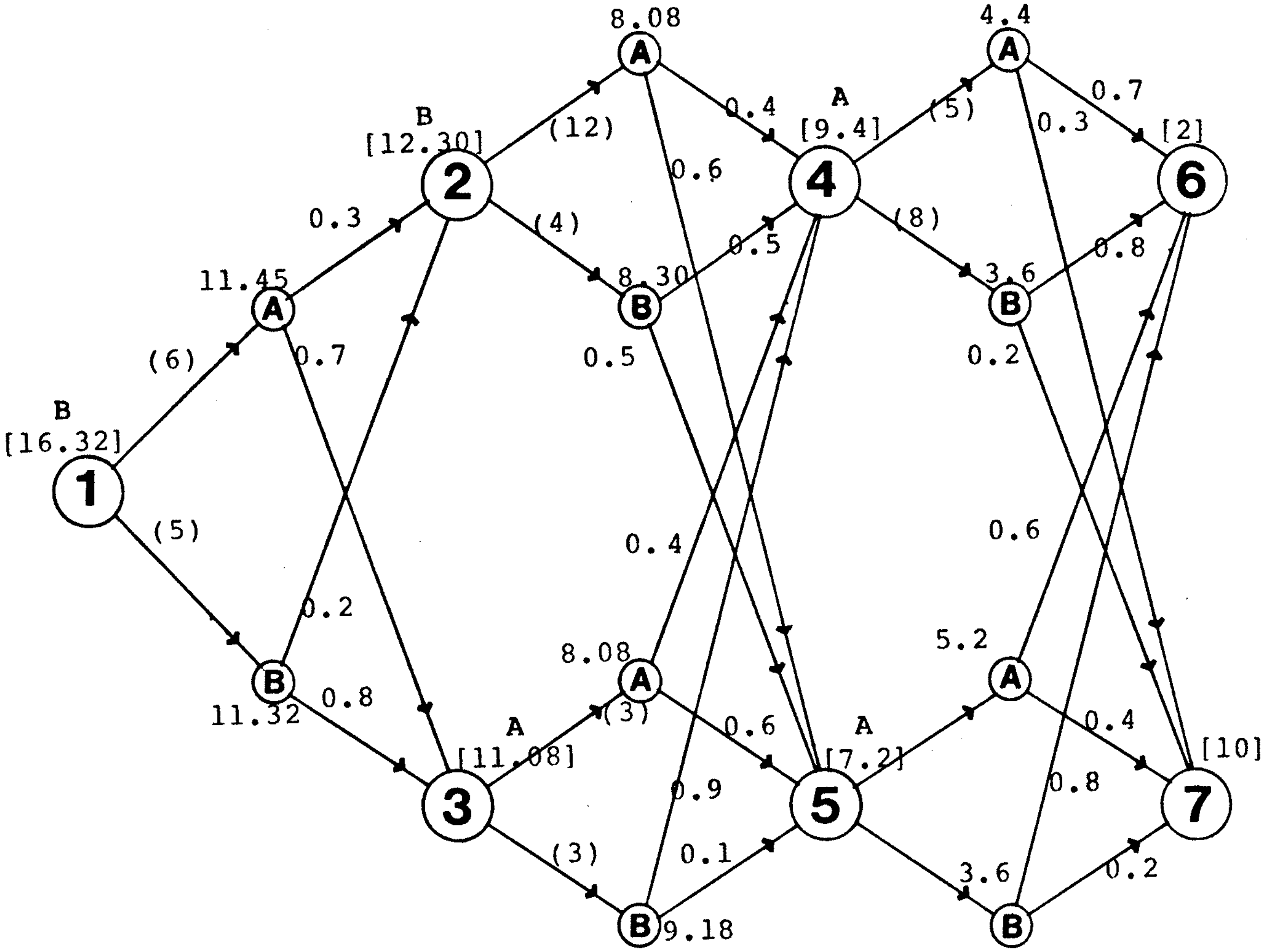


Figure 6: Solutions to probabilistic routing problem

As can be seen from the above example stochastic dynamic programming is similar to deterministic dynamic programming except that each decision must consider some additional stochastic states to account for uncertainty. In developing a solution by stochastic dynamic programming one obtains what is known as an optimal policy. An optimal policy is outcome dependent. The decision at each state is dependent on the current value of the state at that stage. Due to uncertainty in the results of any given decision, it is necessary to review the current state before making the next decision. Recall that optimal decision rules are of the form "if the state resulting from a decision is ... then take action....."

In Chapter 5, the stochastic dynamic programming concept will be applied to reservoir operations and the solutions will be presented in the form of optimal policies. The various characteristics of stochastic dynamic programming associated with Markov processes will be given in Chapter 5.

Chapter III

MARKOV CHAINS

3.1 INTRODUCTION

In this chapter the fundamental concepts and properties of Markov chains [22,30] will be presented with the aid of an example. This chapter only deals with finite and discrete first-order Markov processes that are appropriate for this study.

A Markov process has the property that the future values of the process are dependent on the past values. A Markov chain is a special kind of Markov process where states of the process take on discrete and finite values. An additional feature of the first-order Markov chain is that it has the property that the current state of the system depends only upon the immediately preceeding state of the system. A Markov chain thus represents an approximation to continuous Markov process and it facilitates the construction of stochastic optimization models.

3.2 TRANSITION PROBABILITY MATRIX

Before proceeding with the derivation of the transition probability matrix, two basic concepts in Markov chain analysis are presented. The first concept is the state of the system and the second is the state transition that the system may undergo. The state of a system describes the "position" of the system at any instant in time. Consider a reservoir problem: The state of the system is the reservoir level at the beginning (or end) of any time period, say, a week. The state space, usually continuous, is represented by discrete values. As time passes, the system may move from one state to another state. In other words, the system may undergo a transition from one state to another. For the reservoir problem, the transition from one storage level (state) to another storage level is dependent on the amount of water released and the inflow.

To clarify the concept, consider a fictitious reservoir with the following characteristics:

Maximum Storage Capacity :	4 units (in million of cubic meters)
Dead Storage :	1 unit
Minimum downsteam release:	3 units/week

In this case, the state space may be represented by discrete values such as s=1,2,3 and 4 (units of water). The state transition can also be described by the transition diagram as shown in Figure 7. Each circle denotes a state (storage level) and the arrows represents possible transitions. Note that no change in water level is depicted as a transition to the same state in the next time period.

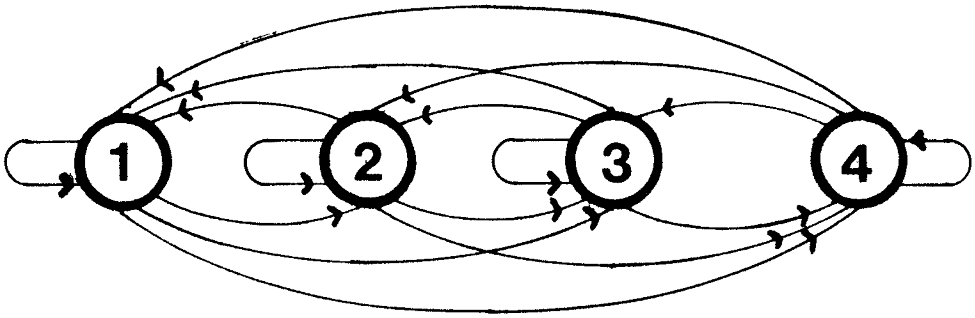


Figure 7: The Transition Diagram

The use of transition diagram can be explained as follows. At the beginning of a week, if the reservoir level is at state 1 and if the inflow is 5 units, releasing 3 units of water for downstream requirements, the reservoir level will be at state 3 at the end of the week. This implies that the system is moving from state 1 at the beginning of the week to state 3 at the end of the week (or the beginning of next week). Such transitions are shown in Figure 7.

Recognizing that a transition from one state in one time period to another state in the following time period may have a certain probability associated with it, it is possible to build up a transition probability matrix. For the reservoir problem, the transition probability matrix, of size 4X4, may be written as follows:

$$P=\begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ p_{41} & p_{42} & p_{43} & p_{44} \end{bmatrix}$$

Here, P_{ij} represents the probability of going from state i, at time t, to state j at time t+1.

3.3 DERIVATION OF TRANSITION PROBABILITY MATRIX

This section describes the method of deriving the inflow transition probability matrix from the given inflow records. In this case, the probability of getting a particular flow in one month given another flow in the previous month will be developed.

Consider the following (partial) historical inflow(cfs) records (see Appendix A) for the Laurie Dam of the example basin:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	130	326	248	313	485	429	446	111	232	141	347	229
1971	121	75	119	416	873	436	219	345	701	962	394	169
1972	151	145	41	168	1094	194	267	223	287	293	183	126
1973	30	30	51	166	757	261	466	193	159	413	390	247
1974	107	50	18	367	721	582	404	117	140	88	289	180
1975	319	45	45	146	766	523	460	291	43	80	103	164
1976	90	113	209	270	316	572	958	201	252	167	285	190
1977	66	70	70	559	734	492	179	6	218	247	359	260
1978	146	261	187	27	558	467	266	643	672	715	411	356
1979	404	313	234	252	610	593	34	95	130	94	22	30
1980	22	0	0	169	399	377	265	446	488	490	357	307

To derive the transition probability matrix one has to decide what the relevant parameters of the Markov chain represent. In this case, the state space is represented by the inflow Q, and the transition is over a period of one month. Note the difference in state space representation between this problem and the previous one. To develop the transition probability matrix, going from January to February, it is necessary to discretize the state space Q according to the magnitudes of inflows in the corresponding months. The transition probability matrix can then be formed by observing the number of times the inflow equaled the inflow at time t+1, Q_j, after having in Q_i at time t. Division by the total number of transitions from i to j completes the calculations. For simplicity, say, the state space Q for January and February is discretized into 4 states as shown below:

State	1	2	3	4
Inflow Interval	0-100	101-200	201-300	301-above

By examining the inflow records for January and February one can categorize each inflow value to a particular state as shown below:

January		February	
Inflow	State	Inflow	State
130	2	326	3
121	2	75	1
151	2	145	2
30	1	30	1
107	2	50	1
319	3 4	45	1
90	1	113	2
66	1	70	1
146	2	261	3
404	4	313	3
22	2 1	0	1

From the above table the number of times the inflow moves from state i in January to state j in February can be counted. This is summarized in the matrix below:

$$\begin{array}{cc|cccc|}
 & & & \text{February} & & \\
 & \text{State} & 1 & 2 & 3 & 4 \\
\hline
\text{J} & 1 & 2 & 1 & 0 & 0 \\
\text{a} & 2 & 3 & 1 & 2 & 0 \\
\text{n} & 3 & 1 & 0 & 0 & 0 \\
. & 4 & 0 & 0 & 1 & 0 \\
\hline
\end{array}$$

The elements in the above matrix simply shows the number of times the inflow in January moves to another inflow in February for any pairs of flows or states. By dividing each element of each row by the corresponding total number of transitions (row sums) the transition probability matrix can be obtained:

		February			
	State	1	2	3	4
J	1	0.67	0.33	0.00	0.00
a	2	0.50	0.17	0.33	0.00
n	3	1.00	0.00	0.00	0.00
	4	0.00	0.00	1.00	0.00

The procedure outlined above develops the transition probability matrix going from January to February. Since there are 12 months in a year, there would be 12 transition matrices, where each matrix can be formed in a similar fashion. In matrix notation the elements of each matrix can be denoted by Pt_{ij} where it defines the probability of a streamflow $Q_{j,t+1}$ in month t+1, given a streamflow $Q_{i,t}$ in month t.

It should be emphasized that the discretization of Q requires considerable attention. Too coarse a Q interval will result in the system being misrepresented and the loss of accuracy. Too fine an interval will increase the computational requirements of the dynamic programming model which by its very nature is already computationally intensive.

The transition probability matrices, used in this study, for different dam sites can be found in Appendix C. Each matrix is developed using the above procedure and each has significantly more discretization intervals than the one used above.

3.4 SOME RELEVANT PROPERTIES OF MARKOV CHAINS

1. Referring to the transition probability matrix P given in previous section, each row represents one-step transition probability over all states. It follows that the row sums of P must be equal to 1:

$$\sum_{j=1}^{m} P_{ij}=1.0 \qquad \text{for all } i$$

This point is obvious if one takes note that the individual values, pij, are derived by simple proportioning.

2. All elements in P must have values between 0 and 1 inclusive. i.e.

$$0 \geq p_{ij} \geq 1 \qquad \text{for all } i, j \text{ and } t$$

3. No row in the matrix should contain purely zero elements. This follows from point 1.

3.5 ASSUMPTIONS USED IN FIRST-ORDER MARKOV CHAINS

It was stated earlier that a Markov process is that process by which future states depend on the previous states. In mathematical notation:

$$Pr(X_t=j_t)=Pr(X_t=j_t|X_{t-1}=j_{t-1},X_{t-2}=j_{t-2},\ldots x_0=j_0)$$

The above expression simply depicts that the probability of being in any particular state t where x_t(a variable) takes on value j_t is the conditional probability of being in state t, where $x_t=j_t$, given all the preceeding states.

In first-order Markov chain, as discussed previously, any future state is assumed to be dependent upon the immediate preceeding state. The practical implication of such statement is that the probability of having a particular inflow in May, say, depends more on the inflow in April rather than the those of the other months. The resulting transition matrix thus describes one-step transition from one state to another because of the dependency of current state on the immediate preceeding state. In mathematical notations:

$$Pr(x_t=j_t) = Pr(x_t=j_t|x_{t-1}=j_{t-1})$$

or

$$P_{ij} = Pr(x_{t+1}=C_j|X_t=C_i)$$

where

X_t = state of the system at time t

C_j = constant

In using first-order Markov chain, serial correlation studies should be carried out to check if the above assumption made is true i.e. to check if indeed the streamflow data of any month has higher correlation coefficient with those of the immediately preceeding month than with those of any other months.

Another underlying assumption of first-order Markov chain is that the transition probability matrix associated with the Markov chain for a given month is stationary because P remains constant over time. This merely suggests that the same transition probability matrix describes the probabilistic behavior of the system for all future one-step transitions. However, in practice, P may not always stay stationary because, as time passes, the inflow records will become longer and the calculation of P may also be changed as a result of new data. Therefore, in practice the 12 transition probability matrices should be updated from time to time.

Finally, a hydrologic cycle of one year is assumed for this study. This assumption implies that the distribution of inflows will be the same in any given month t regardless of the year. Thus:

$$P_{ij}^{t} = P_{ij}^{t+12}$$

3.6 CLASSIFICATIONS OF MARKOV CHAINS

1. Accessibility - State j is said to be accessible if it is possible to go from state i to state j i.e. $P_{ij}>0$.

   For example, if it is possible to go from 400 cfs of flow in May to 900 cfs of flow in June then the state associated with 900 cfs in June is said to be accessible from the state associated with 400 cfs in May.

2. Communication - Two states i and j are said to be communicating if j is accessible from i and i is accessible from j regardless of the number of transitions.

3. Absorbing State - A state is referred to as an absorbing state if it is impossible to leave that state. Consider the matrix P_1 given below:

$$P_1 = \begin{array}{c|ccc|} \text{State} & 1 & 2 & 3 \\ \hline 1 & 1 & 0 & 0 \\ 2 & 1/2 & 1/4 & 1/4 \\ 3 & 1/3 & 1/3 & 1/3 \\ \hline \end{array}$$

State 1 is accessible from states 2 and 3. Once in state 1, it is impossible to leave state 1. A Markov chain is said to be absorbing if any state is absorbing. In hydrology, it is very unlikely that an absorbing state would be found in practice. The natural variability of flows almost guarantees that low flows will eventually be followed by high flows.

4. Periodic Process - A periodic process is characterized by zeros in the diagonal elements. For example, in the matrix P_2, if the process is in states 1 and 2 they will always move to either states 3 or 4, and if the process starts out in states 3 or 4, it will always move to either states 1 or 2. This forms a cyclic process. In hydrology, such cyclic process seldom occurs in monthly streamflow data.

However, if one considers seasonal streamflow data, which is rarely done in reservoir studies, the cyclic process may be evident.

$$P_2 = \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{bmatrix} 0.0 & 0.0 & 0.7 & 0.3 \\ 0.0 & 0.0 & 0.4 & 0.6 \\ 0.2 & 0.8 & 0.0 & 0.0 \\ 0.6 & 0.4 & 0.0 & 0.0 \end{bmatrix}$$

3.7 SUMMARY

This chapter presents an introductory treatment of a special class of stochastic processes called Markov chain. The fundamental concepts and properties of Markov analysis were discussed and related to their applications in hydrology. The study of Markov model provides valuable insight into the analysis of problems that have several potential outcomes after the passage of periods of time. Useful as it is, one should be aware of the simplificatons made in the model and the validity of these simplifications should be verified for each application.

Chapter IV

THE LAURIE RIVER DRAINAGE BASIN

4.1 INTRODUCTION

Manitoba is one of the energy rich provinces of Canada well-endowed with water resources. Its many rivers and lakes facilitate the production of hydroelectric energy for local consumption and export. The Laurie river basin is one of the smallest basins in Manitoba and provides a relatively small amount hydroelectric energy. Small as it may, this basin is appropriate for the testing of the feasibility of an optimization model developed for the purpose of reservoir operations. This chapter gives an account of the geological, physical and hydrological characteristics of the basin. In addition, a final section is included to present a breakdown of the problem as it is considered using optimization techniques, namely, stochastic dynamic programming and Markov chain theory which have been outlined in previous chapters.

4.2 GEOGRAPHICAL AND PHYSICAL CHARACTERISTICS OF THE LAURIE RIVER BASIN

The Laurie river basin, with an area of 560,000 Hectares (2164 square miles), is located in North-Western region of Manitoba, see Figure 8. The major river in the basin is the Laurie river. It links a number of major lakes in the basin in series. These lakes are Laurie Lake, Tod Lake, Eager Lake, Megavock Lake and Granville Lake. The Russell river is the major tributary of Laurie river. It connects the Russell Lake and some of the smaller lakes upstream to the Laurie river. Together they form a Y-shape system, see Figure 9.

As shown in Figure 9, there are three major dam sites which are of importance to this study. The first of these sites is the two Laurie hydroelectric plants, namely, Laurie generating stations number 1 and 2. Laurie generating station number 1 is a two unit power plant capable of producing approximately 5,000 kilowatts of electricity under a 16.8 meter (55 foot) head. Its relative location is shown in Figure 9. Laurie generating station number 2 is located 11 kilometers (7 miles) upstream of Laurie generating station number 1. It is a single unit power plant capable of producing approximately 5,000 kilowatts of electricity under a 17.7 meter (58 foot) head. The next dam site is the Russell dam situated at the outflow of Russell lake. It is a control structure which regulates approximately 60% of the winter dependable storage water for the two Laurie

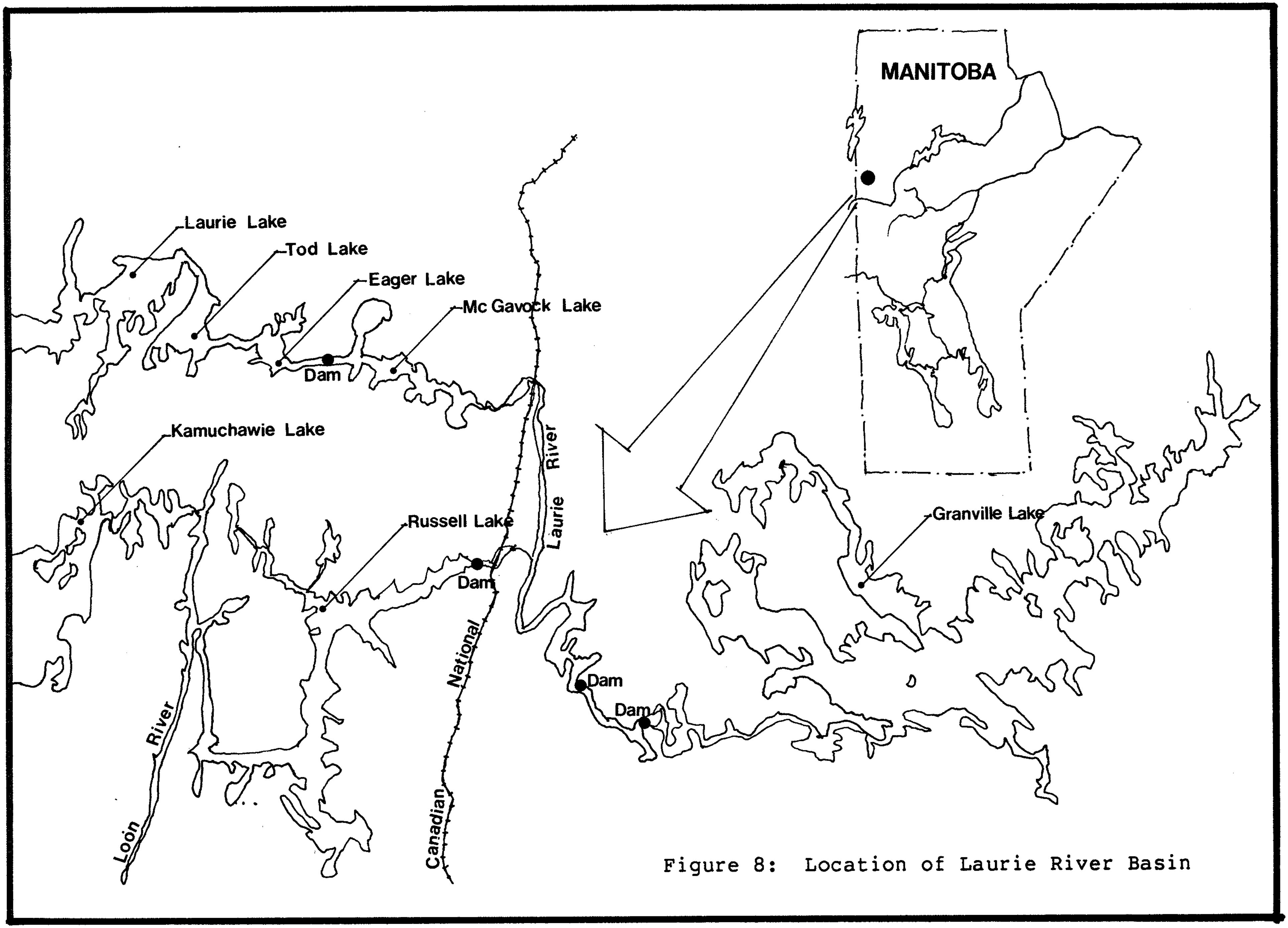


Figure 8: Location of Laurie River Basin

HYDRAULIC SCHEMATIC OF THE LAURIE RIVER DRAINAGE BASIN

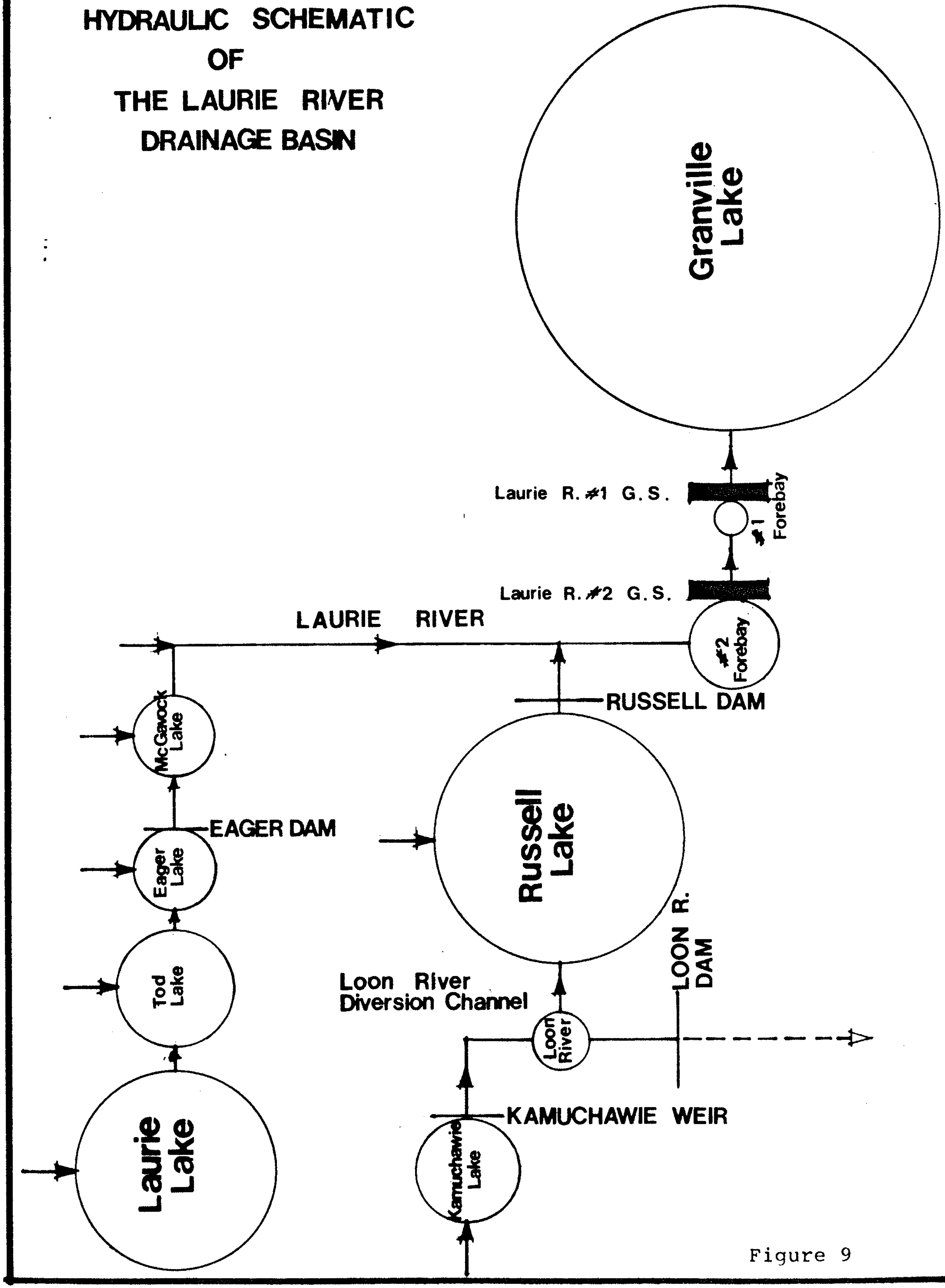


Figure 9

generating stations. The last site is the Eager dam. Located downstream of the Eager Lake, it regulates approximately 40% of winter dependable flow for the two down stream generating stations. It should be noted that the water regulations are done using stop-logs. This condition has an impact on the discretization of storage states when dynamic programming is applied to the problem. The significance of this feature will be discussed in the next chapter.

4.3 HYDROLOGY OF LAURIE RIVER BASIN

This section presents the various hydrologic and hydraulic characteristics of the basin in relation to the three dam sites described above. All data and some specifications and equations are set or provided by Manitoba Hydro [33]. As a result, no detailed derivations regarding some of the equations and specifications are given.

Before describing the various features of the two generating stations it is useful to provide some additional details and definitions about the site. Since the generating stations are relatively small in scale and located close together they may be lumped together as a functional unit. Furthermore, there is relatively little storage in the reservoir associated with generating station number 1 thus indicating that only the reservoir of generating station number 2 is effective as a storage unit.

This suggests that the characteristics of the two generating stations may be based on those of either one of the stations. In this case, Laurie generating station number 2 is used as the basis since it is of larger size. The unification of the two generating stations also simplifies the optimization problem as it requires only one set of optimal policies. It also eliminates the extremely difficult problem of merging two sets of optimal policies; a problem which would occur if the two generating stations were treated separately.

It should also be pointed out that the existing policy operates on a monthly basis with each year being divided into two seasons, namely summer and winter. The summer months start on May and end on October. The remainder of the months are considered winter months. The proposed model also incorporates these features. It was stated by Manitoba Hydro that one megawatt of electricity is worth an average of $16 (1983) during winter months and $10 (1983) during the summer months. Note that these prices are average seasonal values. Detailed breakdown of these prices, i.e. monthly values, can be found in the main program in Appendix B.

Finally, the time taken for water to flow from Eager and Russell reservoirs to Laurie reservoir is 2 days and 1 day respectively. Therefore, as far as this study is concerned, the effect of lag time need not be considered since the lag time is negligible in comparison to a month.

Some of the notations used in this section are:

V = Storage volume in cfs weeks

E = Elevation in feet

FB = Forebay height in feet

Q = Discharge in cfs

MW = Megawatt

H = Head in feet = Forebay - Top of logs

S = Storage level in feet

Table 1 summarizes the hydraulic characteristics of the three dam sites.

Figure 10 shows the energy-inflow curve. The equation given in Figure 10 indicates that energy is a function of the head (forebay) and the inflow. In this case the inflow is the inflow to generating station number 2. This equation incorporates the value of hydroelectric power from both generating stations. Such equation has been set by Manitoba Hydro. The inflow records of the three major dam sites can be found in Appendix A.

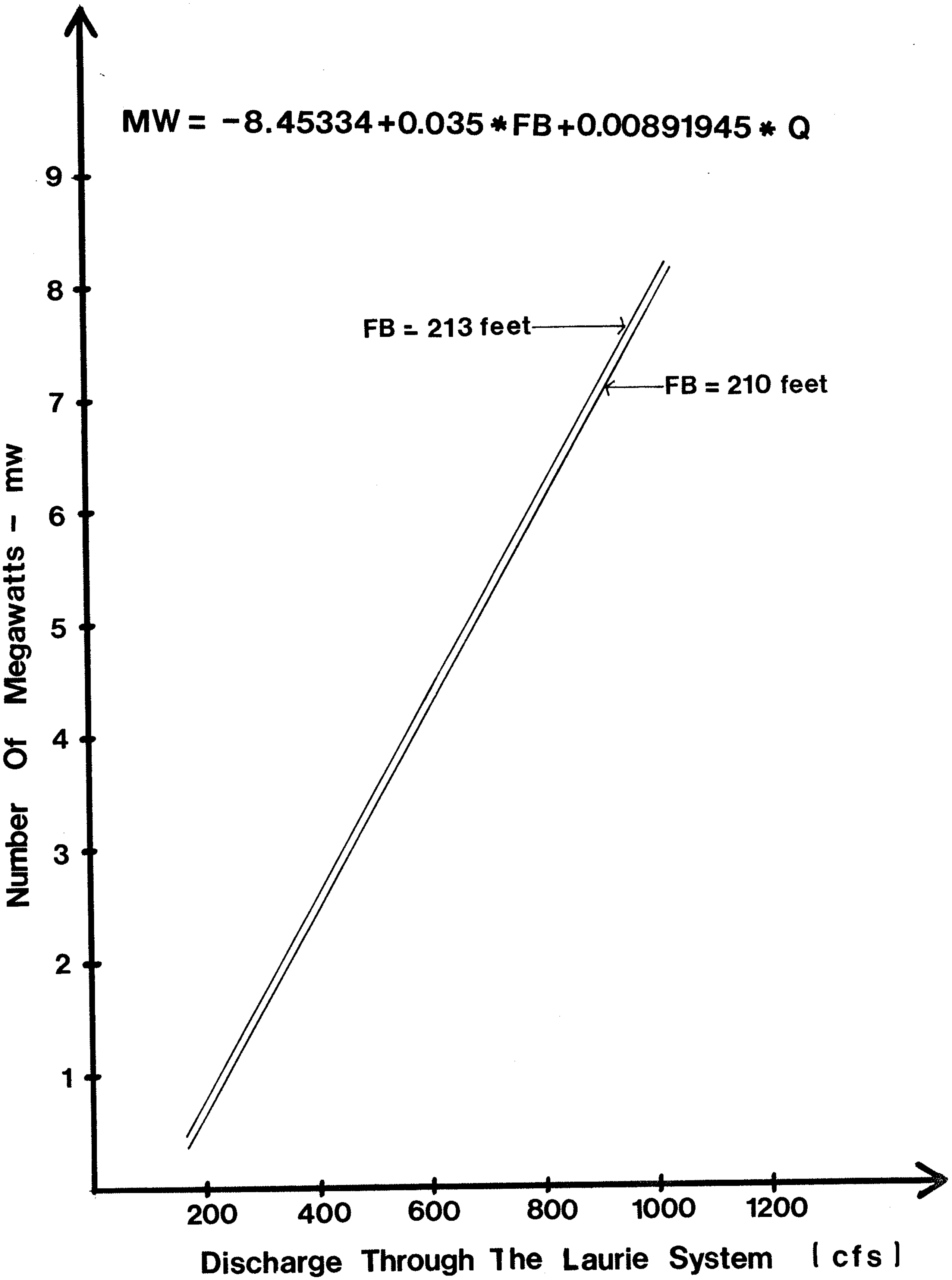
TABLE 1

Hydraulic characteristics of various dams

Feature	Laurie Generating Station		Eager Dam	Russell Dam
	#1	#2		
Stage-Storage Curve	V=920E-176,640	V=9.0462E-2693.11E+200440	V=2070E-207000	V=2580E-260580
Maximum Storage Level	Summer-155 Winter-155	Summer-212 Winter-213	Summer-115 Winter-115	Summer-115 Winter-115
Minimum Discharge	Q=450	Q=450	*	*
Discharge relationship/gate	Q=(3.27+0.4/26H) H1.5(14-0.2H)	Q=(3.27 0.4/48H) H1.5(14-0.2H)	Q=40H3/2	Q=30H3/2
Number of Openings	5	5	2	2
Average height of logs(ft)	1.01	1.01	0.835	0.860

* - unknow at this stage (It depends partly on the policy downstream)

Note - elevations given are with respect to local datum


MW = −8.45334+0.035∗FB+0.00891945∗Q
FB = 213 feet
FB = 210 feet
Number Of Megawatts - mw
1
2
3
4
5
6
7
8
9
200
400
600
800
1000
1200
Discharge Through The Laurie System (cfs)

4.4 THE PROBLEM

This section describes the overall picture of the problem. It serves as an introduction to the formulation of stochastic dynamic programming problem given in the next chapter.

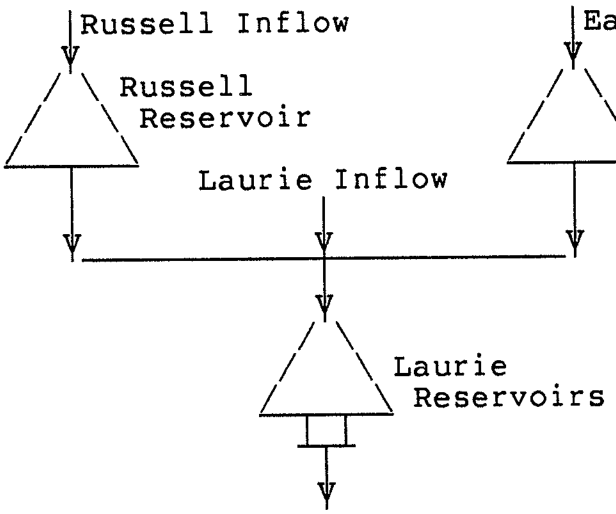


Figure 11: Simplified view of the reservoir system

The problem here is:

Given a system of three resevoirs shown in Figure 11, develop an overall optimal operating policy for the reservoir system. The constraints are really simple. The first constraint requires that at least 450 cfs be released to the Laurie generating stations (with optimum operating plant capacity of 1150 cfs) every month. The second and last constraint is one of environmental concern. It involves the sufficient release of water in Eager dam such that the people who own summer vacation cabins downstream of the dam will not complain about low water levels (and at times flooded docks). This constraint is not as severe as it appears as the reservoir system is situated in a remote area where there are only a handful of cabins located downstream of Eager dam.

Although the problem involves a small reservoir system and seems trivial, to come up with a truly optimal policy would require a tremendous amount of effort and time. To date, there have been no optimization models developed for the analysis of operation of stochastic multireservoir systems. Such a point has been realized by many authors in the literature [31,32]. An attempt to develop a procedure to determine the optimal policy or at least an operating policy better than the existing one will be given in the next chapter.

Chapter V

MODEL FORMULATION

5.1 INTRODUCTION

This chapter begins with the formulation of the stochastic dynamic programming model for the operation of a single reservoir and downstream-use system. Since the primary interest of this study is to develop operating policies for a multireservoir system, an extension of stochastic dynamic programming model to a multireservoir system will subsequently be introduced. In order to facilitate better understanding, some vital components of the model will be presented in seperate sections where their pertinent features can be discussed in more detail.

5.2 DECOMPOSITION OF A SINGLE RESERVOIR PROBLEM

As mentioned previously, all dynamic programming problems must be decomposed into series of stages and associated states. As far as regulation of a single reservoir is concerned, there are a few basic variables to consider, namely, inflow, storage level (or volume), and release. To obtain operating policies for the reservoir using stochastic dynamic programming, the stages and states of the problem must be defined. Since the existing operating policies for the Laurie system are monthly policies, months have been chosen as stages with the state representing the storage level in the reservoir. Associated with each state at every stage there are "substates" representing the random inflows. These "substates" are the flow states which represent the range of possible flows which may occur in that stage i.e. month. The probability of passing from an inflow state in one month to another inflow state in the subsequent month becomes the transition probability; developed in Chapter 3. A schematic of problem decomposition is shown in Figure 12.

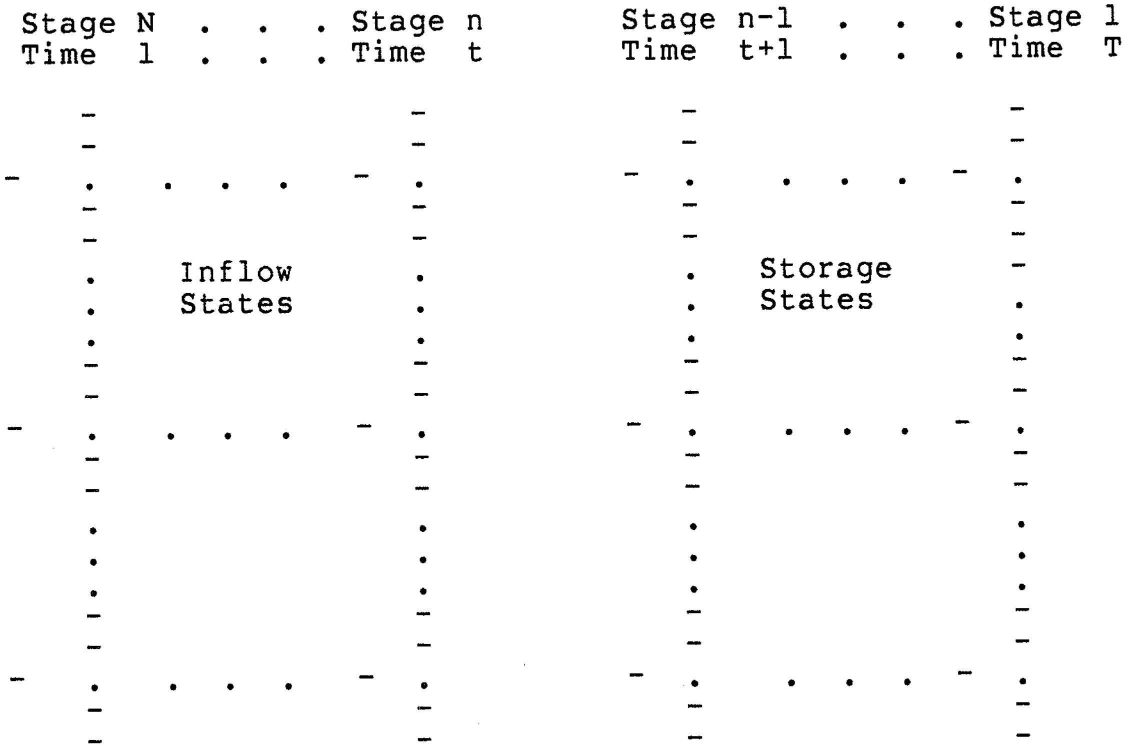


Figure 12: Schematic of stochastic reservoir operation problem

Note that the problem can be thought of as a two-state dynamic programming problem as compared to most problems where they are decomposed into single-state stages. In this case, one state represents the storage in the system in a given month and the other state represents the flow in that month. From Figure 12, it is obvious that the continuous variables, inflow, release, storage and time are represented by their corresponding discrete values where each value takes on certain ranges. For this study, the inflow, Q, is discretized into 10 intervals. Any interval which does not take on any values found in the inflow records will be dropped. The reason for dropping the "empty" intervals is that in Markov chain theory no row in the transition probability matrix should contain pure zero elements. Storage level is discretized according to the number of stop-logs; it may be 2 or 3 logs per storage interval depending on the reservoir considered.

5.3 FORMULATION

In order to facilitate mathematical formulation of stochastic dynamic programming, it is necessary to define a number of variables:

t = time,month

i = index for inflow at time t

j = index for inflow at time $t+1$

k = index for storage at time t

l = index for storage at time $t+1$

Q_{it} = inflow i at time t

S_{kt} = storage k at time t

R_{kilt} = release, at time t, as a result of going from S_k to S_l when the inflow is Q_{it}

P_{ij}^{t} = probability of going from state i, at time t, to state j at time t+1

f_t^n = long range return for any state in stage n, time t

g( ) = a function of; g(t) would be a function of t

F = benefit function describing the monetary value of water

B_{kilt} = short range benefit as a result of a decision to go from storage level k, at time t, to storage level l, at time t+1, given inflow Q_{it}

Referring to Figure 12, at any stage n, time t, given the initial storage level, S_{kt}, the inflow, Q_{it}, and final storage level, $S_{l,t+1}$, the release is calculated as:

$$R_{kilt} = S_{kt} + Q_{it} - S_{l,t+1} \qquad \text{. . . . . (1)}$$

which simply means that: Release=Initial Storage + Inflow - Final Storage. Note that since the reservoirs considered are of small sizes, the effect of evaporation has been ignored. The corresponding short range return is:

$$B_{kilt} = g(R_{kilt},F) \qquad \text{. . . . . (2)}$$

Given the same conditions as before, the associated long range expected return would be:

$$f_t^n(k,i) = \sum_{j=1} P_{ij}^t * f_{t+1}^{n-1}(l,j) \qquad \ldots\ldots (3)$$

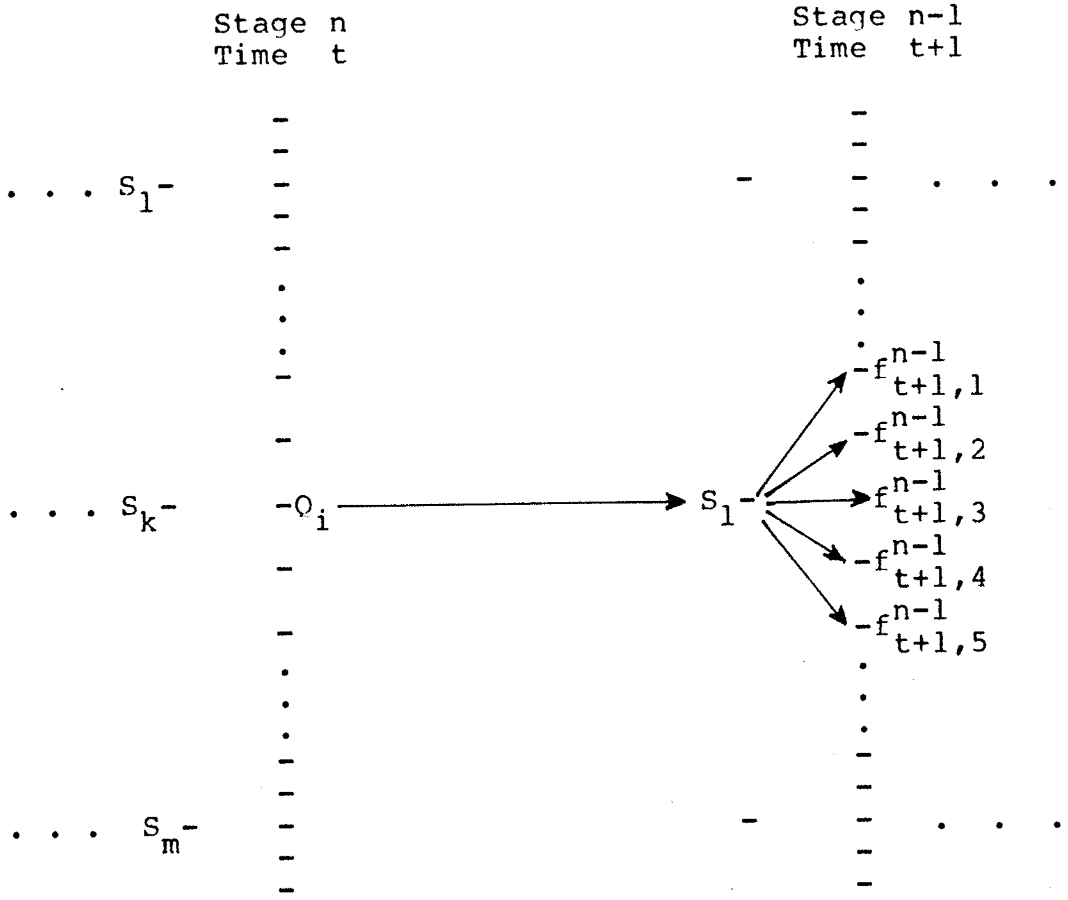


Figure 13: Diagram showing the calculations of long range expected return

With reference to Figure 13, the long range expected return for initial storage level k, inflow state i, ending at final storage level l, can be calculated using equation 3:

$$f_t^n(k,i) = P_{i1}*f_{t+1,1}^{n-1} + P_{i2}*f_{t+1,2}^{n-1} + P_{i3}*f_{t+1,3}^{n-1} + P_{i4}*f_{t+1,4}^{n-1} + P_{i5}*f_{t+5}^{n-1}$$

To apply the dynamic programming algorithm to this problem, it is necessary to use backward recursion i.e. to start at the last stage i.e. stage 1, at time t=T and work backward. Assume the objective function is to maximize return, then for the last stage:

$$f_T^1(k,i) = \underset{l}{\text{maximum}}\ [B_{kilt}]$$

Moving backward one stage to stage 2 i.e. with two periods to go, the long range expected return for any inflow state is given by:

$$f_{T-1}^2(k,i) = \underset{l}{\text{maximum}}\ [B_{kil,T-1} + \sum_j P_{ij}^{T-1} f_T^1(l,j)]$$

for all k, l; l feasible

In general, for any stage and state, the following recursive relationship can be used:

$$f_t^n(k,i) = \underset{l}{\text{maximum}}\ [B_{kilt} + \sum_j Pt_{ij} \cdot f_{t+1}^{n-1}(l,j)]$$

for all k,l; l feasible

. . . . . (4)

Note that the above relationship is merely the sum of equations 2 and 3. One also takes note of the similarities of stochastic dynamic programming outlined in Chapter 2 and Markovian stochastic dynamic programming just presented above. The only difference between them is the adaptation of different statistical techniques to account for uncertainty.

Sometimes, if the planning horizon is long it is impractical to assume that present and future values of a fixed amount of benefit are the same. To account for such a fact a generalized relationship can be rewritten such that the present value of the discounted benefits are maximized. The new relationship is given by:

$$f_t^n(k,i) = \underset{l}{\text{maximum}}\ [B_{kilt} + (1+r)^{-1} \sum_j Pt_{ij} \cdot f_{t+1}^{n-1}(l,j)]$$

for all k,l; l feasible

. . . . . (5)

where r = annual interest rate

Sequential application of the above expressions for each period (month) of the year and repeating the process for a number of annual cycles results in a situation where optimal policy begins to repeat itself on a yearly basis. This policy is referred to as steady-state policy. Steady-state conditions are reached only when $f_t^{n+12}(k,i)-f_t^n(k,i)$ is constant for all states k and i and all periods t within a year. Such constant is the annual expected gain of the system.

It should be noted that the incorporation of interest rate into equation 5 will result in reduced benefits at steady-state [2]. However, the resulting optimal policy is not affected even if the interest rate varies drastically [3].

5.4 PROBABILITY DISTRIBUTION OF STORAGE AND RELEASE

Solution of dynamic programming model will provide a steady-state operating policy that defines the final storage level $S_{1,t+1}$ for each initial storage level S_{kt} and inflow Q_{it}. The monthly optimal policies for various dam sites can be found in Appendix D. An example of an optimal policy is shown in Table 2.

Given the storage level and inflow at the begining of the month, the above policy defines the storage level for the next month and thus the amount of water released. For example, referring to Table 2, if at the end of month i-1

TABLE 2

An example optimal policy for month i

Storage State	Inflow state (cfs) Q_1	Q_2	Q_3	Q_4
S_1(106.0')	$R_{11}(2)$	$R_{12}(2)$	$R_{13}(1)$	$R_{14}(1)$
S_2(104.0')	$R_{21}(3)$	$R_{22}(3)$	$R_{23}(2)$	$R_{24}(2)$
S_3(102.0')	$R_{31}(4)$	$R_{32}(4)$	$R_{33}(3)$	$R_{34}(3)$
S_4(100.0')	$R_{41}(4)$	$R_{42}(4)$	$R_{43}(4)$	$R_{44}(4)$

the storage level is at 104' and if it is predicted that the inflow for month i will be Q_2, then the policy states that the amount of water to be released for the month i is R_{22} cfs-weeks and one ends up at storage state 4 (storage level) at the beginning of month i+1. Note that the integers in parentheses are the optimal pointers which define S_1, given S_k and Q_i for any period t.

It should be emphasized that if the actual inflow for month i is not Q_2 but rather Q_3, then a different reservoir level would be obtained at the end of month i. If such situation occurs the policy still applies. To obtain the new release for month i+1 the same procedure as described above is applied using the new reservoir level, resulting from Q_3 in month i, and a predicted inflow for month i+1.

By the nature of the stochastic dynamic programming, the solutions obtained account for variability of inflows i.e. at any pair of storage and inflow states there always exists a subpolicy that defines the amount of water to be released.

Since the optimal policy defines the next storage level l, given storage level k, the index l is not required. Then, the continuity equation can then be written as:

$$R_{kit} = S_{kt} + Q_{it} - S_{l,t+1} \qquad \text{for all } k,i,t$$

according to the optimal policy

. . . . . (6)

From the optimal policy it is possible to determine the probability distributions of inflow, storage, and release for any month. Let PR_{kit} be the joint probability of initial storage level S_{kt}, the inflow Q_{it}, and the final storage level $S_{l,t+1}$. PR_{kit} is specified by the optimal policy for each k, i and t. The product $PR_{kit} * P^{t}_{ij}$ gives the joint probability S_{kt}, Q_{it} and $Q_{jt,t=1}$. Summing all such joint probabilities over all k and i that result in the same final storage level $S_{l,t+1}$, as defined by the optimal policy, gives the joint probability of $S_{l,t+1}$ and $Q_{j,t+1}$ i.e. $PR_{l,j,t+1}$. There is also an additional constraint that requires the sum of all PR_{kit} in each period t be equal to 1. Therefore, knowing the optimal policy and transition probabilities one can develop a set of simultaneous equations and solve for each PR_{kit}. In mathematical notation the set of simultaneous equations is given by:

$$PR_{l,j,t+1} = \sum_{k} \sum_{i} PR_{kit} P^{t}_{ij} \qquad \text{for all } l,j \text{ and } t \qquad \ldots\ldots (7)$$

$$\sum_{k} \sum_{i} PR_{kit} = 1.0 \quad \text{for all } t \qquad \ldots\ldots (8)$$

Note that one equation in (7) is redundant in each period t. One can solve the system of equations by substituting (8) with any one equation of (7).

To illustrate the formulation of the system of equations, consider the diagrammatic optimal policy given in Figure 14. This policy is developed for a pseudo-year consisting of only two months. The arrows pointing at the next state define the optimal policy. They correspond to the optimal pointers as described before.

Note that, for simplicity, the PR for each inflow state are replaced by X as shown in the above diagram. Starting at t=1, storage level S_1, one finds that there is only one arrow that points at S_1, at time t=1. Therefore, the following equations can be formed:

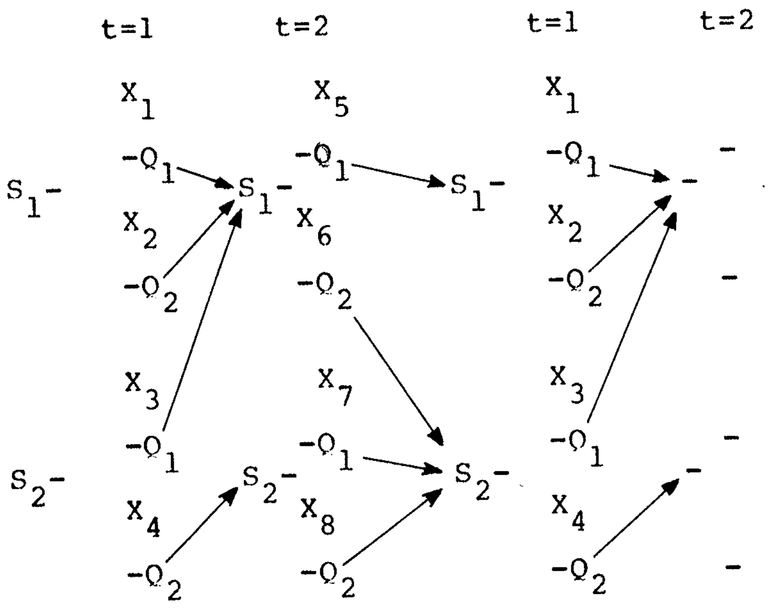


Figure 14: Diagrammatic optimal policy

$X_1 = P_{11} * X_5$

$X_2 = P_{12} * X_5$

For storage level S_2, t=1, there are three arrows that points at S_2, t=1. Therefore, there should be three independent variables in the following equations:

$$X_3 = P_{21} * X_6 + P_{11} * X_7 + P_{21} * X_8$$

$$X_4 = P_{22} * X_6 + P_{12} * X_7 + P_{22} * X_8$$

The constraining equation is:

$$X_1 + X_2 + X_3 + X_4 = 1.0$$

The set of equations for t=2 can be developed in similar fashion:

$$X_8 = P_{11} * X_1 + P_{21} * X_2 + P_{11} * X_3$$
$$X_6 = P_{12} * X_1 + P_{22} * X_2 + P_{12} * X_3$$
$$X_7 = P_{11} * X_4$$
$$X_8 = P_{12} * X_7$$
$$X_5 + X_6 + X_7 + X_8 = 1.0$$

Combining the two sets of equations one obtains a system of eight equations and eight unknowns. In general, the number of equations for a year would be given by:

Number of equations=12(months/year) * Number of Inflow States * Number of Storage States

From the above relationship it can be seen that a considerable amount of computational effort is required to solve the system of equations if the number of storage and inflow states is large.

If the solutions to the above system of equations are presented in matrix form, the derivation of probability distribution for storage, release and inflows can easily be understood. Suppose for any month t, the PR_{kit} are presented in Table 3 below:

TABLE 3

Probability of release for each inflow state

	Q_i				
	Q_1	Q_2	Q_3	. . .	Q_n
S_1	PR_{11}	PR_{12}	PR_{13}	. . .	PR_{1n}
S_2	PR_{21}	PR_{22}	PR_{23}	. . .	PR_{2n}
.	.	.		.	
.	.	.		.	
.	.	.		.	
S_m	PR_{m1}	PR_{m2}	PR_{m3}	. . .	PR_{mn}

To obtain the probability distribution of storage one simply sums the elements in each row:

$$PS_{kt} = \sum_i PR_{kit} \qquad \text{for all k and t} \qquad \ldots\ldots (9)$$

Since the row entries represent the inflows, summing all elements in each column will give rise to the probability distribution of inflow. This can be summarized as:

$$PQ_{kit} = \sum_{k} PR_{kit} \qquad \text{for all } i \text{ and } t \qquad \ldots\ldots (10)$$

In addition, it should be noted that each of the PR_{ij} of the matrix corresponds to a particular final storage $S_{1,t+1}$. By summing the PR_{ij} according to the optimal policy, the probability distribution of release may be obtained since release is defined if the initial storage level S_{kt}, inflow Q_{it} and final storage level $S_{1,t+1}$(defined by the optimal policy) are known. It is therefore possible to write:

$$PS_{1,t+1} = \sum_{k} \sum_{i} PR_{kit} \qquad \text{for all } 1,\ t \text{ according to optimal policy} \qquad \ldots\ldots (11)$$

The monthly probability distributions of storage, inflow, and release for Laurie reservoirs can be found in Appendix D.

5.5 SOME ASPECTS OF DISCRETIZATION

To solve a problem with continuous variables, using numerical methods the variables must be discretized. Discretization of continuous variables is unavoidable when the problem is solved with the aid of a digital computer. With no exceptions, the continuous storage and inflow variables must also be discretized. This section is included not to present the techniques of discretization but to discuss some important aspects of discretization and accuracy in this study. Throughout the course of this study it was found out that discretization has a very significant effect on the value and form of the optimal policy.

It is obvious that the accuracy of a discrete approximation of any continuous variable is directly affected by the way the discretization is done. The smaller the discretization intervals, the more accurate are the results and vice versa. However, finer discretization demands more computational effort and time. This is especially true in dynamic programming where dimensionality is always a problem. On the other hand, if the number of discretization intervals is too few, the continuous variable might be misrepresented. Therefore, there exists a trade-off between accuracy and computational effort.

In stochastic dynamic programming, where there are more state variables than deterministic dynamic programming, the problem of dimensionality has been tackled by some researchers [18,19] who developed a method for approximating solutions to stochastic dynamic programming. Dimensionality is reduced by replacing the probability distributions of stochastic state variables by their corresponding expections. Such method, however has not been found to be applicable to reservoir studies.

In the literature, there have been concerns about the accuracy of a discrete approximation of probability distribution of storage. Many researchers have devoted their efforts to the problem of 'how many storage states are sufficient for practical purposes.' Savarenskiy and Doran [26], using the same discretization method, recomended 5 - 10 states, while Moran [25] suggested 15-20 states with a slightly less efficient discretization technique. Klemes [4] demonstrated, both theoretically and with the aid of a numerical example, that an overly coarse discrete storage representation can not only impede accuracy but may completely distort reality in some unexpected ways. He then developed a statistical method to determine the required number of storage states and its associated limits of accuracy. He also commented that the absolute lower limit on the number of storage states is three and that it is not even a sufficient condition for obtaining accurate, or even meaningful results.

The validity of these concerns have been confirmed by this study. A preliminary test run on the stochastic dynamic programming model, where storage states are arbitrarily discretized to, seven even intervals, shows that the probability distribution of storage is highly skewed at the lower bound. However, when the storage states are discretized according to the number of stop-logs the resulting probability distribution of storage shows less skewness at the lower limit, although the directions of skew are basically the same.

In this study, since the number of discretization intervals falls within the acceptable limits set forth by the above-mentioned researchers, the discretization process has more direct effect on the optimal policies rather than the probability distribution of storage. Since the probability distribution of storage is derived from the optimal policies, it is indirectly affected by the discretization process. To clarify such a point, consider an example where reservoir is regulated by, say, twelve stop-logs and has certain downstream requirements of water. If the discretization interval is one stop-log, no serious problem would be incurred with dimensionality. However, the dimensionality of the stochastic dynamic programming model might prevent the utilization of 12 storage states. If the minimum downstream release can be satisfied by, say, one and a half stop-log depth of water it would be sensible to discretize the storage states such that each discretization interval covers two stop-logs. However, if each interval represents 3 or 4 stop-logs, moving from one storage state to the next might satisfy the minimum release requirement, but the amount of water released may be too much. The way the storage states are discretized will therefore affect the state transformation in dynamic programming and hence the optimal policies as described by optimal pointers, and their associated probability distributions.

Discretization of storage states, consequently, requires a great deal of judgement. One not only has to be aware of accuracy and state dimensionality, but also of the effect on the outcome of optimal policies. The general idea presented here also applies to discretization of inflow.

5.6 OPERATING POLICY FOR MULTIRESERVOIR SYSTEM

As discussed earlier stochastic dynamic formulations in the literature produce optimal operating policy for a single reservoir only. To develop an overall operating policy for a multi-reservoir system, the concept of using a stochastic dynamic programming model as a 'black box' and then applying it to all three reservoirs in an iterative fashion is presented. At each iteration varying inputs derived from the previous iteration are used.

To develop an overall optimal policy for the reservoir system the following steps (making reference to Figure 11) are taken:

1. Assume 'natural' conditions, combine the three local inflow records and use them as input into the Laurie reservoirs.
2. With the resulting input, develop monthly optimal policies for the Laurie reservoirs, subject to downstream release requirement of 450 cfs and target release of 1150 cfs as optimal plant capacity.
3. Derive the monthly probability distribution of release from the resulting optimal policies and determine the expected release for each month.
4. Assume that these monthly expected releases (for Laurie reservoir) are the surrogates for downstream release requirements for the upstream reservoirs, split the expected release proportionately - with Russell reservoir supplying 59% of the flows and Eager reservoir supplying 41% of the flows. The proportion of the split was based on the historical contribution of the flows on these two systems to the Laurie River generating system [33]. The monthly downstream release requirements for Russell and Eager reservoirs are thus obtained.

Note that since the monthly flow inputs into Laurie reservoir can be partially compensated by the local Laurie inflows it is necessary to remove part of these monthly inputs, equivalent to the local Laurie inflow for any month, before they are distributed proportionately to the upstream reservoirs.

5. Derive monthly optimal policies for the Russell and Eager reservoirs subject to the downstream release requirements determined in the previous step.
6. Assuming that the local inflow records are an adequate representation of the generated (future) inflow records, develop the release records for Eager and Russell reservoirs according to their optimal policies. These release records are found by running the historical record through the optimal policy.
7. Combine the resulting release records and the local Laurie inflow records (assumed to be a generated records at this point) and at the same time determine the average annual benefit for the system by running the individual local inflow records (combined records for Laurie reservoirs) through the now complete overall policy. Go back to step 2.

The above process is repeated until the average annual benefit, determined at the end of each iteration, shows no futher increase over that of the previous iteration.

The underlying principle behind the above procedure is that there exists a certain coordination in the reservoir system; the upstream reservoirs respond to the need of downstream reservoir subject to various inputs and constraints. At the same time, the downstream reservoir also responds to the availability of water upstream of it. It should also be noted that the reason for assuming historical inflow records as generated records is that generated records, developed using statistical methods, are no more reliable than the original historical data. Furthermore, while the main aim of this study is to produce a true optimal policy the nature of the solution technique and the problem require that this solution technique be classified semi-heuristic. Therefore, it is not necessary to go through a process of extensive statistical flow generations when the solutions obtained are approximate solutions. Besides, the utilization of historical records facilitates comaprisons of the existing and the proposed models in monetary terms.

5.7 COMPUTER MODEL FOR THE MULTIRESERVOIR SYSTEM

Computer programs have been written for performing each of the operations outlined in the previous section. Due to the problem of dimensionality with stochastic dynamic programming, which requires lengthy computer time and large amount of storage, the main program has been broken into a series of sub-programs. For more detail of these programs, one can refer to Appendix B. Briefly, the following programs (numbered program 1, program 2, etc.), along with their general functions, are described below:

1. Program 1 generates optimal policies for any of the three reservoirs.
2. Program 2 sets up a system of equations according to the optimal policies and solves the system of equations i.e. the probability of release (PR) associated with each inflow state.
3. Program 3 produces the expected release for each month and also develops the probability distributions of inflow, release, and storage.
4. Program 4 generates the monthly release record according to the optimal policies for each reservoir and at the same time determines the average annual benefit derived from the overall policies.

Note that any of the above programs can be applied to any of the three reservoirs. The following flowchart indicates the appropriate program to run for developing an overall operating policies for the reservoir system. Note that the flowchart is developed directly from the steps given in the preceeding section. Each step given in the flowchart corresponds to a step in the previous section.

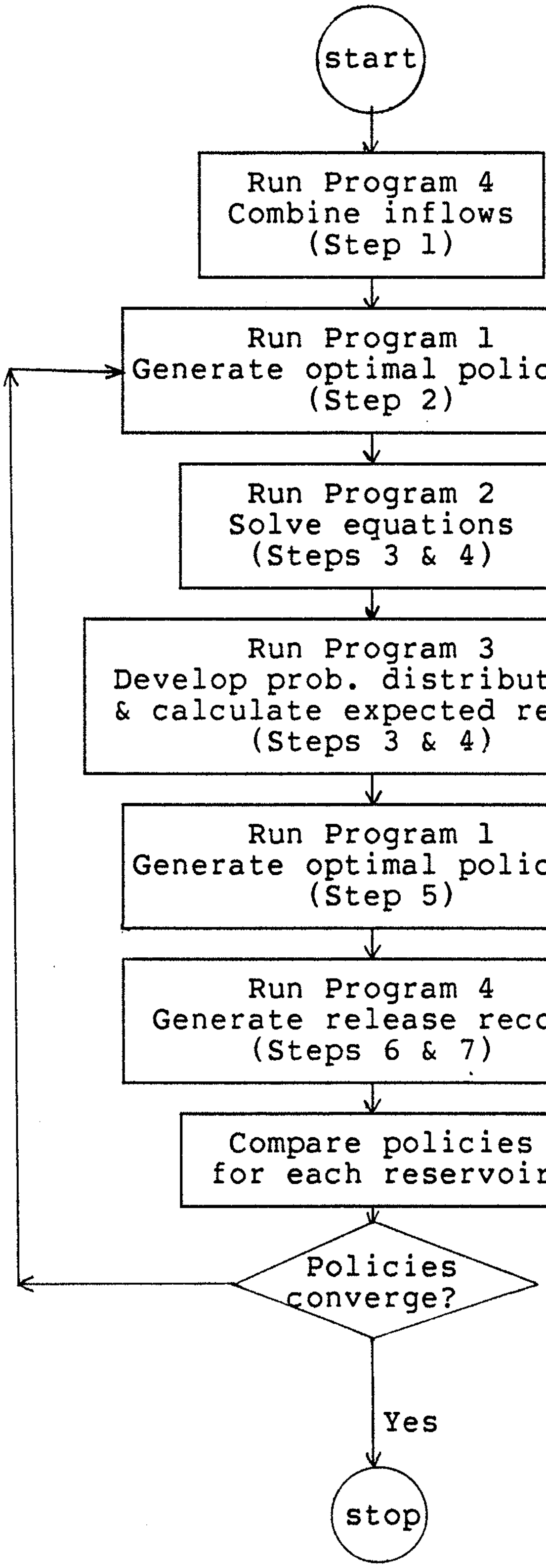


Figure 15: Flowchart for running the appropriate programs

5.8 DISCUSSIONS ON POLICY ITERATIONS

It is obvious that the approach just presented is a semi-heuristic one. The overall optimal policies obtained are most likely sub-optimal. Since the problem of developing an overall optimal policy is highly intractable, it is felt that so long as the new policy provides a better solution, it represents an improvement over the current operating procedures.

The final solutions to the proposed model can be found in Appendix D. Comparisons can be made between different iterations on the basis of average annual benefit derived from the system. Briefly, the average annual benefit for each iteration is summarized below:

Iteration	Average Annual Benefit ($)
0	739955
1	785452
2	790552
3	788287
4	786629

From the above, since iteration 2 gives the highest average annual benefit, the policy associted with iteration 2 is therefore chosen to be the solution to the proposed model. See Appendix D for the monthly policies for each reservoir.

The existing policy operates on the basis of the rule curve shown in Figure 17. The effective use of this rule curve requires a lot of personal judgement and experience. Since the author is inexperienced in using the rule curve, no detailed month by month comparisons will be given. However, from the past performance records, the average annual benefit of the existing policy was found to be $815163. This implies the proposed model does not work as well as the existing one. There are a number of reasons why the proposed model gives a lower value of generation and these reasons are given in the next section.

From this study it was found that the ease of obtaining the overall operating policy is totally dependent on the following factors:

1. The Inflow Record - Different magnitudes of inflow values affects the "size" of the discretization intervals; thus the optimal policy.
2. Range of Operating Levels - The larger the range of operating levels the coarser the storage discretizaton intervals. As discussed previously, discretization affects the optimal policy.

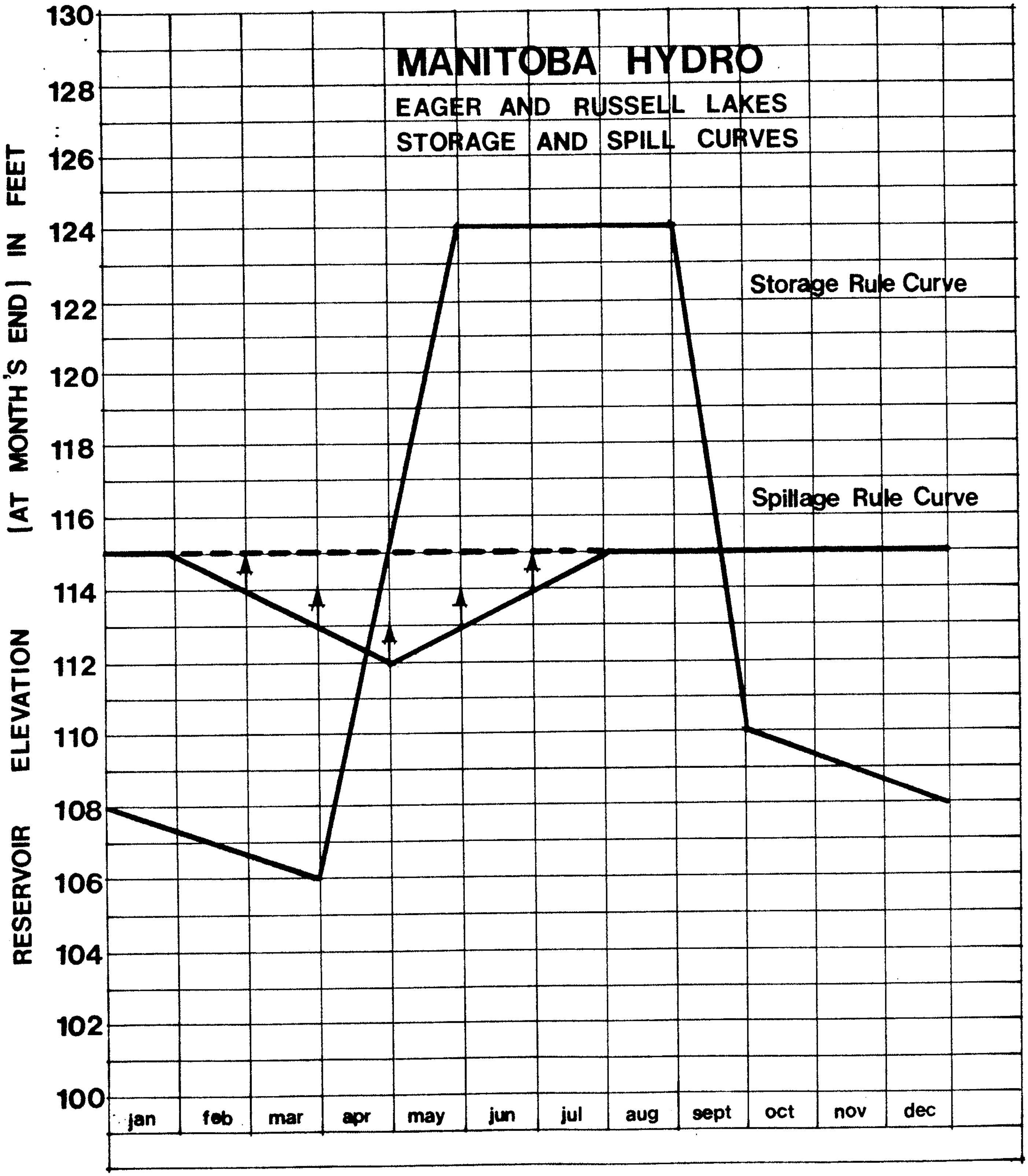


Figure 17: Rule Curve

3. Pricing function - Pricing function affects the objective function; thus the optimal policy. The policies presented here are based on monthly monetary value of electricity produced. However, in earlier part of this study, the Laurie operating policy was also obtained based on (seasonal) average value of electricity. The results obatined were different from the present one. (The iterative process was then stopped as soon as monthly values of electricity were obtained from Manitoba Hydro). The monthly values are actually used as they give better accuracy than seasonal averages.

5.9 DISCUSSION ON OPERATING POLICIES FOR MULTIRESERVOIR SYSTEM

This section dicusses the practical implications and drawbacks of the proposed model.

From Figure 10, the "energy equation" indicates that the value of generation is a function of the forebay (reservoir elevation), the discharge through the turbines, and the monthly values (dollar/megawatt.hour) of the water used in the generation of electricity. These features are therefore expected to be taken account by the proposed model. In other words, to obtain the maximum benefit the overall policy should be able to conserve head and at the same time release the appropriate amount of water at the right time (summer and winter). Referring to the monthly policies given in Appendix D, the above characteristics of the "energy equation" are clearly reflected in the monthly policies for all the reservoirs. Whenever possible or whenever the flows are high enough, there will be a tendency for the system to "go" to a higher storage levels indicated by the state pointers. This merely implies that the reservoirs, after releasing an appropriate amount of water, go into a ponding mode whenever the flows are high enough to do so. It is also evident that ponding is particularly frequent in the summer months for the reason that the dollar value per megawatt hour of water is less in the summer. The monthly probability distributions of inflows derived for the Laurie reservoir system also exhibit a correspondingly similar flow patterns as those of the local inflow records i.e. higher chances of inflow in the summer.

In spite of what was mentioned, there is a problem inherent in stochastic dynamic programming i.e. the problem of "trapping state" (not exactly a true trapping state). The presence of these "trapping states" is indicated by the pointers where each is pointing to the lowest state in the subsequent months. When the overall policy is followed through a number of cycles (years), the state (reservoir level) of the system will eventually stay at the lowest level. Such feature is apparent in the simulated reservoir operations, obtained by running the local inflows records through the overall policy, given in Appendix D. Note that "trapping state" occurs more often in the monthly policies associated with Eager and Russell reservoirs. The reason being the upstream reservoirs receive lower inflows than the Laurie reservoirs. Therefore, after releasing an amount of water to satisfy the downstream requirement, the Laurie reservoir system has still enough water for ponding i.e. "going" to a higher state.

The problem of trapping state in stochastic dynamic programming is unavoidable because at the lowest storage state, if the inflows are not high enough, the pointers are "forced" to point at the lowest storage state in the subsequent month in order to satisfy at least or partially the downstream release requirement. Even if the inflows are high enough, if the storage intervals are too coarse it would still impossible for the system to move to a higher storage state. However, finer discretization intervals demand greater computational effort. This problem will be dicussed later. For almost all the monthly policies it is observed that at the lower storage states there are a large number of pointers pointing at the lowest or the next lowest states. Since the probabilities associated with each and every state of the policy are derived from the pointers, the probability distributions of storage and release are directly affected by the problem of trapping state. From Appendix D, it can be seen that there are relatively large number of pointers pointing at the lower states which results in the probability space over inflow and storage being skewed at the lower storage states. As such, the monthly probability distributions of release given in Appendix D are highly skewed to the right indicating more chances of "going" to the lower storage states. For the same reason, the monthly probability distributions of storage indicate a higher skew at the states associated with lower storage levels.

Since these probability distributions are "distorted", the expected release and storage level for each month are underestimated. (However, the trend of release, i.e. releasing the right amount at the right time, is reflective of the monthly value of generation of water.) Perhaps, the problem of the trapping state serves to explain the concern of the Planning engineer in Manitoba Hydro where he pointed out that the monthly expected storage levels of the proposed model are too low. However, the simulated reservoir operations given in Appendix D show that the Laurie reservoir system does indeed try to conform to the "energy equation" i.e. to keep the reservoir level as high as possible. For Eager and Russell reservoirs the problem of trapping state is clearly portrayed in the simulated reservoir operations. Note that for most months of the year the reservoir levels of these upstream reservoirs are at their lowest storage levels.

The second problem, as far as this study is concerned, is the discretization of storage space (which is related to the problem of trapping state.) For the Laurie reservoir system, because a system of equations has to be derived from the resulting policy, the number of storage states cannot be excessive. Otherwise, if the system of equations is too large, it might be too costly and too time consuming for the computer to solve. However, a finer storage interval is required in order for the policy to provide good accuracy and to avoid partly the problem of the trapping state. For the upstream reservoirs, where by the nature of the solution method the various probability distributions are not required, the storage intervals have been reduced to one foot per interval instead of a certain number of stop-logs as was originally hypothesized. Even then, the problem of trapping state still remains. Possibly, because of lower magnitudes of local inflows, one foot per storage interval might still be too wide for this study. Yet, a further reduction in the size of the storage intervals requires much greater computational effort.

The third would be the problem of discretization in general. This problem is clearly reflected in the simulated reservoir operations. Since the storage and inflow variables are discretized the release variable will automatically be discretized. As a result, the model has no control over the release of the exact amount of water required by downstream requirements. To satisfy a certain downstream demand, a number of discrete quantities of water, usually more than what is required, is released. This results in spillage which is evident in the simulated operations.

The entire problem in stochastic dynamic programming then boils down to the often-mentioned phrase 'curse of dimensionality'. Finally, it should be pointed out that if it is possible to have finer storage intervals for the Laurie reservoir policy, the average annual benefit could by improved. A trial was performed on the overall policy by replacing the Laurie reservoir policy with a policy with 21 storage states (one foot per storage interval) the average annual benefit showed an increase of approximately 3%. This implies that the proposed model could be improved to the point where it is equally as good as the existing one. However, this 21-state policy was derived by feeding the generated records to the model without statistical considerations i.e. without resorting to probability calculations. Furthermore, from the past performance records of the existing policy it was found that when the Laurie reservoir system is operated without the regulations of the upstream reservoirs, the average annual benefit was found to be $784,914. Since the simulated operations of the proposed model show that the Laurie reservoir system is operating as if the upstream reservoirs were not needed, it may be justified to compare the value of $784,914 with $790,552 of the proposed model.

Chapter VI

CONCLUSIONS

This chapter briefly describes the findings uncovered about stochastic dynamic programming and provides some conclusions regarding this study.

6.1 EXPERIENCE GAINED FROM USING STOCHASTIC DYNAMIC PROGRAMMING

The following list of points outlines what has been experienced through the course of this study.

1. With stochastic dynamic programming, a two-state DP in this case, there is more of a limit on state space (storage and inflow states) than in deterministic DP. In the literature such fact is often referred to as 'curse of dimensionality'.

   In this study, however, it was found that the state space affects more directly the size of the system of equations rather than the model itself. As far as deriving the optimal policy is concerned, the actual model developed permits a very large state space (i.e. large number of states, say 20 for storage and 10 for inflow). The time taken for policy convergence under these conditions is relatively small. However, when the resulting system of equations is formed from the optimal policy it may become too large for the computer to handle efficiently (20 Storage States x 10 Inflow states x 12 = 2400 equations !); especially under time sharing conditions with many users.

2. The values used in the objective function of the model have a very great effect on the solutions. In some cases, some objective functions have such an effect on the model that the policy will not converge. In other cases, a slight change in the coefficients of the objective function may change the entire policy in which the storage or release of water are affected.
3. Discretization of continuous variables plays an important role on the final outcome of the solutions. A larger state space provides better accuracy. This is especially true when one tries to derive the probability of various variables. However, increasing the state space for storage, from 8 states to 10, does not affect the annual expected return or the annual expected gain of the system.
4. Regardless of where the starting point (i.e. month of the year) of calculation is taken the 'optimal' policy will eventually converge. For some starting points, however, the policy actually converges faster.

5. When working on large DP system, it is better to have a devoted computer system if one wants to get quick results.
6. One must also take into account the amount of time required in writing and debugging the program; especially when the reservoir system considered is large. If situation permits or if the problem is linear, one might prefer to use stochastic linear programming where canned programs are readily available.

6.2 CONCLUSION

In this study, an attempt was made to produce a model for multireservoir operations using Markovian stochastic dynamic programming. By the nature of stochastic dynamic programming, the 'curse of dimensionality' becomes the main problem encountered in a two-state DP used. Such a fact has not only caused a lot of problem in accuracy but may also hinder the possibility of obtaining an approximate solution. Nevertheless, in this study, an approximate solution was obtained for a four-dam two-reservoir problem. Because of the problem of dimensionality a considerable degree of care and judgement is required to obtain a solution which reflects reality as closely as possible.

As a result of this study, it was recognized that the problem of dimensionality will remain until some form of 'modified stochastic DP' model is produced or a larger and more dedicated computer to solve a large system of equations is available. With the existing computer environment at the University of Manitoba it was, however, possible to obtain an approximate solution for the problem of the size and dimensionality described in the study.

Appendix A

HISTORICAL INFLOW RECORDS

A.1 LOCAL EAGER INFLOW RECORDS (CFS)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1953	345	25	26	16	444	398	411	233	720	479	321	305
1954	221	252	85	202	566	600	256	164	11	20	72	108
1955	10	113	162	187	575	168	34	8	3	92	80	82
1956	84	95	76	64	616	113	17	39	9	16	91	123
1957	105	84	56	168	1416	420	654	346	904	538	382	355
1958	21	29	35	118	860	410	192	229	339	191	369	398
1959	341	202	157	108	797	1165	386	480	9	5	6	13
1960	65	17	38	58	526	873	300	217	40	110	53	6
1961	2	22	11	10	705	476	337	193	33	77	273	230
1962	140	108	153	153	1412	502	370	113	145	149	259	217
1963	174	123	294	159	524	803	706	165	321	270	199	115
1964	312	258	167	221	664	126	327	771	1192	673	137	204
1965	74	15	12	207	640	424	166	184	211	156	138	130
1966	68	15	67	185	267	619	380	65	33	30	129	221
1967	60	93	56	111	725	521	422	197	35	43	93	88
1968	34	52	43	286	359	402	214	43	551	312	186	165
1969	146	112	78	256	336	297	289	694	1105	368	267	306
1970	257	107	37	10	379	393	286	191	110	276	243	211
1971	148	177	184	261	510	460	434	353	692	826	395	318
1972	324	289	217	201	485	488	344	307	289	382	307	271
1973	246	115	132	94	421	495	279	206	221	256	265	231
1974	233	211	186	217	444	514	298	216	145	213	221	215
1975	42	52	87	156	562	361	349	229	141	137	153	167
1976	205	232	152	163	356	713	847	619	370	334	354	319
1977	296	206	121	443	914	617	229	234	244	307	130	64
1978	50	35	28	143	325	126	90	432	392	316	93	30
1979	73	20	20	10	202	282	201	78	265	258	243	209
1980	151	145	187	333	167	139	102	335	411	623	250	175

A.2 LOCAL RUSSELL INFLOW RECORDS (CFS)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1953	132	119	126	108	675	352	220	89	219	220	325	264
1954	196	168	188	108	983	588	394	246	155	251	161	373
1955	121	102	98	184	1427	310	503	289	21	69	119	79
1956	40	45	44	158	1638	253	131	37	12	263	141	48
1957	43	18	21	561	1360	820	1660	159	1442	464	95	66
1958	350	90	553	96	1172	846	464	360	723	830	307	157
1959	60	59	137	387	1423	1457	477	585	412	311	190	175
1960	262	40	155	237	1539	981	378	80	200	88	207	223
1961	124	73	142	151	1223	278	100	79	48	149	312	172
1962	215	159	228	79	2248	725	119	110	173	95	246	206
1963	165	160	64	344	854	931	1199	423	597	451	297	298
1964	272	247	194	318	1341	364	305	1081	1477	845	436	405
1965	277	308	171	382	1252	539	260	178	329	312	276	156
1966	54	14	16	55	634	1383	309	128	61	151	226	220
1967	96	81	97	95	1191	821	576	94	29	27	37	79
1968	63	35	40	195	780	462	312	7	825	589	236	155
1969	244	97	97	707	222	328	376	236	1533	688	574	188
1970	180	141	148	70	625	1023	796	279	336	315	210	192
1971	190	157	99	495	937	823	490	195	744	1203	577	464
1972	283	424	469	397	742	649	484	381	652	531	396	306
1973	257	258	192	306	721	555	453	555	400	436	338	319
1974	340	263	266	582	955	818	468	390	193	151	142	296
1975	186	155	124	413	874	788	502	246	99	110	71	74
1976	84	60	49	45	351	927	1628	906	216	452	283	245
1977	230	89	234	464	1345	706	230	229	302	248.	225	131
1978	88	164	203	407	463	427	251	451	530	366	157	114
1979	169	133	17	63	439	630	18	288	335	348	349	212
1980	153	186	275	547	233	161	106	436	551	594	314	226

A.3 LOCAL LAURIE INFLOW RECORDS (CFS)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1953	74	9	13	9	635	434	306	706	282	313	221	104
1954	2	3	13	134	872	486	30	127	322	156	12	4
1955	38	10	148	357	1012	237	212	109	204	300	232	160
1956	13	10	30	150	552	550	209	298	244	5	9	3
1957	130	141	143	94	752	210	776	1131	250	217	160	100
1958	80	365	330	684	1313	330	448	228	823	109	30	3
1959	2	2	2	270	1154	1062	229	273	248	375	337	235
1960	104	258	257	213	1348	914	330	49	229	122	242	266
1961	235	213	321	277	868	313	15	9	10	10	144	228
1962	180	34	51	160	1790	608	97	10	20	81	47	153
1963	6	95	79	276	777	542	1114	297	446	293	163	51
1964	114	75	104	476	1087	380	401	1022	1016	537	388	254
1965	201	212	178	441	1067	194	41	269	419	401	298	353
1966	439	394	360	410	681	1066	311	164	82	28	13	13
1967	13	107	144	167	775	819	403	50	46	507	298	291
1968	236	250	84	225	638	284	349	238	361	565	449	401
1969	279	209	266	550	287	214	41	223	1510	594	155	38
1970	130	326	248	313	485	429	446	111	232	141	347	229
1971	121	75	119	416	873	436	219	345	701	962	394	169
1972	151	145	41	168	1094	194	267	223	287	293	183	126
1973	30	30	51	166	757	261	466	193	159	413	390	247
1974	107	50	18	367	721	582	404	117	140	88	289	180
1975	119	45	45	146	766	523	460	291	43	80	103	164
1976	90	113	209	270	316	572	958	201	252	167	285	190
1977	66	70	70	559	734	492	179	6	218	247	359	260
1978	146	261	187	27	558	467	266	643	672	715	411	356
1979	404	313	234	252	610	593	34	95	130	94	22	30
1980	22	0	0	169	399	377	265	446	488	490	357	307

Appendix B

COMPUTER PROGRAMS FOR DEVELOPING OVERALL OPTIMAL POLICIES

B.1 PROGRAM 1 - (STOCHASTIC DP)

This program generates optimal monthly operating policies.

********** Program Lisiting **********

```
C       AVGFLO REAL      ARRAY VARIABLE - AVERAGE MONTHLY INFLOW(CFS)
C       BFACTR REAL      BENEFIT FACTOR FOR WINTER AND SUMMER
C       CFLAG  INTEGER   (0,1) VARIABLE - 1 ==> OPTIMALITY CHECK FOR
C                                                EVERY STAGE
C       CONST  REAL      VECTOR VARIABLE CONTAINS THE CONSTANT TERMS OF
C                        STAGE-STORAGE EQNS FOR EACH RESERVOIR
C       COUNT  INTEGER   INDEX FOR COUNTING (MAIN PGM,TRPROB)
C       COUNTR REAL      ARRAY VARIABLE - INDEX FOR COUNTING (TRPROB)
C       ELEV   REAL      ELEVATION FOR STORAGE LEVEL
C       EMAX   REAL      ARRAY VARIABLE - MAX RESERVOIR ELEVATIONS FOR
C                                          EACH MONTH
C       EMIN   REAL      ARRAY VARIABLE - MIN RTESERVOIR ELEVATIONS FOR
C                                          EACH MONTH
C       FLOIJ  REAL      INDEX FOR INFLOW STATE (TRPROB)
C       FLONUM INTEGER   VECTOR VARIABLE - STATE NUMBER FOR INFLOW
C                                           STATE
C       FLOPTR INTEGER   FLOW POINTER
C       FLOW   INTEGER   INDEX FOR LOOPING INFLOW STATES
C       FLOWI  INTEGER   INDEX FOR LOOPING INFLOW STATES IN MONTH(I)
C       FLOWJ  INTEGER   INDEX FOR LOOPING INFLOW STATES IN MONTH(J)
C       I      INTEGER   GENERAL LOOPING INDEX
C       IJ     INTEGER   LOOPING INDEX (TRPROB)
C       INTEGR INTEGER   VARIABLE FOR STORING INTEGER VALUES
C       INTRST REAL      INTEREST RATE
C       IORJ   INTEGER   LOOPING INDEX (TRPROB)
C       J      INTEGER   INDEX FOR GENERAL LOOPING (TRPROB)
C       K      INTEGER   INDEX FOR GENERAL LOOPING (TRPROB)
C       LR     REAL      VECTOR VARIABLE - LONG RANG RETURN FOR INFLOW
C                                           INFLOW STATES (I)
C       MAXFLO REAL      VECTOR VARIABLE - MAX INFLOW FOR EACH MONTH
C                                           (TRPROB)
C       MAXMIN INTEGER   (0,1) VARIABLE - 1 ==> MAXIMIZATION PROBLEM
C       MFACTR REAL      MULTIPLYING FACTOR (TRPROB)
C       MFLST  INTEGER   VECTOR VARIABLE - # OF INFLOW STATES IN
C                        IN TRANSITION MATRIX IN EACH MONTH(MAIN,TRPROB)
C       MINFLO REAL      VECTOR VARIABLE - MIN INLOW FOR EACH MONTH
C                                           (TRPROB)
C       MINR   REAL      VECTOR VARIABLW - MINIMUM RELEASE FOR EACH
C                                           RESERVOIR
C       MONTH  INTEGER   GENERAL LOOPING INDEX FOR EACH STAGE(MONTH)
C       MONTHI INTEGER   INDICATES THE MONTH OF THE YEAR FOR STAGE (I)
C       MONTHJ INTEGER   INDICATES THE MONTH OF THE YEAR FOR STAGE(J)
```

```
C       MTHPTR INTEGER   ARRAY VARIABLE - STORES POINTERS FR EACH MONTH
C       MTHRLS REAL      ARRAY VARIABLE - STORES MONTHLY RELEASES
C       NFLST  INTEGER   # OF INFLOW STATES
C       NFLSTI INTEGER   # OF INFLOW STATES IN MONTH(I)
C       NFLSTJ INTEGER   # OF INFLOWS STATES IN MONTH(J)
C       NPCHK  INTEGER   # OF (YEARS) OF POINTER CHECK
C       NSTAGE INTEGER   # OF STAGE(MONTH) IN PLANNING HORIZON
C       NSTATE INTEGER   # OF STORAGE STATES
C       NUMREC INTEGER   # OF INFLOW RECORDS (TRPROB)
C       OFLAG  INTEGER   (0,1) VARIABLE - 1 ==> OPTIMALITY CHECK OK
C       OPTCOD INTEGER   (0,1) VARIRBLE - 1 ==> OPTIMALITY CHECK FOR
C                                               FOR EVERY STAGE
C       OPTVAI REAL      ARRAY VARIABLE - OPTIMAL VALUES IN STAGE(I)
C       OPTVAJ REAL      ARRAY VARIABLE - OPTIMAL VALUES IN STAGE(J)
C       OPTVYR REAL      ARRAY VARIABLE - OPTIMAL VALUES FOR EACH YEAR
C       OUTFLO REAL      TOTAL OUTFLOW (SPILL+Q TO TURBINE) IN CFS-WKS
C       PCHKOD INTEGER   POINTER CHECK CODE - 1 ==> POINTER CHECK FAIL
C                                             0 ==> POINTER CKECK O.K.
C       PRALL  INTEGER   (0,1) VARIABLE - 1 ==> PRINT ALL RESULTS
C       PRFLOW INTEGER   (0,1) VARIABLE - 1 ==> PRINT FLOW RECIRDS
C       PROB   REAL      ARRAY VARIABLE - MARKOV TRANSITION MATRIX
C                                         (TRPROB)
C       PRPODA INTEGER   (0,1) VARIABLE - 1 ==> PRINT OPTIMAL POLICY
C                                               ON DATASET
C       PRRLDA INTEGER   (0,1) VARIABLE - 1 ==> PRINT RELEASE POLICY
C                                               ON DATASET
C       PRSTAJ INTEGER   (0,1) VARIABLE - 1 ==> PRINT RESULTS AT STAGE 1
C                                         0 ==> PRINT RESULTS AFTER
C                                               OPTIMALITY IS REACHED
C       PRTP   INTEGER   (0,1) VARIABLE - 1 ==> PRINT TRANSITION PROB.
C       PRTPM  INTEGER   (0,1) VARIABLE - 1 ==> PRINT TRANSITION PROB.
C       PTRCHK INTEGER   (0,1) VARIABLE - 1 ==> POINTER CHECK ON POLICY
C                                               OK
C       QI     REAL      ARRAY VARIABLE - STORING INFLOW (CFS) STATES
C                                         FOR EVERY MONTH
C       QOUT   REAL      Q (CFS) FLOWING OUT OF THE TURBINE
C       QVOL   REAL      Q IN CFS-WEEKS
C       RECNO  INTEGER   LOOPING INDEX FOR COUNTING RECORDS
C       RELEAS REAL      VECTOR VARIABLE - STORING RELEASES FOR INFLOW
C                                          STATES(I)
C       RETURN REAL      VECTOR VARIABLE - RETURN ASSOCIATED WITH EACH
C                                          EACH INFLOW STATES
C       RFLAG  INTEGER   VECTOR (-1,0,1) VARIABLE - 1 ==> MIN RELEASE
C                                        REQUIREMENT IS MET
C       RLCODE INTEGER   (0,1) VARIABLE - 1 ==> RELEASE REQT IS MET
C       RNAME  CHAR      VECTOR VARIABLE - CONTAINS NAMES OF RESEVOIRS
C       RPFOOT REAL      VECTOR VARIABLE - (RELEASE PER FOOT) CONTAINS
C                        SLOPES OF STAGE-STORAGE EQN FOR EACH RESERVOIR
C       SEASNI INTEGER   CORRESPONDING SEASON ASSOCIATED WITH MONTH(I)
C       SEASNJ INTEGER   CORRESPONDING SEASON ASSOCIATED WITH MONTH(I)
C       SELEV  REAL      VECTOR VARIABLE - ELEVATION STATES
C                        CORRESPONDING TO SUMMER MONTHS
C       SI     REAL      STORAGE ASSOCIATED WITH ELEVATION STATE(I)
C       SJ     REAL      STORAGE ASSOCIATED WITH ELEVATION STATE(J)
```

```
C        SLEVEL REAL       ARRAY VARIABLE - CONTAINS ELEVATIONS FOR A YEAR
C        STAGNO INTEGER    LOOPING INDEX FOR STAGE(MONTH)
C        STATE  INTEGER    GENERAL LOOPING INDEX FOR ELEVATION STATES
C        STATEI INTEGER    LOOPING INDEX FOR ELEVATION STATE IN MONTH(I)
C        STATEJ INTEGER    LOOPING INDEX FOR ELEVATION STATE IN MONTH(J)
C        TEMP   REAL      TEMPORARY VARIABLE
C        TFLAG  INTEGER   TEMPORARY (0,1) VARIABLE
C        TITLE  CHAR      TITLE OF DATASET
C        TNVAR  INTEGER   TOTAL NUMBER OF VARIABLES(INFLOW STATES) IN A YR
C        TP     REAL      TRANSITION PROBABILITY MATRIX
C        UNITPL INTEGER   UNIT NUMBER FOR 'PLOTTING' DATASET
C        UNITR  INTEGER   UNITR NUMBER FOR 'OPTIMAL POLICY' DATASET OR
C                         RESERVOIR CODE (1,2,3)
C        VALUE  REAL      ARRAY VARIABLE - MONTHLY VALUE ($/MW.HR) OF H20
C        WELEV  REAL      VECTOR VARIABLE - ELEVATION STATES FOR WINTER
C                                           MONTHS
C        YRPTR  INTEGER   ARRAY VARIABLE - STORES OPTIMAL POINTERS
C                                          FOR THE WHOLE YEAR
C        YRRLS  REAL      ARRAY VARIABLE - STORES OPTIMAL RELEASES FOR
C                                          FOR THE WHOLE YEAR
      INTEGER NSTAGE, NSTATE, STATEI, STAGNO, MONTHI, MONTHJ, FLOWI,
     &        STATEJ,FLOWJ,FLOPTR,MONTH,STATE,FLOW, UNITR,NFLSTI,NFLSTJ,
     &        FLONUM(10)/1,2,3,4,5,6,7,8,9,10/,MAXMIN,MFLST(12),NFLST,
     &        YRPTR(21,10,12),TNVAR, PRTPM, TITLE(15),
     &        MTHPTR(21,10), PTRCHK, OPTCOD, NPCHK, PCHKOD, COUNT,
     &        RFLAG(21), RLCODE, PRALL, UNITPL, PRPODA, PRRLDA,
     &        CFLAG, OFLAG, TFLAG, NDELTA, SEASNI, SEASNJ
      REAL SI, SJ, EMAX(12), EMIN(12), RETURN(21), OPTVAI(21,10),
     &     SDELTA(12), LR(21),TP(10,10,12), OPTVYR(21,10,12),FDELTA(12),
     & OPTVAJ(21,10)/210*0.0/, BFACTR, ELEV, QI(10,12), MINR(12),
     &     OUTFLO,RELEAS(21),MTHRLS(21,10), TEMP, QVOL, FREEBD,
     &     YRRLS(21,10,12), SLEVEL(21,12), SELEV(21), WELEV(21),
     &     RPFOOT(3)/2070.0,2580.0,920.0/, INTRST,
     &     CONST(3)/207000.0,260580.0,176640.0/,
     &     VALUE(12)/15.9,15.1,14.2,12.8,10.7,8.3,9.3,10.3,12.3,12.5,
     &               12.8,13.8/, QOPT/1150.0/,
     &     MTHDAY(12)/31.0,28.0,31.0,30.0,31.0,30.0,31.0,31.0,30.0,31.0,
     &                30.0,31.0/
      CHARACTER GRAPH*1(10)
      COMPLEX*8 RNAME(3)/' EAGER  ','RUSSELL ',' LAURIE '/
      COMMON TP, MFLST, FDELTA, QI
      READ(5,7) TITLE
      READ(5,*) NUMREC
C
C
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                        :
C     :  CALCULATE TRANSITION PROBABILITY                      :
C     :                                                        :
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C     CALCULATE THE MARKOV TRANSITION PROBABILITY MATRIX.
C
C
```

```
      CALL TRPROB(NUMREC)
C
      READ(5,*) PRTPM
      READ(5,*) MAXMIN
      READ(5,*) NSTAGE
      READ(5,*) NSTATE
      READ(5,*) EMAX
      READ(5,*) EMIN
      READ(5,*) (SELEV(I), I=1, NSTATE)
      READ(5,*) (WELEV(I), I=1, NSTATE)
      READ(5,*) MINR
      READ(5,*) UNITR
      READ(5,*) OPTCOD
      READ(5,*) PRSTAJ
      READ(5,*) PRGRAF
      READ(5,*) PRALL
      READ(5,*) PRPODA
      READ(5,*) PRRLDA
      READ(5,*) INTRST
      READ(5,*) IDBG
      WRITE(6,1) TITLE
C
C     UNITPL=UNIT NUMBER FOR 'PLOTTING' DATASET.
C
      UNITPL=UNITR+10
      IF (PRPODA .EQ. 1) WRITE(UNITR,111) TITLE
      IF (PRRLDA .EQ. 1) WRITE(UNITPL,111) TITLE
C
C
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                     :
C     :  PRINT TRANSITION PROBABILITY MATRIX                :
C     :                                                     :
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C     IF PRTPM=YES(1) THEN PRINT THE THE MARKOV TRANSITION MATRIIX.
C     OTHERWISE, SKIP THE PRINTING.BUT, PRINTING INTO DATASET IS DONE.
C
C
      IF (PRPODA .EQ. 1) WRITE(UNITR,*) NSTATE
      IF (PRPODA .EQ. 1) WRITE(UNITR,511) MFLST
      IF (PRRLDA .EQ. 1) WRITE(UNITPL,*) NSTATE
      IF (PRRLDA .EQ. 1) WRITE(UNITPL,511) MFLST
C
      IF (PRTPM .EQ. 1) WRITE(6,1) TITLE
      DO 2 MONTHI=1, 12
         MONTHJ=MONTHI+1
         IF (MONTHJ .EQ. 13) MONTHJ=1
         NFLSTI=MFLST(MONTHI)
         NFLSTJ=MFLST(MONTHJ)
         IF (PRTPM .EQ. 1) WRITE(6,5) MONTHI, (FLONUM(J), J=1, NFLSTJ)
         DO 3 FLOWI=1, NFLSTI
            IF (PRTPM .EQ. 1) WRITE(6,4) FLOWI,(TP(FLOWI,FLOWJ,MONTHI),
     &                              FLOWJ=1, NFLSTJ)
```

```
            IF (PRPODA .EQ. 1) WRITE(UNITR,44) (TP(FLOWI,FLOWJ,MONTHI),
     &                         FLOWJ=1, NFLSTJ)
  3        CONTINUE
  2     CONTINUE
C
C
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                     :
C     :  CALCULATE TOTAL NUMBER OF VARIABLES                :
C     :                                                     :
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  CALCULATE TOTAL NUMBER OF VARIABLES I.E. THE TOTAL NUMBER OF
C:::  INFLOW STATES IN A YEAR
C:::  TNVAR = TOTAL NUMBER OF VARIABLES
C
C
      TNVAR=0
      DO 10 MONTH=1, 12
         TNVAR=TNVAR+MFLST(MONTH)*NSTATE
 10   CONTINUE
      WRITE(6,*) 'TNVAR:',TNVAR
C
C
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                     :
C     :  INITIALIZE VARIABLES                               :
C     :                                                     :
C.    :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  INITIALIZE THE MONTH OF THE YEAR FOR THE INITIAL STAGE ( I.E.
C:::  MONTH(I), THE CURRENT STAGE)
C
C
C     MONTHI=NSTAGE/12
C     MONTHI=NSTAGE-12*MONTHI
C     IF (MONTHI .EQ. 0) MONTHI=12
C     MONTHJ=MONTHI+1
C     IF (MONTHJ .EQ. 13) MONTHJ=1
      MONTHI=12
      MONTHJ=1
C
C
C:::  INITIALIZE FLAGS FOR PRINTING "OPTIMAL POINTERS" ON DATASETS.
C
C
      NPCHK=0
      PCHKOD=1
      CFLAG=1
      OFLAG=0
C
C
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                     :
```

```
C     :  BEGIN STAGE(MONTH)                                  :
C     :                                                      :
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  BEGIN LOOPING FOR EACH STAGE(MONTH)
C:::  *** NOTE: MONTH(I) IS THE CURRENT STAGE  (NOT MONTH(J))
C
C
```

```
      DO 20 STAGNO=1, NSTAGE
         TFLAG=OFLAG
         IF (PRSTAJ .EQ. 1) OFLAG=1
         NFLSTI=MFLST(MONTHI)
         NFLSTJ=MFLST(MONTHJ)
         IF ( OFLAG .EQ. 1 .AND. PRALL .EQ. 1) WRITE(6,25) RNAME(UNITR),
     &          STAGNO, NSTAGE,  MONTHI,  (FLONUM(FLOW), FLOW=1, NFLSTI)
         IF (OFLAG .EQ. 1 .AND. PRALL .EQ. 1) WRITE(6,27)
     &      (QI(FLOW,MONTHI)*4.0, FLOW=1, NFLSTI)
         SEASNI=1
         IF (MONTHI .GE. 11 .OR. MONTHI .LE. 4) SEASNI=0
         SEASNJ=1
         IF (MONTHJ .GE. 11 .OR. MONTHJ .LE. 4) SEASNJ=0
C
C
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                     :
C        :  BEGIN STATE(I)                                     :
C        :                                                     :
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::     BEGIN LOOPING FOR EACH STATE(STORAGE)  IN THE CURRENT STAGE
C
C
C        SI=EMAX(MONTHI)-SDELTA(MONTHI)*NPLUS1
         DO 30 STATEI=1, NSTATE
            SI=RPFOOT(UNITR)*(SEASNI*SELEV(STATEI)+(1-SEASNI)*
     &         WELEV(STATEI))-CONST(UNITR)
            FREEBD=(EMAX(MONTHI)-(SEASNI*SELEV(STATEI)+(1-SEASNI)*
     &             WELEV(STATEI)))*RPFOOT(UNITR)
C
C
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C           :                                                     :
C           :  BEGIN FLOW(I)                                      :
C           :                                                     :
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::        BEGIN LOOPING FOR EACH INFLOW STATE ; IN THE CURRENT STAGE
C
C
            DO 40 FLOWI=1, NFLSTI
               QVOL=QI(FLOWI,MONTHI)*4.0
C
C
C              :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C              :                                                     :
C              :  BEGIN STATE(J)                                     :
C              :                                                     :
C              :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::           BEGIN LOOPING FOR EACH STATE(MONTH)  IN THE NEXT STAGE
C
C
```

```
C              SJ=EMAX(MONTHJ)-SDELTA(MONTHJ)*NPLUS1
               RLCODE=0
               DO 50 STATEJ=1, NSTATE
                 SJ=RPFOOT(UNITR)*(SEASNJ*SELEV(STATEJ)+(1-SEASNJ)*
     &             WELEV(STATEJ))-CONST(UNITR)
                 LR(STATEJ)=0.0
C
C
C                :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C                :                                                     :
C                :  BEGIN FLOW(J)                                      :
C                :                                                     :
C                :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::             BEGIN LOOPING FOR EACH INFLOW STATE IN THE NEXT STAGE
C
C
                 DO 60 FLOWJ=1, NFLSTJ
                   LR(STATEJ)=LR(STATEJ)+OPTVAJ(STATEJ,FLOWJ)*
     &                    TP(FLOWI,FLOWJ,MONTHI)/(1.0+INTRST)
C
C                *******************************************************
C                *                                                     *
C                *  END OF LOOP FLOW(J)                                *
C                *                                                     *
C                *******************************************************
C
 60              CONTINUE
                 OUTFLO=SI+QVOL-SJ
                 RELEAS(STATEJ)=OUTFLO
                 IF (STAGNO .NE. 3 .OR. IDBG .EQ. 0) GOTO 49
               BFACTR=10.0
               IF (SEASNI .EQ. 0) BFACTR=16.0
               PRINT 1000, SI,STATEI,Q,FLOWI,SJ,STATEJ,RELEAS(STATEJ),
     &                  RELEAS(STATEJ)*BFACTR
               PRINT 1001, (OPTVAJ(STATEJ,FLOWJ), FLOWJ=1, NFLSTJ)
               PRINT 1002, (TP(FLOWI,FLOWJ,MONTHI), FLOWJ=1, NFLSTJ)
               PRINT 1003, (TP(FLOWI,FLOWJ,MONTHI)*OPTVAJ(STATEJ,FLOWI),
     &                  FLOWJ=1, NFLSTJ), LR(STATEJ)
               PRINT 1004, LR(STATEJ)+RELEAS(STATEJ)*BFACTR
 1000 FORMAT(' ',///,' STATE I:',F8.1,'-',I2,3X,'FLOW I:',F8.1,'-',
     &      I2,3X,'STATE J:',F8.1,'-',I2,3X,'RELEAS:',F10.1,3X,
     &      'I. RETURN:',F10.1/)
 1001 FORMAT(' ',' OPTVAJ:',10(F10.1,1X))
 1002 FORMAT(' ',/,' T.P.',6X,10(F8.3,3X))
 1003 FORMAT(' ',/,' L. RETURN:',10(F9.1,1X),2X,F9.1)
 1004 FORMAT(' ',/,' T. RETURN:',10(F10.1,1X),'  *****')
C
C
C                :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C                :                                                     :
C                :  SET FLAG FOR DIFFERENT CATEGORIES OF RELEASE       :
C                :                                                     :
C                :::::::::::::::::::::::::::::::::::::::::::::::::::::::
```

```
C
C:::        IF OUTFLO >= MINR          ===> RFLAG=1
C:::        IF 0.0 < OUTFLO < MINR     ===> RFLAG=0
C:::        IF OUTFLO <= 0.0           ===> RFLAF=-1
C
C:::        RLCODE=1 ==> THERE IS AT LEAST ONE OUTFLOW, ASSOCIATED
C:::        EACH STATE I AND INFLOW STATE I, THAT SATISFIES THE
C:::        MINIMUM DOWNSTREAM RELEASE REQUIREMENT.
C
 49         IF (OUTFLO .GE. MINR(MONTHI)) RFLAG(STATEJ)=1
            IF (OUTFLO .GE. MINR(MONTHI)) RLCODE=1
            IF (OUTFLO .LT. MINR(MONTHI) .AND. OUTFLO .GT. 0.0)
     &         RFLAG(STATEJ)=0
            IF (OUTFLO .LT. MINR(MONTHI) .AND. OUTFLO .LE. 0.0)
     &         RFLAG(STATEJ)=-1
C
C           SJ=SJ-SDELTA(MONTHJ)*(NPLUS1-STATEJ)
C
C         ********************************************************
C         *                                                      *
C         *  END OF LOOP STATE(J)                                *
C         *                                                      *
C         ********************************************************
C
 50       CONTINUE
C
C
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C         :                                                      :
C         :  DETERMINE BENEFIT FACTOR                            :
C         :                                                      :
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::      DETERMINE THE FACTOR TO BE MULTIPLIED TO THE OPTIMAL
C:::      RETURN. THIS FACTOR DENPENDS ON THE TIME, SUMMER
C:::      (MAY TO OCT.) OR WINTER (NOV. TO APRIL), OF THE YEAR.
C
C
          BFACTR=10.0
          IF (SEASNI .EQ. 0) BFACTR=16.0
C
C
```

```
C              ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C              :                                                    :
C              :  CHECK RFLAG FOR DIFFERENT OUTFLO CATEGORIES       :
C              :                                                    :
C              ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C              IF RFLAG ARRAY CONTAINS AT LEAST A '1' (CAN BE 0, 1, -1)
C              I.E. RLCODE=1
C              RFLAG .EQ. 1          ===>  RETURN=RELEASE
C              RFLAG .NE. 1 (0,-1)   ===>  RETURN=-555.0
C
C              IF RFLAG ARRAY CONTAINS NO '1' (ONLY 0 OR -1 ==> MIN
C              RELEASE REQUIREMENT ARE NOT MET) I.E RLCODE=0
C              RFLAG .EQ. 0          ===>  RETURN=RELEASE
C              RFLAG .NE. 0 (-1)     ===>  RETURN=-555.0
C
C
               DO 51 STATEJ=1, NSTATE
                  RETURN (STATEJ) =-99999.0
                  IF  (RLCODE .NE. 1) GOTO 52
                     IF  (RFLAG (STATEJ)  .EQ. 1) RETURN (STATEJ) =
     &                                            RELEAS (STATEJ)
                     GO TO 53
 52                  IF  (RFLAG (STATEJ)  .EQ. 0) RETURN (STATEJ) =
     &                                         RELEAS (STATEJ)
 53               IF  (RETURN (STATEJ)  .GT. 0.0 .AND. RETURN (STATEJ)  .LT.
     &            QOPT*4.0 .AND. UNITR .EQ. 3) QOUT=RETURN (STATEJ) /4.0
                  IF  (RETURN (STATEJ)  .GT. 0.0 .AND. RETURN (STATEJ)  .GE.
     &            QOPT*4.0 .AND. UNITR .EQ. 3) QOUT=QOPT
                  IF  (RETURN (STATEJ)  .GT. 0.0 .AND. RETURN (STATEJ)  .LT.
     &           MINR (MONTHI)  .AND. UNITR .LE. 2) QOUT=RETURN (STATEJ) /4.
                  IF  (RETURN (STATEJ)  .GT. 0.0 .AND. RETURN (STATEJ)  .GE.
     &            MINR (MONTHI)  .AND. UNITR .LE. 2) QOUT=MINR (MONTHI) /4.0
                  IF  (RETURN (STATEJ)  .GT. 0.0 .AND. UNITR .EQ. 9)
     &                RETURN (STATEJ) =RETURN (STATEJ) *BFACTR+LR (STATEJ)
                  IF  (UNITR .EQ. 3 .AND. RETURN (STATEJ)  .GT. 0.0)
     &             RETURN (STATEJ) = (-8.45334+0.035* (SEASNJ*SELEV (STATEJ)
     &                             (1-SEASNJ) *WELEV (STATEJ) )
     &                             0.00891945*QOUT) *VALUE (MONTHI) *
     &                             MTHDAY (MONTHI) *24.0+LR (STATEJ)
                  IF  (UNITR .LE. 2 .AND. RETURN (STATEJ)  .GT. 0.0)
     &             RETURN (STATEJ) = (0.035* (SEASNJ*SELEV (STATEJ)
     &                             (1-SEASNJ) *WELEV (STATEJ) )
     &                             0.00891945*QOUT) *VALUE (MONTHI) *
     &                             MTHDAY (MONTHI) *24.0+LR (STATEJ)
                   IF  (RETURN (STATEJ)  .NE. -99999.0 .AND. RETURN (STATEJ)
     &             .LT. 0.0) RETURN (STATEJ) =0.0
 51            CONTINUE
               IF (STAGNO .EQ. 3 .AND. IDBG .EQ. 1)
     &         PRINT 1005, (RETURN (STATEJ) , STATEJ=1, NSTATE)
 1005          FORMAT (' ',/,' ***=>CHOSE',10(F10.1,1X))
C
C
```

```
C            :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C            :                                                     :
C            :  DETERMINE OPTIMAL RETURNS AND POINTERS             :
C            :                                                     :
C            :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::          DETERMINE THE OPTIMAL RETURN FOR EACH INFLOW STATE AND
C:::          ITS CORRESPONDING POINTER (POINTING TO THE NEXT STAGE(J))
C
C
              FLOPTR=1
              DO 70 STATEJ=2, NSTATE
                 IF (RETURN(STATEJ) .LT. RETURN(1) .AND. MAXMIN .EQ. 0)
     &               FLOPTR=STATEJ
                 IF (RETURN(STATEJ) .LT. RETURN(1) .AND. MAXMIN .EQ. 0)
     &              RETURN(1)=RETURN(STATEJ)
                 IF (RETURN(STATEJ) .GT. RETURN(1) .AND. MAXMIN .EQ. 1)
     &               FLOPTR=STATEJ
                 IF (RETURN(STATEJ) .GT. RETURN(1) .AND. MAXMIN .EQ. 1)
     &              RETURN(1)=RETURN(STATEJ)
 70           CONTINUE
C
C
C            :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C            :                                                     :
C            :  STORE OPTIMAL RETURN AND POINTERS                  :
C            :                                                     :
C            :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::          STORE THE OPTIMAL RETURN AND ITS CORRESPONING POINTER
C:::          FOR EACH INFLOW STATE
C
              OPTVAI(STATEI,FLOWI)=RETURN(1)
              MTHPTR(STATEI,FLOWI)=FLOPTR
              MTHRLS(STATEI,FLOWI)=RELEAS(FLOPTR)
C
C          *******************************************************
C          *                                                     *
C          *  END OF LOOP FLOW(I)                                *
C          *                                                     *
C          *******************************************************
C
 40         CONTINUE
C
C
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C           :                                                     :
C           :  DETERMINE WATER ELEVATION                          :
C           :                                                     :
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::         DETERMINE THE ELEVATION OF WATER LEVEL CORRESPONDING TO
C:::         A PARTICULAR STORAGE STATE.
C:::         UNITR=1  ==> EAGER RESERVOIR
```

```
C:::        UNITR=2  ==> RUSSELL RESERVOIR
C:::        UNITR=3  ==> EAGER RESERVOIR
C
C
C           IF (UNITR .EQ. 1) ELEV=(SI+207000.0)/2070.0
C           IF (UNITR .EQ. 2) ELEV=(SI+260580.0)/2580.0
C           IF (UNITR .EQ. 3) ELEV=(SI+191360.0)/920.0
            IF (STAGNO .LE. 12)
     &      SLEVEL(STATEI,MONTHI)=SEASNI*SELEV(STATEI)
     &                                (1-SEASNI)*WELEV(STATEI)
C
C
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C           :                                                       :
C           :  PRINT STAGE RESULTS                                  :
C           :                                                       :
C           :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::        PRINT OUT THE OPTIMAL RETURN FOR EACH STATE AND ITS
C:::        CORRESPONDING POINTER; IN THE CURENT STAGE.
C
C
            ELEV=SEASNI*SELEV(STATEI)+(1-SEASNI)*WELEV(STATEI)
            IF (PRALL .EQ. 0) GO TO 30
            IF (OFLAG .EQ.0) GO TO 30
            WRITE(6,80) STATEI, SI,
     &      (OPTVAI(STATEI,FLOWI), FLOWI=1,NFLSTI)
            WRITE(6,83) (MTHRLS(STATEI,FLOWI), FLOWI=1, NFLSTI)
            WRITE(6,85) ELEV, (MTHPTR(STATEI,FLOWI),
     &                          FLOWI=1, NFLSTI)
C           SI=SI-SDELTA(MONTHI)*(NPLUS1-STATEI)
C
C        *********************************************************
C        *                                                       *
C        * END OF LOOP STATE(I)                                  *
C        *                                                       *
C        *********************************************************
C
 30      CONTINUE
C
C
         WRITE(6,103) MINR(MONTHI)
C
C
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                       :
C        :  PRINT POINTERS(GRAPHICAL)                            :
C        :                                                       :
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::     PRESENT THE OPTIMAL POINTERS IN GRAPHICAL FORM FOR EACH STATE.
C:::     PRINTING IS DONE ONLY IF OPTIMALITY HAS BEEN REACHED.
C
C
```

```
C        IF ((.NOT. OFLAG .OR. PRGRAF .EQ. 0) .AND. PRALL .EQ. 1)
C    &      GO TO 230
C        WRITE(6,98)
C        DO 90 STATEI=1, NSTATE
C           DO 95 FLOWI=1, NFLSTI
C              IF (MTHPTR(7,FLOWI) .EQ. (NSTATE+1-STATEI))
C    &             GRAPH(FLOWI)='X'
C              IF (MTHPTR(7,FLOWI) .NE. (NSTATE+1-STATEI))
C    &             GRAPH(FLOWI)=' '
C95         CONTINUE
C           WRITE(6,96) NSTATE+1-STATEI, (GRAPH(FLOW), FLOW=1, NFLSTI)
C           WRITE(6,101)
C           IF (STATEI .EQ. NSTATE) WRITE(6,97) FLONUM
C90      CONTINUE
C
C
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                     :
C        :  CHECK POINTERS                                     :
C        :                                                     :
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::     AFTER OPTIMALITY HAS BEEN ACHIEVED, CHECK POINTERS OF
C:::     CORRESSPONDING MONTHS OF TWO CONSECUTIVE YEARS.
C
C
         IF (PRALL .EQ. 0) WRITE(6,*) '*****=> SATEGE NO:',STAGNO
 230     IF (STAGNO .LE. 12) GO TO 99
         PTRCHK=0
         DO 91 STATEI=1, NSTATE
            DO 92 FLOWI=1, NFLSTI
               PTRCHK=PTRCHK+(YRPTR(STATEI,FLOWI,MONTHI)
     &                       -MTHPTR(STATEI,FLOWI))
 92         CONTINUE
 91      CONTINUE
C
C:::     PTRCHK=0 ==> ALL POINTERS ASSOCIATED WITH EACH STORAGE AND
C:::     INFLOW STATE ARE THE SAME BETWEEN THE CORRESPONDING MONTHS
C
         IF (PTRCHK .EQ. 0) WRITE(6,*) '*****=> POINTER CHECK O.K.'
         IF (PTRCHK .NE. 0) WRITE(6,*) 'XXXXX=> POINTER CHECK FAILS'
         IF (PTRCHK .EQ. 0) NPCHK=NPCHK+1
         IF (PTRCHK .NE. 0 .AND. NPCHK .GT. 0) NPCHK=0
         IF (NPCHK .LT. 24 .OR. PCHKOD .EQ. 0) GO TO 99
C
C:::     NPCHK >= 24  ==>  POINTER CHECK O.K. FOR AT LEAST 24 MONTHS
C
         IF (PRPODA .EQ. 1) WRITE(UNITR,*) TNVAR
         WRITE(6,*) '**********   POLICY CONVERGES !!   **********'
         DO 86 MONTH=1, 12
            NFLST=MFLST(MONTH)
            IF (PRRLDA .EQ. 1) WRITE(UNITPL,521) (QI(FLOW,MONTH),
     &                         FLOW=1, NFLST)
            IF (PRPODA .EQ. 1) WRITE(UNITR,521) (QI(FLOW,MONTH),
```

```
     &                          FLOW=1, NFLST)
            DO 87 STATE=1, NSTATE
               IF (PRPODA .EQ. 1) WRITE(UNITR,89) SLEVEL(STATE,MONTH),
     &         (YRPTR(STATE,FLOW,MONTH), FLOW=1, NFLST)
               IF (PRRLDA .EQ. 1) WRITE(UNITPL,531) SLEVEL(STATE,MONTH)
               IF (PRRLDA .EQ. 1) WRITE(UNITPL,521)
     &         (YRRLS(STATE,FLOW,MONTH), FLOW=1, NFLST)
 87          CONTINUE
 86       CONTINUE
          PCHKOD=0
C
C
C         :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C         :                                                       :
C         :  CHECK FOR OPTIMAL POLICY                             :
C         :                                                       :
C         :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::      CHECK FOR OPTIMAL POLICY AFTER 12 STAGES OF CALCULATIONS.
C
C
 99       OFLAG=TFLAG
                            IF (PCHKOD .EQ. 0) STOP
          IF (OPTCOD .EQ. 1) CFLAG=1
          IF (STAGNO .LE. 12 .OR. CFLAG .EQ. 0) GO TO 112
          TEMP=ABS(OPTVAI(1,1)-OPTVYR(1,1,MONTHI))
          COUNT=0
          DO 200 STATE=1, NSTATE
             DO 210 FLOW=1, NFLSTI
                DIFF=ABS(OPTVAI(STATE,FLOW)-OPTVYR(STATE,FLOW,MONTHI))
                IF (ABS(DIFF-TEMP) .LE. 0.01*TEMP) COUNT=COUNT+1
 210         CONTINUE
 200      CONTINUE
          IF (COUNT .EQ. NSTATE*NFLSTI) OFLAG=1
          IF ( OFLAG .EQ. 1) CFLAG=1
          IF ( OFLAG .EQ. 1) WRITE(6,*) '*****> OPTIMALITY CHECK O.K.'
          IF (OFLAG .EQ. 1 .AND. UNITR .EQ. 3) WRITE(6,104) TEMP
          IF (OFLAG .EQ. 0) WRITE(6,220) COUNT, NSTATE*NFLSTI
C
C
C         :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C         :                                                       :
C         :  TRANSFER POINTERS AND RETURNS                        :
C         :                                                       :
C         :::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::      TRANSFER THE OPTIMAL RETURNS AND THE CORRESPONDING POINTERS
C:::      FROM THE PRESENT STAGE TO THE NEXT STAGE
C
C
 112      DO 100 STATE=1, NSTATE
 106         DO 110 FLOWI=1, NFLSTI
                OPTVYR(STATE,FLOWI,MONTHI)=OPTVAI(STATE,FLOWI)
                OPTVAJ(STATE,FLOWI)=OPTVAI(STATE,FLOWI)
```

```
               YRPTR(STATE,FLOWI,MONTHI)=MTHPTR(STATE,FLOWI)
               YRRLS(STATE,FLOWI,MONTHI)=MTHRLS(STATE,FLOWI)
 110        CONTINUE
 100     CONTINUE
C
C
C        ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                    :
C        :  RECACULATE MONTH FOR THE NEXT STAGE               :
C        :                                                    :
C        ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
         MONTHI=MONTHI-1
         IF (MONTHI .EQ. 0) MONTHI=12
         MONTHJ=MONTHJ-1
         IF (MONTHJ .EQ. 0) MONTHJ=12
C
C     ******************************************************
C     *                                                    *
C     *  END OF LOOP STAGE(MONTH)                          *
C     *                                                    *
C     ******************************************************
C
 20   CONTINUE
 1    FORMAT('1',20(/),40X,50('#'),/,T41,'#',T90,'#',/, T41,'#',T54,
     &       'MARKOV TRANSITION MATRIX',T90,'#',/,T41,'#',T54,15A4,
     &       T90,'#',/,T41,'#',T90,'#' ,/,40X,50('#'))
 4    FORMAT('0',//,T10,I2,T30,10(F4.2,4X))
C4    FORMAT(' ',1X,I2,6X,10(F4.2,1X))
 5    FORMAT('1',T50,10('*'),' MONTH NO: ',I3,' ',10('*')////,
     &       T31,10(I2,6X)///)
C5    FORMAT(' ',///,' .CE ',10('*'),' MONTH NO: ',I3,' ',10('*')//,
C    &' STORAGE',T27,'INFLOW STATE',/,' STATE',T11,10(I2,3X))
 7    FORMAT(15A4)
 25   FORMAT('1',T54,10('*'),2A4,10('*'),//,
     &           T49,10('*'),' STAGE ',I3,' OF ',I3,' ',10('*')//,
     &       T50,10('*'),' MONTH NO: ',I3,' ',10('*')///,
     &       T3,'STORAGE',T15,'STORAGE',T62,'FLOW STATE',/,T4,'STATE',
     &       T14,'(CFS-WKS)',/,T27,9(I2,9X),I2)
 27   FORMAT(' ',T21,10(3X,F8.1))
 44   FORMAT(' ',1X,10(F5.3,2X))
 80   FORMAT('0',//,T5,I2,T13,F8.1,T22,10(1X,E10.3))
 83   FORMAT(' ',T22,10(1X,E10.3))
 85   FORMAT(' ',T14,'(',F6.2,')',T19,10(7X,'(',I2,')'))
 89   FORMAT(' ',3X,F8.1,2X,10(I2,2X))
 96   FORMAT(' ',35X,I2,3X,'+',10(4X,A1))
 97   FORMAT(' ',36X,'0',3X,'+',10(4('-'),'+'),/,T46,10(I2,3X))
 98   FORMAT(' ',//,T44,'GRAPHICAL PRESENTATION OF POINTERS FOR STATE',
     &       ' 7',//)
 101  FORMAT(' ',40X,'|',/,41X,'|')
 103  FORMAT(' ',//,T10,'MINIMUM RELEASE: ',F10.2,/)
 104  FORMAT(' ',/,T10,'ANNUAL EXPECTED RETURN: ',F10.1)
 111  FORMAT(' ',1X,15A4)
 220  FORMAT(' ',//,'XXXXX=> OPTIMALITY CHECK FAILS',
```

```
     &       3X,'COUNT=',I3,2X,'WHICH IS NOT EQUAL TO ',I3 ,
     &        ' FLOW STATES/STAGE')
 511  FORMAT(' ',1X,12(I2,1X))
 521  FORMAT(' ',1X,5(1X,F8.1))
 531  FORMAT(' ',1X,F8.1)
      STOP
      END
C
C
++EMBED F=TRPROB_DROPO
C
C
C++EMBED G=THESIS.DATA.MTH4 F=C40
C++EMBED F=LAURIE1
$ENTRY
++EMBED G=THESIS.DATA.MTH4 F=C40
++EMBED F=LAURIE1
( INPUT DATA )
```

B.1.1 Sample Input

```
LAURIE INFLOW RECORD (TITLE OF FLOW RECORD)
28 RECORDS
(28 YEARS OF INFLOW OR RELEASE RECORDS; GIVEN IN APPENDIX A)
0     PRINT THE FLOW RECORDS IN THE TRPROB ROUTINE?
0     PRINT THE TRANSITION MATRIX IN THE TRPROB ROUTINE?
1     PRINT TRANSITION PROBABILITY MATRIX IN THE MAIN PGM?
1     MAX. OR MIN. OBJECTIVE FUNCTION?  (MIN=0, MAX=1)
240   NUMBER OF STAGES?
8     NUMBER OF STATES?
213.0  213.0  213.0  213.0  212.0 212.0 212.0 212.0 212.0
212.0 213.0 213.0  MAX. MONTHLY RESERVOIR ELEVATIONS
192.0 192.0 192.0 192.0 192.0 192.0 192.0 192.0 192.0 192.0
192.0 192.0 192.0  MIN MONTHLY RESERVOIR ELEVATIONS
213.0 210.0 207.0 204.0
201.0 198.0 195.0 192.0  STORAGE LEVELS (STATES) FOR SUMMER
212.0 209.0 207.0 204.0
201.1 198.0 195.0 192.0  STORAGE LEVELS (STATES) FOR WINTER
1800.0 1800.0 1800.0 1800.0 1800.0 1800.0 1800.0 1800.0 1800.0
1800.0 1800.0  MIN. MONTHLY DOWNSTREAM RELEASE REQUIREMENT (CFS-WKS)
1800.0     WHAT IS THE MINMUM RELEASE (CFS-WEEKS) ?
3     WHICH RESERVOIR?  (EAGER=1, RUSSELL=2, LAURIE=3)
1     PERFORM OPTIMALITY CHECK FOR EVERY STAGE AFTER OPTIMAL POINT?
1     PRINT RESULTS STARTING AT STAGE 1 OR AT OPTIMAL STAGE? (STAGE 1=1)
1     DO U WANT RESULTS TO BE PRINTED AT ALL?
1     PRINT OPTIMAL POLICY IN DATASET?
1     PRINT OPTIMAL RELEASE IN DATASET?
0.0    WHAT IS THE INTEREST RATE?
```

B.1.2 Sample Output

The output produced by this program is similar to those given in Appendix B for Eager and Russell reservoirs except that it also prints out the optimal releases. Note: This program also prints optimal monthly policies and optimal monthly releases on two different datasets.

B.2 PROGRAM 2 - (EQN SYSTEM)

This program sets up the system of equations according to the optimal policies and solve for the system of equations. The results obtained are the probability of release (PR) associated with each inflow state.

********** Program Listing **********

```
C
C
C
         INTEGER TNVAR, NSTAGE, NSTATE, MONTHI, MONTHJ,
     &           EQNPTR, VARPTR, VARNUM, FLOWI, FLOWJ, STATEI, STATEJ,
     &           IER, ENDPTR, UNITPR, NUM(10)/1,2,3,4,5,6,7,8,9,10/,
     &           YRPTR(10,10,12), STATE, FLOW, NFLSTI,NFLSTJ,NFLST,
     &           MFLST(12), TITLE(15), UNITR
         REAL A(832,833),B(832) ,PS,
     &        PQ(10), SUMPR, TP(10,10,12)
         UNITR=3
         UNITPR=UNITR+20
C
C
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                     :
C        :  READ IN OPTIMAL POLICY FROM THE MAIN PROGRAM      :
C        :                                                     :
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::     READ IN POINTERS AND TRANSITION PROBABILITY MATRIX
C
         READ(UNITR,520) TITLE
         READ(UNITR,*) NSTATE
         READ(UNITR,*) MFLST
         WRITE(6,1) TITLE
         WRITE(UNITPR,570) TITLE
         DO 530 MONTHI=1, 12
            MONTHJ=MONTHI+1
            IF (MONTHJ .EQ. 13) MONTHJ=1
            NFLSTI=MFLST(MONTHI)
            NFLSTJ=MFLST(MONTHJ)
            DO 540 FLOWI=1, NFLSTI
               READ(UNITR,*) (TP(FLOWI,FLOWJ,MONTHI), FLOWJ=1, NFLSTJ)
 540        CONTINUE
 530     CONTINUE
         READ(UNITR,*) TNVAR
         M=TNVAR+1
         DO 550 MONTH=1, 12
            NFLST=MFLST(MONTH)
```

```
            READ(UNITR,*)  DUMMY
            READ(UNITR,*)  DUMMY
            DO 560 STATE=1, NSTATE
           READ(UNITR,*)  DUMMY,  (YRPTR(STATE,FLOW,MONTH), FLOW=1, NFLST)
 560        CONTINUE
 550     CONTINUE
C
C
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C        :                                                     :
C        :  DETERMINE CHOLESKY AUGMENTED MATRIX                :
C        :                                                     :
C        :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C        DETERMINE THE AUGMENTED MATRIX ACCORDING TO THE OPTIMAL POLICY.
C
C
         EQNPTR=0
         VARPTR=TNVAR-MFLST(12)*NSTATE
         DO 10 MONTHJ=1, 12
            MONTHI=MONTHJ-1
            IF (MONTHI .EQ. 0) MONTHI=12
            NFLSTI=MFLST(MONTHI)
            NFLSTJ=MFLST(MONTHJ)
            VARNUM=VARPTR
            DO 20 STATEJ=1, NSTATE
               DO 30 FLOWJ=1, NFLSTJ
                  EQNPTR=EQNPTR+1
                  DO 160 J=1, M
                     A(EQNPTR,J)=0.0
 160              CONTINUE
                  IF (STATEJ .EQ. NSTATE .AND. FLOWJ .EQ. NFLSTJ)
     &                 GO TO 150
                  A(EQNPTR,EQNPTR)=1.0
                  DO 40 STATEI=1, NSTATE
                     DO 50 FLOWI=1, NFLSTI
                        VARNUM=VARNUM+1
                        IF (YRPTR(STATEI,FLOWI,MONTHI) .EQ. STATEJ)
     &                  A(EQNPTR,VARNUM)=-TP(FLOWI,FLOWJ,MONTHI)
 50                  CONTINUE
 40               CONTINUE
                  VARNUM=VARPTR
 30            CONTINUE
 20         CONTINUE
 150        NVARPS=MFLST(MONTHJ)*NSTATE
            VARPTR=EQNPTR-NVARPS
C
C
C           REPLACE THE LAST EQN OF EACH STAGE WITH THE CONSTRAINT
C           EQN WHERE SUM OF PR'S=1.0
C
C
            DO 60 VARNUM=1, TNVAR
               IF (VARNUM .GT. (EQNPTR-NVARPS) .AND. VARNUM .LE. EQNPTR)
```

```
    &          A(EQNPTR,VARNUM)=1.0
 60          CONTINUE
             A(EQNPTR,M)=1.0
 10       CONTINUE
C
C
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::
C         :                                                  :
C         :  CALL EQUATION SOLVING SUBROUTINE                :
C         :                                                  :
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C         SOLVE SYSTEM OF EQUATIONS USING CHOLESKY METHOD
C
C
          CALL CHLSKY(A,N,M,B,NR)
C
C
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::
C         :                                                  :
C         :  PRINT RESULTS                                   :
C         :                                                  :
C         ::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C         PRESENT RESULTS IN THE FORM OF OPTIMAL POLICY
C
C
          WRITE(UNITPR,599) MFLST
 599      FORMAT(' ',1X,12(I2,1X))
          WRITE(UNITPR,*) NSTATE
          VARPTR=1
          DO 80 MONTH=1, 12
             NFLST=MFLST(MONTH)
             WRITE(6,90) MONTH, (NUM(I), I=1, NFLST)
             ENDPTR=VARPTR+NFLST-1
             DO 95 FLOW=1, NFLST
                PQ(FLOW)=0.0
 95          CONTINUE
             SUMPR=0.0
             DO 100 STATE=1, NSTATE
                PS=0.0
                J=1
                DO 105 I=VARPTR, ENDPTR
                   PS=B(I)+PS
                   PQ(J)=PQ(J)+B(I)
                   J=J+1
 105            CONTINUE
                SUMPR=SUMPR+PS
                WRITE(6,110) STATE, (B(I), I=VARPTR, ENDPTR)
                WRITE(UNITPR,580)  (B(I), I=VARPTR, ENDPTR)
                WRITE(6,115) PS
                WRITE(6,116)  (YRPTR(STATE,FLOW,MONTH), FLOW=1, NFLST)
                VARPTR=ENDPTR+1
                ENDPTR=VARPTR+NFLST-1
```

```
100         CONTINUE
            WRITE(6,120)  (PQ(I), I=1, NFLST)
            WRITE(6,125)  SUMPR
80       CONTINUE
         STOP
1     FORMAT('1',20(/),40X,50('#'),/,T41,'#',T90,'#',/, T41,'#',T54,
     &       'MARKOV TRANSITION MATRIX',T90,'#',/,T41,'#',T54,15A4,
     &       T90,'#',/,T41,'#',T90,'#'  ,/,40X,50('#'))
90       FORMAT('1',T50,'PROBABILITY OF RELEASE',//,T60,'MONTH: ',
     &          I2,///,T3,'STORAGE',T62,'INFLOW STATE',T121,
     &          'PROBABILITY',/,T4,'STATE',T122,'(STORAGE)',/,
     &          T22,10(I2,8X))
110      FORMAT('0',//,T5,I2,T16,10(2X,F8.3))
115      FORMAT('+',T122,F8.3)
116      FORMAT(' ',T15,10(7X,'(',I1,')'))
120      FORMAT('0',//,T2,'PROB(INFLOWS)',T16,10(2X,F8.3))
125      FORMAT('0',///,T50,'*****=> TOTAL PR= ',F8.3)
520      FORMAT(15A4)
570      FORMAT(' ',1X,15A4)
580      FORMAT(' ',1X,10(F5.3,1X))
      STOP
C
C
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                    :
C     :  THE CHOLESKY METHOD                               :
C     :                                                    :
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  SOLVE THE SYSTEM OF EQUATION USING THE CHOLESKY METHOD
C
      SUBROUTINE CHLSKY(A,N,M,X,NR)
      REAL A(NR,1), X(N)
C    CALCULATE FIRST ROW OF THE UPPER UNIT TRIANGULAR MATRIX
         DO 3 J=2, M
3           A(1,J)=A(1,J)/A(1,1)
C    CALCULATE OTHER ELEMENTS OF U AND L MATRICES
         DO 8 I=2, N
            J=I
            DO 5 II=J, N
               SUM=0.0
               JM1=J-1
               DO 4 K=1, JM1
4              SUM=SUM+A(II,K)*A(K,J)
5          A(II,J)=A(II,J)-SUM
           IP1=I+1
           DO 7 JJ=IP1, M
              SUM=0.0
              IM1=I-1
              DO 6 K=1, IM1
6             SUM=SUM+A(I,K)*A(K,JJ)
7          A(I,JJ)=(A(I,JJ)-SUM)/A(I,I)
8        CONTINUE
C   SOLVE FOR X(I) BY BACK SUBSTITUTION
```

```
        X(N)=A(N,N+1)
        L=N-1
        DO 10 NN=1, L
           SUM=0.0
           I=N-NN
           IP1=I+1
           DO 9 J=IP1, N
 9         SUM=SUM+A(I,J)*X(J)
 10     X(I)=A(I,M)-SUM
      RETURN
      END
$ENTRY
( INPUT DATA )
```

B.2.1 Sample Input

The inputs to this program are the optimal monthly policies (in dataset) produced by Program 1.

B.2.2 Sample Output

The output of this program are the probability of release associated to each inflow state and the monthly optimal pointers which are stored in datasets and later used by Program 3.

B.3 PROGRAM 3 - (ASSEMBLE INFO)

This determines the probability distributions of inflow, release, and storage and also the monthly expected releases.

********** Program Listing **********

```
      INTEGER TITLE(15), MFLST(12), NSTATE, NFLST, STATE,
     &        UNITPL, FLOW, NUMSKIP, YRPTR(10), PTR,
     &        FLONUM(10)/1,2,3,4,5,6,7,8,9,10/, UNITR, UNITPR
      REAL Q(10), RELEAS(10), PRS(10), DUMMY, PRDIST(10), EXPRLS,
     &    PQ(10), PS(10), ELEV, EXPSTO,
     &    AVGFLO(12)/126.1,136.3,133.8,276.6,818.6,484.6,331.3,281.2,
     &                351.2,296.5,226.4,175.5/
      COMPLEX*8 RNAME(3)/' EAGER  ','RUSSELL ',' LAURIE '/
C
C
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                  :
C     :  READ OPTIMAL POLICY                             :
C     :                                                  :
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  READ IN OPTIMAL POLICY FROM DIFFERENT FILES
C
      READ(5,*) UNITR
      UNITPL=UNITR+10
      UNITPR=UNITR+20
      READ (UNITPL,10) TITLE
      READ (UNITPR,10) TITLE
      READ (UNITR,10) TITLE
10    FORMAT(15A4)
      READ(UNITPL,*) NSTATE
      READ(UNITPL,*) MFLST
      READ(UNITPR,*) MFLST
      READ(UNITPR,*) NSTATE
      NUMSKIP=0
C
C:::  SKIP UNWANTED DATA LINES
C
      DO 15 I=1, 12
         NUMSKIP=NUMSKIP+MFLST(I)
 15   CONTINUE
      NUMSKIP=NUMSKIP+3
      DO 17 I=1, NUMSKIP
         READ(UNITR,*) DUMMY
 17   CONTINUE
C
C
```

```
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                     :
C     :  CALCULATE PROBABILITY DISTRIBUTIONS                :
C     :                                                     :
C     :::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C:::  CALCULATE THE PROBABLITY DISTRIBUTIONS OF STORAGE, RELEASE,
C:::  AND INFLOW. ALSO, CALCULATE THE EXPETED RELEASE AND EXPECTED
C:::  STORAGE LEVEL FOR EACH MONTH.
C
      DO 20 MONTH=1, 12
         NFLST=MFLST(MONTH)
         READ(UNITPL,*)  (Q(FLOW), FLOW=1, NFLST)
         READ(UNITR,*)  (Q(FLOW), FLOW=1, NFLST)
         EXPRLS=0.0
         EXPSTO=0.0
         DO 25 FLOW=1, 10
            PRDIST(FLOW)=0.0
            PQ(FLOW)=0.0
            PS(FLOW)=0.0
 25      CONTINUE
         WRITE(6,26)  RNAME(UNITR),
     &             MONTH,  (FLONUM(FLOW), FLOW=1, NFLST)
         WRITE(6,27)
     &          (Q(FLOW), FLOW=1, NFLST)
         DO 30 STATE=1, NSTATE
            READ(UNITPL,*)  ELEV,  (RELEAS(FLOW),
     &                                     FLOW=1, NFLST)
            READ(UNITPR,*)  (PRS(FLOW), FLOW=1, NFLST)
            READ(UNITR,*)  ELEV,  (YRPTR(FLOW),
     &                                   FLOW=1, NFLST)
            DUMMY=0.0
            DO 40 FLOW=1, NFLST
               PQ(FLOW)=PQ(FLOW)+PRS(FLOW)
               DUMMY=PRS(FLOW)+DUMMY
               PTR=YRPTR(FLOW)
               PRDIST(PTR)=PRDIST(PTR)+PRS(FLOW)
               EXPRLS=EXPRLS+RELEAS(FLOW)*PRS(FLOW)
 40         CONTINUE
            PS(STATE)=DUMMY
            EXPSTO=EXPSTO+PS(STATE)*ELEV
            WRITE(6,80)  STATE, ELEV,
     &          (RELEAS(FLOW), FLOW=1,NFLST)
            WRITE(6,83)  (PRS(FLOW), FLOW=1, NFLST)
            WRITE(6,85)   (YRPTR(FLOW),
     &                            FLOW=1, NFLST)
 30      CONTINUE
         WRITE(6,90)  (PQ(FLOW), FLOW=1, NFLST)
         WRITE(6,100)  (PS(STATE), STATE=1, NSTATE)
         WRITE(6,110)  (PRDIST(STATE), STATE=1, NSTATE)
         TEMP=EXPRLS-AVGFLO(MONTH)*4.0
         WRITE(6,120)  EXPRLS, TEMP
         WRITE(6,130)  EXPRLS*0.41, TEMP*0.41
         WRITE(6,140)  EXPRLS*0.59, TEMP*0.59
```

```
         WRITE(6,150) EXPSTO
 20   CONTINUE
      STOP
 26   FORMAT('1',T54,10('*'),2A4,10('*'),//,
     &       T50,10('*'),' MONTH NO: ',I3,' ',10('*')///,
     &       T3,'STORAGE',T15,'STORAGE',T60,'INFLOW STATE (CFS)',/,T4,
     &       'STATE',T16,'LEVEL',/,T27,9(I2,9X),I2)
 27   FORMAT(' ',T21,10(3X,F8.1))
 80   FORMAT('0',//,T5,I2,T13,F8.1,T22,10(1X,E10.3))
 83   FORMAT(' ',T20,10(3X,F8.3))
 85   FORMAT(' ',T19,10(7X,'(',I2,')'))
 90   FORMAT(' ',///,'PROB. DISTR. (INFLOWS)',
     &       T20,10(3X,F8.3)/)
 100  FORMAT('0','PROB. DISTR. (STORAGE)',
     &       T20,10(3X,F8.3)/)
 110  FORMAT('0','PROB. DISTR. (RELEASE)',
     &       T20,10(3X,F8.3)/)
 120  FORMAT('0','EXPECTED RELEASE FOR THE MONTH (CFS-WKS)',
     &       T50,F10.2,T80,'DEDUCT INFLOW   ',F10.2)
 130  FORMAT('0','EXPECTED RELEASE FOR EAGER (CFS-WKS)',
     &       T50,F10.2,T80,'DEDUCT INFLOW   ',F10.2)
 140  FORMAT('0','EXPECTED RELEASE RUSSELL (CFS-WKS)',
     &       T50,F10.2,T80,'DEDUCT INFLOW   ',F10.2)
 150  FORMAT('0','EXPECTED STORAGE LEVEL',
     &       T50,F10.2,' FEET')
      END
$ENTRY
( INPUT DATA )
```

B.3.1 Sample Input

3   WHICH RESERVOIR (1=EAGER, 2=RUSSELL, 3=LAURIE) ? (part of input)

The sample inputs for this program are: 1) Monthly release policies (in dataset) produced by Program 1, and 2) Probability of release (in dataset) produced by Program 2.

B.3.2 Sample Output

The sample output for this program can be found in Appendix C for Laurie reservoir.

B.4 PROGRAM 4 - (GENRTN)

This program generates the monthly release records according to the optimal policies.

********** Program Listing **********

```
      INTEGER TITLE1(18,3), MFLST(12,3), NSTATE(3), NFLST, STATE, YR,
     &        UNITPL, FLOW, NUMSKIP, YRPTR(21,10,12,3), FLOPTR,STPTR,
     &        PRFLDA, UNITR, NUMREC, RECNO,
     &       PTR3(3), UNITFL, RESNO, INFLOW(28,12,3), TITLE(18),
     &        COMENT(18)
      REAL QDUMMY(10), RELEAS(21,10,12,3), DUMMY, Q(12,10,3),
     &     ELEV(12,21,3), SLEVEL(28,12,3), RETURN(12),
     &     VALUE(12)/15.9,15.1,14.2,12.8,10.7,8.3,9.3,10.3,12.3,
     &                12.5,12.8,13.8/,
     &     MTHDAY(12)/31.0,28.0,31.0,30.0,31.0,30.0,31.0,31.0,30.0,31.0,
     &                30.0,31.0/,
     &     LAVGQI(12)/126.1,136.3,133.8,276.6,818.6,484.6,331.3,281.2,
     &                351.2,296.5,226.4,175.5/,
     &        TINFLO, OUTFLO(28,12,3), ADFLOW(28,12),
     &        QOPT/1150.0/, QOUT,AVGIN(12,3)/36*0.0/,
     &        AVGOUT(12,3)/36*0.0/
      COMPLEX*8 RNAME(3)/' EAGER   ','RUSSELL ',' LAURIE '/
C
C
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                  :
C     :  READ IN OPTIMAL RELEASE POLICY                  :
C     :                                                  :
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C::: READ IN THE OPTIMAL RELEASE POLICY FROM DIFFERENT FILES
C
      READ(5,10) COMENT
      WRITE(6,11) COMENT
      DO 5 UNITR=1, 3
      UNITPL=UNITR+10
      READ(5,10)  (TITLE1(I,UNITR), I=1, 18)
      READ(5,*) NUMREC
      READ  (UNITPL,10) TITLE
      READ  (UNITR,10) TITLE
      READ(UNITPL,*) NSTATE(UNITR)
      READ(UNITPL,*)  (MFLST(MONTH,UNITR), MONTH=1, 12)
C
C:::  SKIP UNWANTED DATA LINES
C
      NUMSKIP=0
      DO 15 I=1, 12
         NUMSKIP=NUMSKIP+MFLST(I,UNITR)
 15   CONTINUE
```

```
      NUMSKIP=NUMSKIP+3
      DO 17 I=1, NUMSKIP
         READ(UNITR,*) DUMMY
 17   CONTINUE
C
C
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C     :                                                    :
C     :  DETERMINE THE AMOUNT TO RELEASE FOR EACH MONTH    :
C     :                                                    :
C     ::::::::::::::::::::::::::::::::::::::::::::::::::::::
C
C::: DETERMINE THE AMOUNT TO RELEASE AND PRINT RESULTS
C
      DO 20 MONTH=1, 12
         NFLST=MFLST(MONTH,UNITR)
         READ(UNITPL,*) (QDUMMY(FLOW), FLOW=1, NFLST)
         READ(UNITR,*) (Q(MONTH,FLOW,UNITR), FLOW=1, NFLST)
C        WRITE(6,*) 'QDUMMY', (QDUMMY(FLOW), FLOW=1, NFLST)
C        WRITE(6,*) 'TRUE Q', (Q(MONTH,FLOW,UNITR), FLOW=1, NFLST)
         ITEMP=NSTATE(UNITR)
         DO 30 STATE=1, ITEMP
            READ(UNITPL,*) DUMMY, (RELEAS(STATE,FLOW,MONTH,UNITR),
     &                                     FLOW=1, NFLST)
            READ(UNITR,*) ELEV(MONTH,STATE,UNITR), (YRPTR(STATE,FLOW,
     &                             MONTH,UNITR), FLOW=1, NFLST)
 30      CONTINUE
 20   CONTINUE
            DO 40 RECNO=1, NUMREC
               READ, YR, (INFLOW(RECNO,MONTH,UNITR), MONTH=1, 12)
 40         CONTINUE
 5    CONTINUE
      DO 250 UNITR=1, 3
C
C     START OPERATION AT FSL
         STPTR=1
C
         YR=1953
         TVALUE=0.0
      DO 100 RECNO=1, NUMREC
         YVALUE=0.0
         DO 110 MONTH=1, 12
            TINFLO=INFLOW(RECNO,MONTH,UNITR)
            IF (UNITR .EQ. 3) TINFLO=TINFLO
     &      OUTFLO(RECNO,MONTH,1)+OUTFLO(RECNO,MONTH,2)
            ITEMP=MFLST(MONTH,UNITR)-1
            DO 120 FLOW=1, ITEMP
               BOUND=(Q(MONTH,FLOW+1,UNITR)+Q(MONTH,FLOW,UNITR))/2.0
               IF (TINFLO .LT. BOUND) GOTO 200
 120        CONTINUE
 200        FLOPTR=FLOW
            OUTFLO(RECNO,MONTH,UNITR)=RELEAS(STPTR,FLOPTR,MONTH,UNITR)
     &      /4.0
            IF (UNITR .EQ. 3) ELEV1=ELEV(MONTH,STPTR,UNITR)
```

```
            STPTR=YRPTR(STPTR,FLOPTR,MONTH,UNITR)
            MTHJ=MONTH+1
            IF (MTHJ .EQ. 13) MTHJ=1
            SLEVEL(RECNO,MONTH,UNITR)=ELEV(MTHJ,STPTR,UNITR)
            AVGIN(MONTH,UNITR)=AVGIN(MONTH,UNITR)+TINFLO
            AVGOUT(MONTH,UNITR)=AVGOUT(MONTH,UNITR)
     &      OUTFLO(RECNO,MONTH,UNITR)
            IF (UNITR .NE. 3) GOTO 110
               IF (ELEV1 .EQ. SLEVEL(RECNO,MONTH,UNITR) .OR.
     &         FLOPTR .EQ. ITEMP+1) OUTFLO(RECNO,MONTH,UNITR)=TINFLO
               FB=(SLEVEL(RECNO,MONTH,UNITR)+ELEV1)/2.0
               QOUT=OUTFLO(RECNO,MONTH,UNITR)
               IF (QOUT .GT. QOPT) QOUT=QOPT
               RETURN(MONTH)=(-8.45334+0.035*FB
     &         0.00891945*
     &         QOUT)*VALUE(MONTH)*MTHDAY(MONTH)*24.0
               YVALUE=YVALUE+RETURN(MONTH)
               IF (RETURN(MONTH) .LT. 0.0) RETURN(MONTH)=0.0
               ADFLOW(RECNO,MONTH)=TINFLO
110      CONTINUE
         IF (UNITR .NE. 3) GOTO 100
            IF (MOD(RECNO,4) .EQ. 1) WRITE(6,130)
            DO 140 MONTH=1, 12
               SPILL=0.0
               IF (OUTFLO(RECNO,MONTH,UNITR) .GT. QOPT) SPILL=
     &         OUTFLO(RECNO,MONTH,UNITR)-QOPT
               WRITE(6,150) YR,MONTH,INFLOW(RECNO,MONTH,3),
     &         INFLOW(RECNO,MONTH,1),SLEVEL(RECNO,MONTH,1),
     &         OUTFLO(RECNO,MONTH,1),INFLOW(RECNO,MONTH,2),
     &         SLEVEL(RECNO,MONTH,2),
     &         OUTFLO(RECNO,MONTH,2),ADFLOW(RECNO,MONTH),
     &         SLEVEL(RECNO,MONTH,3),
     &         OUTFLO(RECNO,MONTH,UNITR)-SPILL,SPILL,RETURN(MONTH)
140         CONTINUE
         WRITE(6,*) ' '
         WRITE(6,*) ' '
         YR=YR+1
         TVALUE=TVALUE+YVALUE
100   CONTINUE
250   CONTINUE
      WRITE(6,160) TVALUE/NUMREC
      WRITE(6,*) 'INITIAL RES. ELEVATIONS FOR EAGER RUSSELL & LAURIE'
      WRITE(6,*) ELEV(1,1,1), ELEV(1,1,2), ELEV(1,1,3)
      DO 170 UNITR=1, 3
         WRITE(6,180) UNITR,(AVGIN(MONTH,UNITR)/NUMREC, MONTH=1, 12)
         WRITE(6,190) (AVGOUT(MONTH,UNITR)/NUMREC, MONTH=1, 12)
         IF (UNITR .NE. 3) GOTO 170
            DO 175 MONTH=1, 12
               TEMP=(AVGOUT(MONTH,3)/NUMREC-LAVGQI(MONTH))*1.64
               IF (TEMP .GT. QOPT*1.64) TEMP=QOPT*1.64
               AVGOUT(MONTH,1)=TEMP
               TEMP=(AVGOUT(MONTH,3)/NUMREC-LAVGQI(MONTH))*2.36
               IF (TEMP .GT. QOPT*2.36) TEMP=QOPT*2.36
               AVGOUT(MONTH,2)=TEMP
```

```
 175          CONTINUE
           WRITE(6,11) RNAME(1)
           WRITE(6,340) (AVGOUT(MONTH,1), MONTH=1, 12)
           WRITE(6,11) RNAME(2)
           WRITE(6,340) (AVGOUT(MONTH,2), MONTH=1, 12)
 170    CONTINUE
        DO 199 UNITR=1, 3
           WRITE(6,310) COMENT, RNAME(UNITR)
           YR=1952
           DO 210 RECNO=1, NUMREC
              YR=YR+1
 210          WRITE(6,221) YR, (INFLOW(RECNO,MONTH,UNITR), MONTH=1, 12)
           IF (UNITR .NE. 3) GOTO 230
           WRITE(6,320)
           YR=1952
           DO 240 RECNO=1, NUMREC
              YR=YR+1
 240          WRITE(6,220) YR, (ADFLOW(RECNO,MONTH), MONTH=1, 12)
 230       WRITE(6,330) COMENT, RNAME(UNITR)
              YR=1952
           DO 260 RECNO=1, NUMREC
              YR=YR+1
 260          WRITE(6,220) YR, (OUTFLO(RECNO,MONTH,UNITR), MONTH=1, 12)
 199    CONTINUE
        STOP
10      FORMAT(18A4)
11      FORMAT(' ',/////,10('*'),' ',18A4,10('*'))
130     FORMAT('1',18X,'..........EAGER...........  .........RUSSELL',
       &'..........  ..................PLANT # 2.................',
       &/,11X,'UNREG.',10X,'END  OF',21X,'END OF',23X,'END OF',21X,
       &'VALUE OF',/,' YEAR MTH  INFLOW  INFLOW  MO. ELEV.  OUTFLOW',
       &'  INFLOW  MO. ELEV.  OUTFLOW   INFLOW  MO. ELEV.  OUTFLOW  SPILL'
       &,'  GENERATION',//)
 150    FORMAT(' 'I5,I4,I7,I8,F10.2,F10.0,I8,F10.2,F10.0,F9.0,F10.2,F10.0,
       &F8.0,F10.0)
 160    FORMAT('1',5X,'EXPECTED ANNUAL RETURN:',F10.0///)
 180    FORMAT('0',3X,///,'RESERVOIR NO: ',I1,//,4X,'AVERAGE MONTHLY '
       &       ,'INFLOW: ',2X,12(F7.1,1X))
 190    FORMAT('0',3X,'AVERAGE MONTHLY OUTFLOW:',2X,12(F7.1,1X))
 220    FORMAT(' ',1X,I4,12(1X,F5.0))
 221    FORMAT(' ',1X,I4,12(1X,I4))
 310    FORMAT('1',18A4,/,2A4,'UNREGULATED INFLOWS (CFS)'/)
 320    FORMAT('1','TOTAL INFLOWS INTO LAURIE RESERVOIRS'/,' 28 RECORDS')
 330    FORMAT('1',18A4,/,2A4,'REGULATED OUTFLOWS (CFS)'/,' 28 RECORDS')
 340    FORMAT(' ',6(1X,F7.1))
        END
$ENTRY
Comment line to indicate which iteration the program is processing.
( INPUT DATA )
{ Eager Inflow Records }
{ Russell Inflow Records }
{ Laurie Inflow Records }
```

B.4.1 Sample Input

The sample inputs to this program are just the individual inflow records.

B.4.2 Sample Output

The output ot this program are:

1. The local inflow record for each reservoir
2. The release record for each for each reservoir
3. The simulated reservoir operations which can be found in Appendix C.

Appendix C

TRANSITION PROBABILITY MATRIX

This section contains the three sets of 12 transition probability matrices for each of the reservoirs. Note that these transition probability matrices are developed from the original inflow records.

C.1 EAGER RESERVOIR

********** EAGER RESERVOIR - MONTH NO: 1 **********

STORAGE				INFLOW STATE						
STATE	1	2	3	4	5	6	7	8	9	10
1	0.50	0.25	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
2	0.60	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.67	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.50	0.25	0.25	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00
8	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
10	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.25

********** EAGER RESERVOIR - MONTH NO: 2 **********

STORAGE				INFLOW STATE					
STATE	1	2	3	4	5	6	7	8	9
1	0.88	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.67	0.33	0.00	0.00	0.00	0.00	0.00	0.00
4	0.17	0.00	0.17	0.00	0.17	0.33	0.00	0.00	0.17
5	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
7	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00
9	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

```
   ********** EAGER RESERVOIR - MONTH NO:  3 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9


  1     0.50 0.13 0.13 0.13 0.13 0.00 0.00 0.00 0.00

  2     0.00 0.00 0.33 0.33 0.00 0.00 0.33 0.00 0.00

  3     0.00 0.20 0.00 0.20 0.40 0.20 0.00 0.00 0.00

  4     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00

  5     0.00 0.50 0.00 0.50 0.00 0.00 0.00 0.00 0.00

  6     0.00 0.00 0.25 0.25 0.50 0.00 0.00 0.00 0.00

  7     0.00 0.00 0.00 0.00 0.33 0.33 0.00 0.33 0.00

  8     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00

  9     0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00



   ********** EAGER RESERVOIR - MONTH NO:  4 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7


  1     0.25 0.25 0.25 0.00 0.25 0.00 0.00

  2     0.00 0.00 0.67 0.33 0.00 0.00 0.00

  3     0.00 0.00 0.00 0.00 0.33 0.67 0.00

  4     0.00 0.33 0.17 0.17 0.00 0.00 0.33

  5     0.14 0.00 0.29 0.57 0.00 0.00 0.00

  6     0.00 0.50 0.50 0.00 0.00 0.00 0.00

  7     0.00 1.00 0.00 0.00 0.00 0.00 0.00

  8     1.00 0.00 0.00 0.00 0.00 0.00 0.00

  9     0.00 0.00 0.00 0.00 0.00 1.00 0.00
```

********** EAGER RESERVOIR - MONTH NO: 5 **********

STORAGE STATE	INFLOW STATE								
	1	2	3	4	5	6	7	8	9
1	0.33	0.33	0.00	0.00	0.33	0.00	0.00	0.00	0.00
2	0.20	0.20	0.40	0.00	0.00	0.20	0.00	0.00	0.00
3	0.00	0.00	0.14	0.57	0.00	0.00	0.14	0.14	0.00
4	0.50	0.00	0.33	0.00	0.17	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.33
7	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00

********** EAGER RESERVOIR - MONTH NO: 6 **********

STORAGE STATE	INFLOW STATE								
	1	2	3	4	5	6	7	8	9
1	0.60	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
3	0.00	0.14	0.29	0.14	0.29	0.00	0.14	0.00	0.00
4	0.00	0.00	0.00	0.57	0.29	0.14	0.00	0.00	0.00
5	0.00	0.00	0.67	0.00	0.33	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
8	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

```
    ********** EAGER RESERVOIR - MONTH NO:  7 **********

STORAGE                    INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9   10


  1     0.67 0.00 0.00 0.00 0.00 0.33 0.00 0.00 0.00 0.00

  2     0.00 0.00 0.50 0.00 0.50 0.00 0.00 0.00 0.00 0.00

  3     0.40 0.00 0.60 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  4     0.00 0.00 0.63 0.13 0.00 0.00 0.00 0.00 0.13 0.13

  5     0.17 0.17 0.50 0.00 0.00 0.00 0.17 0.00 0.00 0.00

  6     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  7     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  8     0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  9     0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00
```

```
    ********** EAGER RESERVOIR - MONTH NO:  8 **********

STORAGE                    INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9


  1     0.60 0.00 0.20 0.00 0.20 0.00 0.00 0.00 0.00

  2     0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  3     0.38 0.31 0.23 0.00 0.00 0.00 0.08 0.00 0.00

  4     0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00

  5     0.00 0.00 0.00 0.33 0.00 0.33 0.00 0.33 0.00

  6     0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  7     1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  8     0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  9     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00

 10     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00
```

********** EAGER RESERVOIR - MONTH NO: 9 **********

STORAGE				INFLOW STATE						
STATE	1	2	3	4	5	6	7	8	9	10
1	0.67	0.22	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.60	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.20	0.60	0.20	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.33	0.00	0.00
5	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
7	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00

********** EAGER RESERVOIR - MONTH NO: 10 **********

STORAGE				INFLOW STATE						
STATE	1	2	3	4	5	6	7	8	9	10
1	0.17	0.17	0.33	0.17	0.00	0.00	0.17	0.00	0.00	0.00
2	0.00	0.40	0.00	0.40	0.00	0.00	0.20	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50
4	0.00	0.00	0.13	0.13	0.25	0.00	0.38	0.00	0.13	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
9	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

```
   ********** EAGER RESERVOIR - MONTH NO: 11 **********

STORAGE                          INFLOW STATE
STATE      1    2    3    4    5    6    7    8    9   10


  1      1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  2      0.33 0.33 0.33 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  3      0.33 0.00 0.67 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  4      0.00 0.20 0.00 0.20 0.20 0.40 0.00 0.00 0.00 0.00

  5      0.00 0.00 0.50 0.00 0.50 0.00 0.00 0.00 0.00 0.00

  6      0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00

  7      0.00 0.00 0.00 0.00 0.14 0.71 0.00 0.14 0.00 0.00

  8      0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00

  9      0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00

 10      0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.33 0.33 0.33

   ********** EAGER RESERVOIR - MONTH NO: 12 **********

STORAGE                          INFLOW STATE
STATE      1    2    3    4    5    6    7    8    9   10


  1      0.00 0.67 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.33

  2      0.50 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.50 0.00

  3      0.00 0.25 0.25 0.00 0.00 0.25 0.25 0.00 0.00 0.00

  4      0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  5      0.33 0.33 0.00 0.00 0.33 0.00 0.00 0.00 0.00 0.00

  6      0.13 0.13 0.13 0.00 0.13 0.00 0.13 0.25 0.00 0.13

  7      0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00

  8      0.00 0.00 0.00 0.00 0.50 0.25 0.00 0.00 0.00 0.25

  9      0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00

 10      1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
```

C.2 RUSSELL RESERVOIR

```
  ********** RUSSELL RESERVOIR - MONTH NO:  1 **********

STORAGE                         INFLOW STATE
STATE      1    2    3    4    5    6    7    8    9


  1      0.80 0.20 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  2      0.00 0.67 0.00 0.33 0.00 0.00 0.00 0.00 0.00

  3      0.00 0.33 0.67 0.00 0.00 0.00 0.00 0.00 0.00

  4      0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00

  5      0.00 0.00 0.20 0.80 0.00 0.00 0.00 0.00 0.00

  6      0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  7      0.00 0.50 0.50 0.00 0.00 0.00 0.00 0.00 0.00

  8      0.20 0.00 0.00 0.00 0.00 0.40 0.00 0.20 0.20

  9      0.00 0.50 0.00 0.00 0.00 0.00 0.50 0.00 0.00
```

```
  ********** RUSSELL RESERVOIR - MONTH NO:  2 **********

STORAGE                         INFLOW STATE
STATE      1    2    3    4    5    6    7


  1      0.80 0.00 0.20 0.00 0.00 0.00 0.00

  2      0.17 0.17 0.33 0.00 0.17 0.00 0.17

  3      0.25 0.50 0.25 0.00 0.00 0.00 0.00

  4      0.14 0.14 0.29 0.43 0.00 0.00 0.00

  5      0.00 0.00 0.00 0.00 1.00 0.00 0.00

  6      0.00 0.00 0.00 1.00 0.00 0.00 0.00

  7      0.00 0.00 0.00 0.00 1.00 0.00 0.00

  8      0.00 0.00 1.00 0.00 0.00 0.00 0.00

  9      0.00 0.00 0.00 0.00 0.00 1.00 0.00
```

********** RUSSELL RESERVOIR - MONTH NO: 3 **********

STORAGE STATE	INFLOW STATE									
	1	2	3	4	5	6	7	8	9	10
1	0.43	0.14	0.14	0.00	0.14	0.00	0.00	0.14	0.00	0.00
2	0.25	0.00	0.25	0.00	0.00	0.00	0.25	0.00	0.00	0.25
3	0.29	0.14	0.14	0.00	0.00	0.43	0.00	0.00	0.00	0.00
4	0.40	0.00	0.00	0.20	0.20	0.20	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.33	0.00
6	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
7	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

********** RUSSELL RESERVOIR - MONTH NO: 4 **********

STORAGE STATE	INFLOW STATE							
	1	2	3	4	5	6	7	8
1	0.11	0.22	0.22	0.11	0.22	0.00	0.00	0.11
2	0.00	0.00	0.00	0.00	0.50	0.00	0.50	0.00
3	0.00	0.00	0.33	0.00	0.00	0.33	0.33	0.00
4	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00
6	0.00	0.20	0.20	0.20	0.00	0.40	0.00	0.00
7	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00
8	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00
9	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
10	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

```
********** RUSSELL RESERVOIR - MONTH NO:  5 **********

STORAGE                          INFLOW STATE
STATE     1    2    3    4    5    6    7    8


  1     0.33 0.33 0.00 0.00 0.00 0.33 0.00 0.00

  2     0.00 0.00 0.33 0.33 0.00 0.00 0.33 0.00

  3     0.00 0.20 0.20 0.40 0.00 0.00 0.00 0.20

  4     0.00 0.00 0.00 0.20 0.20 0.60 0.00 0.00

  5     0.33 0.00 0.00 0.00 0.00 0.67 0.00 0.00

  6     0.00 0.33 0.17 0.00 0.17 0.17 0.00 0.17

  7     0.50 0.00 0.00 0.00 0.00 0.00 0.50 0.00

  8     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00


********** RUSSELL RESERVOIR - MONTH NO:  6 **********

STORAGE                          INFLOW STATE
STATE     1    2    3    4    5    6    7


  1     1.00 0.00 0.00 0.00 0.00 0.00 0.00

  2     0.00 0.50 0.50 0.00 0.00 0.00 0.00

  3     0.00 1.00 0.00 0.00 0.00 0.00 0.00

  4     0.25 0.00 0.75 0.00 0.00 0.00 0.00

  5     0.33 0.33 0.33 0.00 0.00 0.00 0.00

  6     0.00 0.00 0.43 0.14 0.00 0.14 0.29

  7     0.00 0.00 0.50 0.00 0.50 0.00 0.00

  8     0.00 0.50 0.50 0.00 0.00 0.00 0.00
```

```
********** RUSSELL RESERVOIR - MONTH NO:  7 **********

STORAGE                        INFLOW STATE
STATE     1     2     3     4     5     6     7     8


  1      0.60  0.00  0.20  0.20  0.00  0.00  0.00  0.00

  2      0.29  0.29  0.14  0.00  0.14  0.00  0.00  0.14

  3      0.09  0.09  0.36  0.27  0.00  0.18  0.00  0.00

  4      1.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00

  5      0.00  0.00  1.00  0.00  0.00  0.00  0.00  0.00

  6      0.00  0.00  0.00  1.00  0.00  0.00  0.00  0.00

  7      0.00  0.50  0.00  0.00  0.00  0.00  0.50  0.00
```

```
********** RUSSELL RESERVOIR - MONTH NO:  8 **********

STORAGE                        INFLOW STATE
STATE     1     2     3     4     5     6     7


  1      0.43  0.43  0.00  0.00  0.00  0.14  0.00

  2      0.25  0.00  0.25  0.00  0.25  0.00  0.25

  3      0.43  0.14  0.29  0.00  0.00  0.00  0.14

  4      0.00  0.20  0.00  0.40  0.40  0.00  0.00

  5      0.00  0.00  0.00  1.00  0.00  0.00  0.00

  6      0.00  0.00  1.00  0.00  0.00  0.00  0.00

  7      0.00  1.00  0.00  0.00  0.00  0.00  0.00

  8      0.00  0.00  0.00  0.00  0.00  0.00  1.00
```

```
********** RUSSELL RESERVOIR - MONTH NO:  9 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7    8


  1     0.43 0.43 0.14 0.00 0.00 0.00 0.00 0.00

  2     0.33 0.50 0.00 0.17 0.00 0.00 0.00 0.00

  3     0.00 0.00 0.80 0.20 0.00 0.00 0.00 0.00

  4     0.00 0.00 0.33 0.33 0.33 0.00 0.00 0.00

  5     0.00 0.00 0.00 0.00 0.33 0.00 0.33 0.33

  6     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00

  7     0.00 0.00 0.00 0.33 0.00 0.33 0.33 0.00
```

```
********** RUSSELL RESERVOIR - MONTH NO: 10 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9


  1     0.40 0.20 0.00 0.40 0.00 0.00 0.00 0.00 0.00

  2     0.00 0.17 0.17 0.33 0.00 0.33 0.00 0.00 0.00

  3     0.00 0.17 0.33 0.17 0.17 0.17 0.00 0.00 0.00

  4     0.00 0.25 0.00 0.00 0.50 0.25 0.00 0.00 0.00

  5     0.00 0.00 0.00 0.33 0.00 0.33 0.33 0.00 0.00

  6     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00

  7     0.00 0.00 0.00 0.00 0.50 0.00 0.00 0.50 0.00

  8     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00
```

********** RUSSELL RESERVOIR - MONTH NO: 11 **********

STORAGE	INFLOW STATE									
STATE	1	2	3	4	5	6	7	8	9	10
1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.75	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00
3	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.00
4	0.00	0.00	0.33	0.33	0.33	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.50	0.00	0.25	0.00	0.25	0.00	0.00	0.00
6	0.00	0.00	0.00	0.40	0.20	0.20	0.20	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
9	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50

********** RUSSELL RESERVOIR - MONTH NO: 12 **********

STORAGE	INFLOW STATE								
STATE	1	2	3	4	5	6	7	8	9
1	0.40	0.20	0.20	0.00	0.20	0.00	0.00	0.00	0.00
2	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.25
4	0.17	0.00	0.17	0.00	0.33	0.17	0.17	0.00	0.00
5	0.25	0.25	0.00	0.25	0.00	0.00	0.00	0.25	0.00
6	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.50
7	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.67	0.00
8	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
10	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00

C.3 LAURIE RESERVOIR

********** LAURIE RESERVOIR - MONTH NO: 1 **********

STORAGE STATE	INFLOW STATE								
	1	2	3	4	5	6	7	8	9
1	0.75	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
2	0.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.33
3	0.00	0.50	0.13	0.13	0.00	0.13	0.00	0.13	0.00
4	0.00	0.00	0.00	0.50	0.00	0.50	0.00	0.00	0.00
5	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.50

********** LAURIE RESERVOIR - MONTH NO: 2 **********

STORAGE STATE	INFLOW STATE									
	1	2	3	4	5	6	7	8	9	10
1	0.63	0.25	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00
2	0.20	0.40	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.33	0.00	0.33	0.33	0.00	0.00	0.00	0.00
4	0.00	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.33	0.00
6	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.33	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

********** LAURIE RESERVOIR - MONTH NO: 3 **********

STORAGE				INFLOW STATE					
STATE	1	2	3	4	5	6	7	8	9
1	0.17	0.17	0.33	0.17	0.00	0.17	0.00	0.00	0.00
2	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.20	0.00
3	0.00	0.00	0.00	0.67	0.00	0.00	0.33	0.00	0.00
4	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00
5	0.00	0.00	0.33	0.00	0.00	0.33	0.33	0.00	0.00
6	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00
9	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50

********** LAURIE RESERVOIR - MONTH NO: 4 **********

STORAGE				INFLOW STATE					
STATE	1	2	3	4	5	6	7	8	9
1	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
3	0.14	0.14	0.00	0.43	0.00	0.14	0.00	0.00	0.14
4	0.17	0.00	0.33	0.17	0.00	0.17	0.00	0.17	0.00
5	0.00	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.67	0.00	0.33	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.33	0.00	0.67	0.00	0.00	0.00
8	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

```
  ********** LAURIE RESERVOIR - MONTH NO:  5 **********

STORAGE                       INFLOW STATE
STATE     1    2    3    4    5    6    7    8


  1     0.33 0.00 0.33 0.00 0.33 0.00 0.00 0.00

  2     0.00 0.00 0.33 0.33 0.33 0.00 0.00 0.00

  3     0.00 0.17 0.17 0.17 0.33 0.00 0.00 0.17

  4     0.25 0.13 0.13 0.25 0.13 0.13 0.00 0.00

  5     1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  6     0.50 0.00 0.25 0.00 0.00 0.00 0.00 0.25

  7     0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00

  8     0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00

  9     0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00



  ********** LAURIE RESERVOIR - MONTH NO:  6 **********

STORAGE                       INFLOW STATE
STATE     1    2    3    4    5    6    7    8


  1     0.33 0.17 0.17 0.00 0.17 0.17 0.00 0.00

  2     0.33 0.00 0.00 0.67 0.00 0.00 0.00 0.00

  3     0.00 0.20 0.40 0.40 0.00 0.00 0.00 0.00

  4     0.25 0.25 0.25 0.00 0.25 0.00 0.00 0.00

  5     0.33 0.17 0.00 0.17 0.00 0.00 0.17 0.17

  6     0.00 0.00 0.00 1.00 0.00 0.00 0.00 0.00

  7     0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00

  8     0.00 0.50 0.50 0.00 0.00 0.00 0.00 0.00
```

********** LAURIE RESERVOIR - MONTH NO: 7 **********

STORAGE				INFLOW STATE			
STATE	1	2	3	4	5	6	7
1	0.50	0.33	0.17	0.00	0.00	0.00	0.00
2	0.40	0.00	0.40	0.20	0.00	0.00	0.00
3	0.17	0.33	0.00	0.17	0.17	0.17	0.00
4	0.50	0.17	0.17	0.00	0.00	0.00	0.17
5	0.00	0.50	0.50	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	1.00
7	0.00	1.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	1.00	0.00	0.00	0.00	0.00

********** LAURIE RESERVOIR - MONTH NO: 8 **********

STORAGE				INFLOW STATE				
STATE	1	2	3	4	5	6	7	8
1	0.56	0.44	0.00	0.00	0.00	0.00	0.00	0.00
2	0.29	0.29	0.14	0.00	0.00	0.14	0.00	0.14
3	0.17	0.33	0.50	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
6	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.50	0.00	0.00	0.00	0.00	0.50	0.00

```
  ********** LAURIE RESERVOIR - MONTH NO:  9 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9


  1     0.75 0.00 0.00 0.00 0.13 0.13 0.00 0.00 0.00

  2     0.10 0.30 0.20 0.40 0.00 0.00 0.00 0.00 0.00

  3     0.00 0.25 0.00 0.25 0.25 0.25 0.00 0.00 0.00

  4     0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00

  5     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.50 0.50

  6     0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

  7     0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00 0.00

  8     0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.00


  ********** LAURIE RESERVOIR - MONTH NO: 10 **********

STORAGE                        INFLOW STATE
STATE     1    2    3    4    5    6    7    8    9


  1     0.57 0.14 0.14 0.00 0.00 0.14 0.00 0.00 0.00

  2     0.40 0.00 0.00 0.00 0.20 0.20 0.20 0.00 0.00

  3     0.00 0.00 0.50 0.00 0.00 0.00 0.50 0.00 0.00

  4     0.00 0.00 0.20 0.40 0.20 0.00 0.20 0.00 0.00

  5     0.00 0.00 0.00 0.00 0.00 0.50 0.00 0.50 0.00

  6     0.00 0.00 0.00 0.00 0.00 0.25 0.25 0.25 0.25

  7     0.00 0.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00

  8     0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00

  9     0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.00 0.00
```

********** LAURIE RESERVOIR - MONTH NO: 11 **********

STORAGE STATE	INFLOW STATE									
	1	2	3	4	5	6	7	8	9	10
1	0.83	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
3	0.25	0.25	0.25	0.00	0.00	0.25	0.00	0.00	0.00	0.00
4	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.25	0.25	0.00
7	0.00	0.00	0.00	0.00	0.00	0.50	0.25	0.25	0.00	0.00
8	0.00	0.00	0.00	0.00	0.33	0.00	0.67	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50

********** LAURIE RESERVOIR - MONTH NO: 12 **********

STORAGE STATE	INFLOW STATE							
	1	2	3	4	5	6	7	8
1	0.33	0.17	0.00	0.00	0.00	0.00	0.17	0.33
2	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
4	0.33	0.00	0.00	0.33	0.33	0.00	0.00	0.00
5	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
6	0.33	0.00	0.33	0.00	0.00	0.33	0.00	0.00
7	0.25	0.25	0.50	0.00	0.00	0.00	0.00	0.00
8	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00

Appendix D

THE OVERALL OPTIMAL POLICY

This section contains the overall optimal policy which was obtained from iteration 2 of the solution technique. A simulated reservoir operation is also included in the latter part of the Appendix.

D.1 ITERATION 2

D.1.1 LAURIE RESERVOIR

```
**********  LAURIE  - PASS 2 - MONTH NO:  1 **********

STORAGE                 INFLOW STATE (CFS)
 STATE     1     2     3     4     5     6     7     8     9
          78   236   393   551   866  1023  1181  1338  1496

       0.002 0.007 0.000 0.001 0.002 0.004 0.005 0.001 0.004
1-213.0 ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

       0.001 0.005 0.000 0.001 0.002 0.003 0.003 0.001 0.003
2-210.0 ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 1)

       0.003 0.007 0.001 0.002 0.004 0.005 0.006 0.001 0.006
3-207.0 ( 4)  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 2)  ( 3)  ( 2)

       0.004 0.019 0.001 0.003 0.005 0.008 0.006 0.001 0.006
4-204.0 ( 5)  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)

       0.010 0.035 0.001 0.007 0.013 0.016 0.022 0.005 0.019
5-201.0 ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)

       0.016 0.034 0.003 0.011 0.018 0.042 0.024 0.007 0.020
6-198.0 ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)

       0.015 0.031 0.003 0.015 0.019 0.018 0.021 0.006 0.024
7-195.0 ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)

       0.056 0.077 0.026 0.103 0.043 0.047 0.020 0.013 0.025
8-192.0 ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8) . ( 8)  ( 7)  ( 7)


        PROBABILITY DISTRIBUTION OF INFLOWS
   0.107 0.215 0.035 0.143 0.106 0.143 0.107 0.035 0.107

        PROBABILITY DISTRIBUTION OF STORAGE
   0.026 0.019 0.035 0.053 0.128 0.175 0.152 0.410

        PROBABILITY DISTRIBUTION OF RELEASE
   0.020 0.031 0.029 0.072 0.083 0.178 0.164 0.421

   EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 3006.7

   EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2502.3

     EXPECTED RELEASE FOR EAGER (CFS-WKS): 1026.0

      EXPECTED RELEASE RUSSELL (CFS-WKS): 1476.4

        EXPECTED STORAGE LEVEL (FEET):  196.3
```

```
 **********  LAURIE  - PASS 2 - MONTH NO:  2 **********

STORAGE                INFLOW STATE  (CFS)
 STATE       1     2     3     4     5     6     7     8     9
            75   226   377   679   830   981  1132  1283  1434

         0.002 0.000 0.001 0.002 0.006 0.006 0.001 0.002 0.001
1-213.0  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

         0.006 0.004 0.001 0.003 0.004 0.006 0.001 0.003 0.001
2-210.0  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)

         0.006 0.003 0.001 0.002 0.006 0.007 0.001 0.002 0.002
3-207.0  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)

         0.010 0.005 0.002 0.007 0.015 0.017 0.002 0.007 0.005
4-204.0  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)

         0.022 0.012 0.005 0.000 0.018 0.015 0.004 0.000 0.007
5-201.0  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)

         0.042 0.030 0.015 0.008 0.026 0.032 0.011 0.008 0.006
6-198.0  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)

         0.048 0.030 0.008 0.007 0.021 0.026 0.004 0.007 0.013
7-195.0  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)

         0.186 0.129 0.038 0.007 0.012 0.033 0.012 0.007 0.000
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)



          PROBABILITY DISTRIBUTION OF INFLOWS
    0.322 0.213 0.071 0.036 0.108 0.142 0.036 0.036 0.035

          PROBABILITY DISTRIBUTION OF STORAGE
    0.021 0.029 0.030 0.070 0.083 0.178 0.164 0.424

          PROBABILITY DISTRIBUTION OF RELEASE
    0.022 0.021 0.039 0.058 0.068 0.136 0.152 0.503

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2470.9

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1925.7

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  789.5

       EXPECTED RELEASE RUSSELL (CFS-WKS): 1136.1

         EXPECTED STORAGE LEVEL (FEET):  196.4
```

```
**********  LAURIE   - PASS 2 - MONTH NO:   3 **********

STORAGE                   INFLOW STATE  (CFS)
 STATE       1       2       3       4       5       6       7       8
            74     223     372     521     670     819    1266    1415

          0.000   0.000   0.003   0.002   0.000   0.008   0.004   0.003
1-213.0   ( 2)    ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

          0.001   0.001   0.004   0.003   0.000   0.005   0.004   0.003
2-210.0   ( 3)    ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)

          0.003   0.004   0.007   0.002   0.001   0.011   0.008   0.004
3-207.0   ( 4)    ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)

          0.003   0.003   0.012   0.007   0.001   0.010   0.014   0.009
4-204.0   ( 5)    ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)

          0.004   0.006   0.014   0.000   0.001   0.020   0.014   0.010
5-201.0   ( 6)    ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)

          0.010   0.013   0.030   0.008   0.002   0.025   0.032   0.017
6-198.0   ( 7)    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)    ( 5)    ( 5)

          0.019   0.032   0.045   0.007   0.005   0.021   0.011   0.014
7-195.0   ( 8)    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)    ( 6)    ( 6)

          0.104   0.155   0.170   0.007   0.026   0.008   0.020   0.013
8-192.0   ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)



           PROBABILITY DISTRIBUTION OF INFLOWS
      0.144 0.214 0.285 0.036 0.036 0.108 0.107 0.073

           PROBABILITY DISTRIBUTION OF STORAGE
      0.020 0.021 0.040 0.059 0.069 0.137 0.154 0.503

           PROBABILITY DISTRIBUTION OF RELEASE
      0.020 0.027 0.043 0.056 0.088 0.076 0.100 0.593

      EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2360.7

      EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1825.5

        EXPECTED RELEASE FOR EAGER (CFS-WKS):  748.5

         EXPECTED RELEASE RUSSELL (CFS-WKS): 1077.1

           EXPECTED STORAGE LEVEL (FEET):  196.6
```

```
**********  LAURIE  - PASS 2 - MONTH NO:  4 **********

STORAGE                 INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7     8     9
           61   185   308   432   555   679   802  1049  1173

        0.000 0.000 0.003 0.004 0.000 0.006 0.001 0.004 0.001
1-213.0  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

        0.000 0.001 0.002 0.005 0.000 0.004 0.005 0.006 0.004
2-210.0  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)

        0.001 0.002 0.005 0.007 0.000 0.009 0.006 0.008 0.005
3-207.0  ( 4)  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)

        0.003 0.003 0.006 0.013 0.001 0.010 0.007 0.008 0.005
4-204.0  ( 5)  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 4)  ( 3)

        0.003 0.005 0.009 0.010 0.001 0.017 0.014 0.017 0.011
5-201.0  ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 5)  ( 4)

        0.005 0.006 0.012 0.013 0.001 0.014 0.008 0.012 0.005
6-198.0  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 5)

        0.011 0.013 0.015 0.025 0.002 0.013 0.010 0.007 0.002
7-195.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)

        0.119 0.112 0.091 0.100 0.031 0.000 0.092 0.009 0.038
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)


          PROBABILITY DISTRIBUTION OF INFLOWS
      0.142 0.142 0.143 0.177 0.036 0.073 0.143 0.071 0.071

          PROBABILITY DISTRIBUTION OF STORAGE
      0.019 0.027 0.043 0.056 0.087 0.076 0.098 0.592

          PROBABILITY DISTRIBUTION OF RELEASE
      0.029 0.029 0.021 0.052 0.079 0.061 0.071 0.656

      EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2382.9

      EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1276.5

        EXPECTED RELEASE FOR EAGER (CFS-WKS):  523.4

         EXPECTED RELEASE RUSSELL (CFS-WKS):  753.1

          EXPECTED STORAGE LEVEL (FEET):  195.4
```

```
 **********  LAURIE  - PASS 2 - MONTH NO:  5 **********

STORAGE                  INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7
           85   255   425   595   765  1105  1615

         0.009 0.009 0.008 0.000 0.001 0.003 0.000
1-212.0  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)

         0.008 0.010 0.006 0.001 0.001 0.002 0.000
2-209.0  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 1)

         0.005 0.003 0.009 0.002 0.000 0.003 0.000
3-207.0  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 2)  ( 1)

         0.014 0.014 0.014 0.003 0.001 0.006 0.000
4-204.0  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 2)

         0.018 0.026 0.024 0.005 0.003 0.002 0.001
5-201.1  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 4)

         0.013 0.019 0.022 0.004 0.002 0.000 0.001
6-198.0  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 5)

         0.016 0.021 0.024 0.005 0.003 0.001 0.001
7-195.0  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 6)

         0.166 0.184 0.143 0.087 0.025 0.019 0.032
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)



          PROBABILITY DISTRIBUTION OF INFLOWS
    0.249 0.286 0.250 0.107 0.036 0.036 0.035

          PROBABILITY DISTRIBUTION OF STORAGE
    0.030 0.028 0.022 0.052 0.079 0.061 0.071 0.656

          PROBABILITY DISTRIBUTION OF RELEASE
    0.004 0.033 0.026 0.028 0.053 0.075 0.095 0.685

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2235.5

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS):    0.0

      EXPECTED RELEASE FOR EAGER (CFS-WKS):    0.0

       EXPECTED RELEASE RUSSELL (CFS-WKS):    0.0

         EXPECTED STORAGE LEVEL (FEET):  195.1
```

```
**********  LAURIE  - PASS 2 - MONTH NO:  6 **********

STORAGE                  INFLOW STATE (CFS)
 STATE      1      2      3      4      5      6      7      8
           75    227    378    530    681    833   1136   1439

        0.000  0.003  0.000  0.000  0.001  0.000  0.000  0.000
1-212.0  ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

        0.004  0.010  0.004  0.008  0.004  0.002  0.001  0.001
2-209.0  ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)

        0.004  0.004  0.004  0.008  0.002  0.002  0.001  0.001
3-207.0  ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

        0.002  0.010  0.002  0.005  0.005  0.003  0.000  0.001
4-204.0  ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)

        0.006  0.010  0.006  0.013  0.008  0.005  0.002  0.002
5-201.1  ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

        0.008  0.012  0.008  0.023  0.010  0.006  0.003  0.003
6-198.0  ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)

        0.006  0.011  0.006  0.050  0.011  0.007  0.002  0.003
7-195.0  ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)

        0.078  0.119  0.078  0.178  0.102  0.082  0.026  0.023
8-192.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)


          PROBABILITY DISTRIBUTION OF INFLOWS
    0.108 0.179 0.108 0.285 0.143 0.107 0.035 0.034

          PROBABILITY DISTRIBUTION OF STORAGE
    0.004 0.034 0.026 0.028 0.052 0.073 0.096 0.686

          PROBABILITY DISTRIBUTION OF RELEASE
    0.002 0.020 0.031 0.029 0.043 0.067 0.121 0.686

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2280.1

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS):  341.7

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  140.1

       EXPECTED RELEASE RUSSELL (CFS-WKS):  201.6

         EXPECTED STORAGE LEVEL (FEET):  194.4
```

```
 **********  LAURIE  - PASS 2 - MONTH NO:  7 **********

STORAGE                  INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8      9     10
            78    235    392    549    706    863   1020   1177   1334   1491

         0.000  0.000  0.000  0.000  0.002  0.000  0.000  0.000  0.000  0.000
1-212.0  ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

         0.002  0.001  0.002  0.005  0.005  0.003  0.001  0.001  0.001  0.000
2-209.0  ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 2)   ( 1)

         0.002  0.002  0.003  0.004  0.006  0.003  0.002  0.005  0.002  0.001
3-207.0  ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)

         0.003  0.002  0.001  0.004  0.007  0.002  0.002  0.004  0.001  0.001
4-204.0  ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)

         0.004  0.002  0.004  0.005  0.013  0.005  0.002  0.005  0.002  0.001
5-201.1  ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)

         0.007  0.005  0.005  0.011  0.015  0.008  0.005  0.008  0.002  0.002
6-198.0  ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)

         0.008  0.009  0.009  0.017  0.040  0.015  0.009  0.010  0.002  0.003
7-195.0  ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)

         0.081  0.050  0.048  0.096  0.126  0.070  0.050  0.109  0.026  0.028
8-192.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)


        PROBABILITY DISTRIBUTION OF INFLOWS
    0.107 0.071 0.072 0.142 0.214 0.106 0.071 0.142 0.036 0.036

        PROBABILITY DISTRIBUTION OF STORAGE
    0.002 0.021 0.030 0.027 0.043 0.068 0.122 0.684

        PROBABILITY DISTRIBUTION OF RELEASE
    0.003 0.025 0.024 0.030 0.043 0.064 0.261 0.547

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2469.3

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1144.1

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  469.1

       EXPECTED RELEASE RUSSELL (CFS-WKS):  675.0

         EXPECTED STORAGE LEVEL (FEET):  193.8
```

```
**********  LAURIE   - PASS 2 - MONTH NO:  8 **********

STORAGE                  INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8
            90    270    451    631    812    992   1173   1714

         0.000  0.001  0.001  0.001  0.000  0.000  0.000  0.000
1-212.0  ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

         0.001  0.003  0.009  0.003  0.001  0.003  0.002  0.003
2-209.0  ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)

         0.003  0.003  0.007  0.002  0.002  0.003  0.002  0.001
3-207.0  ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 2)   ( 3)   ( 1)

         0.005  0.005  0.008  0.002  0.003  0.004  0.002  0.002
4-204.0  ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 2)

         0.005  0.006  0.014  0.004  0.004  0.006  0.003  0.002
5-201.1  ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

         0.007  0.009  0.021  0.005  0.006  0.009  0.006  0.002
6-198.0  ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

         0.034  0.020  0.088  0.055  0.011  0.018  0.009  0.026
7-195.0  ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

         0.087  0.096  0.138  0.000  0.080  0.098  0.048  0.000
8-192.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)


          PROBABILITY DISTRIBUTION OF INFLOWS
    0.142 0.143 0.286 0.072 0.107 0.141 0.072 0.036

          PROBABILITY DISTRIBUTION OF STORAGE
    0.003 0.025 0.023 0.031 0.044 0.065 0.261 0.547

          PROBABILITY DISTRIBUTION OF RELEASE
    0.006 0.024 0.019 0.028 0.046 0.087 0.236 0.553

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2376.3

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1251.5

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  513.1

       EXPECTED RELEASE RUSSELL (CFS-WKS):  738.4

         EXPECTED STORAGE LEVEL (FEET):  194.6
```

```
 **********  LAURIE  - PASS 2 - MONTH NO:  9 **********

STORAGE                  INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7     8     9
          127   383   638   894  1149  1405  1660  2171  2427

        0.000 0.000 0.000 0.001 0.004 0.000 0.000 0.000 0.000
1-212.0  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

        0.001 0.004 0.002 0.004 0.008 0.002 0.002 0.001 0.000
2-209.0  ( 3)  ( 3)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

        0.001 0.002 0.002 0.005 0.005 0.003 0.000 0.002 0.001
3-207.0  ( 4)  ( 4)  ( 3)  ( 3)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)

        0.001 0.004 0.003 0.005 0.008 0.003 0.001 0.001 0.001
4-204.0  ( 5)  ( 5)  ( 4)  ( 4)  ( 3)  ( 3)  ( 2)  ( 2)  ( 1)

        0.002 0.007 0.004 0.009 0.012 0.006 0.002 0.003 0.001
5-201.1  ( 6)  ( 6)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 3)  ( 2)

        0.003 0.010 0.006 0.013 0.040 0.008 0.002 0.004 0.002
6-198.0  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 4)  ( 4)

        0.027 0.030 0.011 0.041 0.071 0.026 0.005 0.024 0.002
7-195.0  ( 8)  ( 8)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)

        0.000 0.120 0.080 0.138 0.068 0.094 0.025 0.000 0.029
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)


        PROBABILITY DISTRIBUTION OF INFLOWS
    0.035 0.177 0.108 0.216 0.216 0.142 0.037 0.035 0.036

        PROBABILITY DISTRIBUTION OF STORAGE
    0.005 0.024 0.021 0.027 0.046 0.088 0.237 0.554

        PROBABILITY DISTRIBUTION OF RELEASE
    0.022 0.017 0.026 0.037 0.054 0.199 0.252 0.395

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2924.9

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1520.1

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  623.2

       EXPECTED RELEASE RUSSELL (CFS-WKS):  896.9

         EXPECTED STORAGE LEVEL (FEET):  195.2
```

```
 **********  LAURIE  - PASS 2 - MONTH NO: 10 **********

STORAGE                INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7     8     9
           76   383   537   690   844   997  1151  1304  1458

        0.000 0.000 0.000 0.002 0.002 0.002 0.003 0.006 0.007
1-212.0  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

        0.000 0.001 0.001 0.001 0.003 0.002 0.003 0.003 0.004
2-209.0  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 1)

        0.003 0.002 0.002 0.001 0.004 0.003 0.003 0.005 0.003
3-207.0  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)

        0.002 0.001 0.002 0.002 0.005 0.004 0.005 0.008 0.007
4-204.0  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)

        0.003 0.002 0.004 0.000 0.008 0.003 0.005 0.026 0.005
5-201.1  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)

        0.005 0.004 0.005 0.018 0.019 0.023 0.029 0.025 0.070
6-198.0  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)

        0.007 0.009 0.012 0.011 0.062 0.025 0.042 0.035 0.047
7-195.0  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)

        0.087 0.053 0.080 0.000 0.076 0.046 0.053 0.000 0.000
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)


          PROBABILITY DISTRIBUTION OF INFLOWS
    0.107 0.072 0.106 0.035 0.179 0.108 0.143 0.108 0.143

          PROBABILITY DISTRIBUTION OF STORAGE
    0.022 0.018 0.026 0.036 0.056 0.198 0.250 0.395

          PROBABILITY DISTRIBUTION OF RELEASE
    0.026 0.023 0.032 0.054 0.142 0.194 0.172 0.358

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2611.7

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1425.7

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  584.5

       EXPECTED RELEASE RUSSELL (CFS-WKS):  841.2

         EXPECTED STORAGE LEVEL (FEET):  196.2
```

```
**********  LAURIE  - PASS 2 - MONTH NO: 11 **********

STORAGE                    INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8      9
            83    249    416    582    749    915   1082   1248   1581

         0.001  0.002  0.002  0.003  0.010  0.001  0.004  0.002  0.000
1-213.0   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

         0.002  0.003  0.003  0.005  0.003  0.001  0.003  0.003  0.000
2-210.0   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

         0.002  0.004  0.004  0.005  0.007  0.001  0.005  0.004  0.001
3-207.0   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

         0.003  0.010  0.006  0.011  0.007  0.001  0.005  0.009  0.001
4-204.0   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

         0.009  0.010  0.013  0.016  0.054  0.001  0.027  0.010  0.001
5-201.0   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

         0.012  0.015  0.024  0.030  0.058  0.008  0.034  0.013  0.002
6-198.0   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

         0.017  0.006  0.054  0.022  0.024  0.008  0.034  0.004  0.004
7-195.0   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

         0.063  0.057  0.108  0.015  0.015  0.015  0.030  0.027  0.027
8-192.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)


           PROBABILITY DISTRIBUTION OF INFLOWS
     0.109 0.107 0.214 0.107 0.178 0.036 0.142 0.072 0.036

           PROBABILITY DISTRIBUTION OF STORAGE
     0.025 0.023 0.033 0.053 0.141 0.196 0.173 0.357

           PROBABILITY DISTRIBUTION OF RELEASE
     0.023 0.022 0.036 0.045 0.132 0.170 0.193 0.380

     EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2881.3

     EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1975.7

       EXPECTED RELEASE FOR EAGER (CFS-WKS):  810.1

        EXPECTED RELEASE RUSSELL (CFS-WKS): 1165.7

          EXPECTED STORAGE LEVEL (FEET):  197.2
```

```
 **********  LAURIE  - PASS 2 - MONTH NO: 12 **********

STORAGE                INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7     8     9    10
           71   214   357   500   643   786   929  1072  1215  1358

        0.000 0.000 0.000 0.004 0.008 0.001 0.004 0.005 0.002 0.000
1-213.0  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

        0.000 0.002 0.001 0.004 0.004 0.001 0.002 0.004 0.001 0.001
2-210.0  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)

        0.001 0.003 0.002 0.006 0.009 0.002 0.004 0.008 0.001 0.001
3-207.0  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)

        0.001 0.004 0.003 0.010 0.009 0.002 0.004 0.010 0.001 0.001
4-204.0  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)

        0.001 0.007 0.007 0.024 0.035 0.008 0.020 0.019 0.011 0.002
5-201.0  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)

        0.003 0.014 0.007 0.036 0.033 0.011 0.030 0.020 0.012 0.004
6-198.0  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)

        0.004 0.021 0.010 0.027 0.031 0.013 0.026 0.029 0.005 0.027
7-195.0  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)

        0.026 0.128 0.042 0.067 0.014 0.035 0.053 0.013 0.003 0.000
8-192.0  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)


          PROBABILITY DISTRIBUTION OF INFLOWS
    0.036 0.179 0.072 0.178 0.143 0.073 0.143 0.108 0.036 0.036

          PROBABILITY DISTRIBUTION OF STORAGE
    0.024 0.020 0.037 0.045 0.134 0.170 0.193 0.381

          PROBABILITY DISTRIBUTION OF RELEASE
    0.026 0.017 0.034 0.054 0.130 0.177 0.153 0.413

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 2644.5

    EXPECTED RELEASE FOR THE MONTH (CFS-WKS): 1942.5

      EXPECTED RELEASE FOR EAGER (CFS-WKS):  796.4

       EXPECTED RELEASE RUSSELL (CFS-WKS): 1146.1

         EXPECTED STORAGE LEVEL (FEET):  197.5
```

D.1.2

EAGER RESERVOIR

```
**********  EAGER    - PASS 2 - MONTH NO:   1 **********

STORAGE                     INFLOW STATE  (CFS)
 STATE      1      2      3      4      5      6      7      8      9     10
           17     51     86    120    155    189    224    258    293    327

 1-115.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)

 2-114.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)

 3-113.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)

 4-112.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)

 5-111.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)

 6-110.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)

 7-109.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)

 8-108.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)

 9-107.0  (10)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)

10-106.0  (11)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)

11-105.0  (12)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)

12-104.0  (13)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)

13-103.0  (14)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)

14-102.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)

15-101.0  (16)   (16)   (16)   (16)   (16)   (16)   (16)   (15)   (15)   (15)

16-100.0  (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  2 **********

 STORAGE                  INFLOW STATE  (CFS)
  STATE       1      2      3      4      5      6      7      8      9     10
             13     41     68     96    123    151    178    206    233    261

 1-115.0   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)

 3-113.0   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)

 4-112.0   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)

 5-111.0   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)

 6-110.0   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)

 7-109.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)

 8-108.0   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)

 9-107.0   (10)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)

10-106.0   (11)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)

11-105.0   (12)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)

12-104.0   (13)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)

13-103.0   (14)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)

14-102.0   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)

15-101.0   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (15)   (15)   (15)

16-100.0   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)
```

```
 **********  EAGER   - PASS 2 - MONTH NO:  3 **********

STORAGE                     INFLOW STATE  (CFS)
 STATE      1      2      3      4      5      6      7      8      9
           14     42     71     99    128    156    185    213    270

 1-115.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

 2-114.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

 3-113.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

 4-112.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

 5-111.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

 6-110.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

 7-109.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

 8-108.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

 9-107.0  (10)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)

10-106.0  (11)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)

11-105.0  (12)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)

12-104.0  (13)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)

13-103.0  (14)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)

14-102.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)

15-101.0  (16)   (16)   (16)   (16)   (16)   (16)   (16)   (15)   (15)

16-100.0  (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  4 **********

 STORAGE                    INFLOW STATE  (CFS)
  STATE        1       2       3       4       5       6       7       8       9
              21      65     108     152     195     239     282     326     413

 1-115.0    ( 2)    ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

 2-114.0    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)

 3-113.0    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)

 4-112.0    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)

 5-111.0    ( 6)    ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)

 6-110.0    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)

 7-109.0    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)

 8-108.0    ( 9)    ( 9)    ( 9)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)

 9-107.0    (10)    (10)    (10)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)

10-106.0    (11)    (11)    (11)    (10)    (10)    (10)    (10)    (10)    (10)

11-105.0    (12)    (12)    (12)    (11)    (11)    (11)    (11)    (11)    (11)

12-104.0    (13)    (13)    (13)    (12)    (12)    (12)    (12)    (12)    (12)

13-103.0    (14)    (14)    (14)    (13)    (13)    (13)    (13)    (13)    (13)

14-102.0    (15)    (15)    (15)    (14)    (14)    (14)    (14)    (14)    (14)

15-101.0    (16)    (16)    (16)    (15)    (15)    (15)    (15)    (15)    (15)

16-100.0    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)
```

```
 **********  EAGER   - PASS 2 - MONTH NO:  5 **********

STORAGE                      INFLOW STATE  (CFS)
 STATE      1      2      3      4      5      6      7
           62    188    313    439    564    690   1192

 1-115.0  ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)

 3-113.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 1)

 4-112.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 2)

 5-111.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 3)

 6-110.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 4)

 7-109.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 5)

 8-108.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 6)

 9-107.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 7)

10-106.0  (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 8)

11-105.0  (11)   (11)   (11)   (11)   (10)   (10)   ( 9)

12-104.0  (12)   (12)   (12)   (12)   (11)   (11)   (10)

13-103.0  (13)   (13)   (13)   (13)   (12)   (12)   (11)

14-102.0  (14)   (14)   (14)   (14)   (13)   (13)   (12)

15-101.0  (15)   (15)   (15)   (15)   (14)   (14)   (13)

16-100.0  (16)   (16)   (16)   (16)   (15)   (15)   (14)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  6 **********

 STORAGE                    INFLOW STATE  (CFS)
  STATE       1       2       3       4       5       6       7       8       9
             52     158     263     369     474     580     685     791    1002

 1-115.0    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

 2-114.0    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)

 3-113.0    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)

 4-112.0    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 3)

 5-111.0    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 4)

 6-110.0    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 5)

 7-109.0    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)    ( 6)    ( 6)

 8-108.0    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)    ( 7)    ( 7)

 9-107.0    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 8)    ( 8)    ( 8)    ( 8)

10-106.0    (10)    (10)    (10)    (10)    (10)    ( 9)    ( 9)    ( 9)    ( 9)

11-105.0    (11)    (11)    (11)    (11)    (11)    (10)    (10)    (10)    (10)

12-104.0    (12)    (12)    (12)    (12)    (12)    (11)    (11)    (11)    (11)

13-103.0    (13)    (13)    (13)    (13)    (13)    (12)    (12)    (12)    (12)

14-102.0    (14)    (14)    (14)    (14)    (14)    (13)    (13)    (13)    (13)

15-101.0    (15)    (15)    (15)    (15)    (15)    (14)    (14)    (14)    (14)

16-100.0    (16)    (16)    (16)    (16)    (16)    (15)    (15)    (15)    (15)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  7 **********

STORAGE                    INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8      9
            41    125    208    292    375    459    626    709    793

  1-115.0  ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

  2-114.0  ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

  3-113.0  ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

  4-112.0  ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

  5-111.0  ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

  6-110.0  ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

  7-109.0  ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

  8-108.0  ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

  9-107.0  (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

 10-106.0  (11)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)

 11-105.0  (12)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)

 12-104.0  (13)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)

 13-103.0  (14)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)

 14-102.0  (15)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)

 15-101.0  (16)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)

 16-100.0  (16)   (16)   (16)   (16)   (16)   (16)   (16)   (15)   (15)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  8 **********

STORAGE                     INFLOW STATE  (CFS)
 STATE       1       2       3       4       5       6       7       8       9      10
            38     115     192     269     346     423     500     577     654     731

 1-115.0   ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

 2-114.0   ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)    ( 1)

 3-113.0   ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)

 4-112.0   ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)

 5-111.0   ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)

 6-110.0   ( 7)    ( 7)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 5)    ( 5)

 7-109.0   ( 8)    ( 8)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)

 8-108.0   ( 9)    ( 9)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)

 9-107.0   (10)    (10)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 8)    ( 8)

10-106.0   (11)    (11)    (10)    (10)    (10)    (10)    (10)    (10)    ( 9)    ( 9)

11-105.0   (12)    (12)    (11)    (11)    (11)    (11)    (11)    (11)    (10)    (10)

12-104.0   (13)    (13)    (12)    (12)    (12)    (12)    (12)    (12)    (11)    (11)

13-103.0   (14)    (14)    (13)    (13)    (13)    (13)    (13)    (13)    (12)    (12)

14-102.0   (15)    (15)    (14)    (14)    (14)    (14)    (14)    (14)    (13)    (13)

15-101.0   (16)    (16)    (15)    (15)    (15)    (15)    (15)    (15)    (14)    (14)

16-100.0   (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (15)    (15)
```

```
**********  EAGER   - PASS 2 - MONTH NO:  9 **********

 STORAGE                   INFLOW STATE  (CFS)
  STATE      1      2      3      4      5      6      7      8      9
            59    179    298    418    537    657    776    896   1135

 1-115.0   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)

 3-113.0   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)

 4-112.0   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)

 5-111.0   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)

 6-110.0   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)

 7-109.0   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)

 8-108.0   ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)

 9-107.0   (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)

10-106.0   (11)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)

11-105.0   (12)   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)

12-104.0   (13)   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)

13-103.0   (14)   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)

14-102.0   (15)   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)

15-101.0   (16)   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)

16-100.0   (16)   (16)   (16)   (16)   (16)   (16)   (15)   (15)   (15)
```

```
**********  EAGER   - PASS 2 - MONTH NO: 10 **********

 STORAGE                       INFLOW STATE  (CFS)
  STATE        1       2       3       4       5       6       7       8       9      10
              41     123     206     288     371     453     536     618     701     783

 1-115.0     ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

 2-114.0     ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)    ( 1)

 3-113.0     ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)

 4-112.0     ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)

 5-111.0     ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)

 6-110.0     ( 7)    ( 7)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 5)    ( 5)

 7-109.0     ( 8)    ( 8)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)

 8-108.0     ( 9)    ( 9)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)

 9-107.0     (10)    (10)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 8)    ( 8)

10-106.0     (11)    (11)    (10)    (10)    (10)    (10)    (10)    (10)    ( 9)    ( 9)

11-105.0     (12)    (12)    (11)    (11)    (11)    (11)    (11)    (11)    (10)    (10)

12-104.0     (13)    (13)    (12)    (12)    (12)    (12)    (12)    (12)    (11)    (11)

13-103.0     (14)    (14)    (13)    (13)    (13)    (13)    (13)    (13)    (12)    (12)

14-102.0     (15)    (15)    (14)    (14)    (14)    (14)    (14)    (14)    (13)    (13)

15-101.0     (16)    (16)    (15)    (15)    (15)    (15)    (15)    (15)    (14)    (14)

16-100.0     (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (15)    (15)
```

```
**********  EAGER   - PASS 2 - MONTH NO: 11 **********

 STORAGE               INFLOW STATE  (CFS)
  STATE      1      2      3      4      5      6      7      8      9     10
            19     58     97    136    175    214    253    292    331    370

 1-115.0   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)

 3-113.0   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)

 4-112.0   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)

 5-111.0   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)

 6-110.0   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)

 7-109.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)

 8-108.0   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)

 9-107.0   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)

10-106.0   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)   (10)   (10)

11-105.0   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)   (11)   (11)

12-104.0   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)   (12)   (12)

13-103.0   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)   (13)   (13)

14-102.0   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)   (14)   (14)

15-101.0   (16)   (16)   (16)   (16)   (16)   (15)   (15)   (15)   (15)   (15)

16-100.0   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)   (16)
```

```
**********  EAGER   - PASS 2 - MONTH NO: 12 **********

 STORAGE                       INFLOW STATE  (CFS)
  STATE         1       2       3       4       5       6       7       8       9      10
               19      59      98     138     177     217     256     296     335     375

 1-115.0     ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

 2-114.0     ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)

 3-113.0     ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)

 4-112.0     ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)

 5-111.0     ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)

 6-110.0     ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)

 7-109.0     ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)

 8-108.0     ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)

 9-107.0     (10)    (10)    (10)    (10)    (10)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)

10-106.0     (11)    (11)    (11)    (11)    (11)    (10)    (10)    (10)    (10)    (10)

11-105.0     (12)    (12)    (12)    (12)    (12)    (11)    (11)    (11)    (11)    (11)

12-104.0     (13)    (13)    (13)    (13)    (13)    (12)    (12)    (12)    (12)    (12)

13-103.0     (14)    (14)    (14)    (14)    (14)    (13)    (13)    (13)    (13)    (13)

14-102.0     (15)    (15)    (15)    (15)    (15)    (14)    (14)    (14)    (14)    (14)

15-101.0     (16)    (16)    (16)    (16)    (16)    (15)    (15)    (15)    (15)    (15)

16-100.0     (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)    (16)
```

D.1.3 RUSSELL RESERVOIR

```
********** RUSSELL  - PASS 2 - MONTH NO:  1 **********

 STORAGE                    INFLOW STATE  (CFS)
  STATE      1      2      3      4      5      6      7      8      9
            15     46     77    108    139    170    201    232    294

 1-115.0   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)

 2-114.0   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)

 3-113.0   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)

 4-112.0   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)

 5-111.0   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)

 6-110.0   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)

 7-109.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)

 8-108.0   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)

 9-107.0   (10)   (10)   (10)   (10)   (10)   (10)   (10)   (10)   (10)

10-106.0   (11)   (11)   (11)   (11)   (11)   (11)   (11)   (11)   (11)

11-105.0   (12)   (12)   (12)   (12)   (12)   (12)   (12)   (12)   (12)

12-104.0   (13)   (13)   (13)   (13)   (13)   (13)   (13)   (13)   (13)

13-103.0   (14)   (14)   (14)   (14)   (14)   (14)   (14)   (14)   (14)

14-102.0   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)

15-101.0   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  2 **********

 STORAGE                   INFLOW STATE  (CFS)
  STATE      1      2      3      4      5      6      7      8      9
            20     62    103    145    186    228    269    311    394

  1-115.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

  2-114.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

  3-113.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

  4-112.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

  5-111.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

  6-110.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

  7-109.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

  8-108.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

  9-107.0  (10)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)

 10-106.0  (11)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)

 11-105.0  (12)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)

 12-104.0  (13)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)

 13-103.0  (14)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)

 14-102.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)

 15-101.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  3 **********

 STORAGE                     INFLOW STATE  (CFS)
  STATE      1      2      3      4      5      6      7
            27     81    135    189    243    459    513

 1-115.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

 2-114.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

 3-113.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

 4-112.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

 5-111.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

 6-110.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

 7-109.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

 8-108.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

 9-107.0  (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)

10-106.0  (11)   (11)   (11)   (11)   (11)   (10)   (10)

11-105.0  (12)   (12)   (12)   (12)   (12)   (11)   (11)

12-104.0  (13)   (13)   (13)   (13)   (13)   (12)   (12)

13-103.0  (14)   (14)   (14)   (14)   (14)   (13)   (13)

14-102.0  (15)   (15)   (15)   (15)   (15)   (14)   (14)

15-101.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  4 **********

STORAGE                    INFLOW STATE (CFS)
 STATE      1     2     3     4     5     6     7     8     9    10
           33    99   166   232   299   365   432   498   565   631

 1-115.0  ( 2)  ( 2)  ( 2)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)  ( 1)

 2-114.0  ( 3)  ( 3)  ( 3)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)  ( 2)

 3-113.0  ( 4)  ( 4)  ( 4)  ( 3)  ( 3)  ( 3)  ( 3)  ( 3)  ( 3)  ( 3)

 4-112.0  ( 5)  ( 5)  ( 5)  ( 4)  ( 4)  ( 4)  ( 4)  ( 4)  ( 4)  ( 4)

 5-111.0  ( 6)  ( 6)  ( 6)  ( 5)  ( 5)  ( 5)  ( 5)  ( 5)  ( 5)  ( 5)

 6-110.0  ( 7)  ( 7)  ( 7)  ( 6)  ( 6)  ( 6)  ( 6)  ( 6)  ( 6)  ( 6)

 7-109.0  ( 8)  ( 8)  ( 8)  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)  ( 7)

 8-108.0  ( 9)  ( 9)  ( 9)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)  ( 8)

 9-107.0  (10)  (10)  (10)  ( 9)  ( 9)  ( 9)  ( 9)  ( 9)  ( 9)  ( 9)

10-106.0  (11)  (11)  (11)  (10)  (10)  (10)  (10)  (10)  (10)  (10)

11-105.0  (12)  (12)  (12)  (11)  (11)  (11)  (11)  (11)  (11)  (11)

12-104.0  (13)  (13)  (13)  (12)  (12)  (12)  (12)  (12)  (12)  (12)

13-103.0  (14)  (14)  (14)  (13)  (13)  (13)  (13)  (13)  (13)  (13)

14-102.0  (15)  (15)  (15)  (14)  (14)  (14)  (14)  (14)  (14)  (14)

15-101.0  (15)  (15)  (15)  (15)  (15)  (15)  (15)  (15)  (15)  (15)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  5 **********

STORAGE                    INFLOW STATE  (CFS)
 STATE      1      2      3      4      5      6      7      8
           101    304    507    710    913   1116   1319   1928

 1-115.0  ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0  ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 3-113.0  ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

 4-112.0  ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

 5-111.0  ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

 6-110.0  ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

 7-109.0  ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

 8-108.0  ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

 9-107.0  ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

10-106.0  (10)   (10)   (10)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

11-105.0  (11)   (11)   (11)   (10)   (10)   (10)   ( 9)   ( 9)

12-104.0  (12)   (12)   (12)   (11)   (11)   (11)   (10)   (10)

13-103.0  (13)   (13)   (13)   (12)   (12)   (12)   (11)   (11)

14-102.0  (14)   (14)   (14)   (13)   (13)   (13)   (12)   (12)

15-101.0  (15)   (15)   (15)   (14)   (14)   (14)   (13)   (13)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  6 **********

STORAGE                   INFLOW STATE  (CFS)
 STATE        1      2      3      4      5      6      7      8
             65    195    325    455    585    715    845   1235

 1-115.0   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)

 3-113.0   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)

 4-112.0   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)

 5-111.0   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)

 6-110.0   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)

 7-109.0   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)

 8-108.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)

 9-107.0   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)

10-106.0   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)

11-105.0   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)

12-104.0   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)

13-103.0   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)

14-102.0   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)

15-101.0   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  7 **********

 STORAGE
  STATE                    INFLOW STATE  (CFS)
            1      2      3      4      5      6      7
           82    246    411    575    740   1233   1562

 1-115.0  ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0  ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

 3-113.0  ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 1)

 4-112.0  ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 2)

 5-111.0  ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 3)

 6-110.0  ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 4)

 7-109.0  ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 5)

 8-108.0  ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 6)

 9-107.0  (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 7)

10-106.0  (11)   (10)   (10)   (10)   (10)   ( 9)   ( 8)

11-105.0  (12)   (11)   (11)   (11)   (11)   (10)   ( 9)

12-104.0  (13)   (12)   (12)   (12)   (12)   (11)   (10)

13-103.0  (14)   (13)   (13)   (13)   (13)   (12)   (11)

14-102.0  (15)   (14)   (14)   (14)   (14)   (13)   (12)

15-101.0  (15)   (15)   (15)   (15)   (15)   (14)   (13)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  8 **********

 STORAGE                    INFLOW STATE  (CFS)
  STATE       1      2      3      4      5      6      7      8
             54    162    270    378    486    594    918   1026

 1-115.0   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)

 3-113.0   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)

 4-112.0   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)

 5-111.0   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)

 6-110.0   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)

 7-109.0   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)

 8-108.0   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)

 9-107.0   (10)   (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)

10-106.0   (11)   (11)   (10)   (10)   (10)   (10)   ( 9)   ( 9)

11-105.0   (12)   (12)   (11)   (11)   (11)   (11)   (10)   (10)

12-104.0   (13)   (13)   (12)   (12)   (12)   (12)   (11)   (11)

13-103.0   (14)   (14)   (13)   (13)   (13)   (13)   (12)   (12)

14-102.0   (15)   (15)   (14)   (14)   (14)   (14)   (13)   (13)

15-101.0   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)
```

```
********** RUSSELL  - PASS 2 - MONTH NO:  9 **********

 STORAGE                    INFLOW STATE  (CFS)
  STATE         1       2       3       4       5       6       7
               76     228     381     533     686     838    1448

  1-115.0     ( 2)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)    ( 1)

  2-114.0     ( 3)    ( 2)    ( 2)    ( 2)    ( 2)    ( 2)    ( 1)

  3-113.0     ( 4)    ( 3)    ( 3)    ( 3)    ( 3)    ( 3)    ( 2)

  4-112.0     ( 5)    ( 4)    ( 4)    ( 4)    ( 4)    ( 4)    ( 3)

  5-111.0     ( 6)    ( 5)    ( 5)    ( 5)    ( 5)    ( 5)    ( 4)

  6-110.0     ( 7)    ( 6)    ( 6)    ( 6)    ( 6)    ( 6)    ( 5)

  7-109.0     ( 8)    ( 7)    ( 7)    ( 7)    ( 7)    ( 7)    ( 6)

  8-108.0     ( 9)    ( 8)    ( 8)    ( 8)    ( 8)    ( 8)    ( 7)

  9-107.0     (10)    ( 9)    ( 9)    ( 9)    ( 9)    ( 9)    ( 8)

 10-106.0     (11)    (10)    (10)    (10)    (10)    (10)    ( 9)

 11-105.0     (12)    (11)    (11)    (11)    (11)    (11)    (10)

 12-104.0     (13)    (12)    (12)    (12)    (12)    (12)    (11)

 13-103.0     (14)    (13)    (13)    (13)    (13)    (13)    (12)

 14-102.0     (15)    (14)    (14)    (14)    (14)    (14)    (13)

 15-101.0     (15)    (15)    (15)    (15)    (15)    (15)    (14)
```

```
********** RUSSELL  - PASS 2 - MONTH NO: 10 **********

STORAGE                    INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8
            59    177    295    413    531    649    767   1121

 1-115.0   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)

 3-113.0   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)

 4-112.0   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)

 5-111.0   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)

 6-110.0   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)

 7-109.0   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)

 8-108.0   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)

 9-107.0   (10)   (10)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)

10-106.0   (11)   (11)   (10)   (10)   (10)   (10)   (10)   ( 9)

11-105.0   (12)   (12)   (11)   (11)   (11)   (11)   (11)   (10)

12-104.0   (13)   (13)   (12)   (12)   (12)   (12)   (12)   (11)

13-103.0   (14)   (14)   (13)   (13)   (13)   (13)   (13)   (12)

14-102.0   (15)   (15)   (14)   (14)   (14)   (14)   (14)   (13)

15-101.0   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)
```

```
********** RUSSELL  - PASS 2 - MONTH NO: 11 **********

STORAGE                      INFLOW STATE  (CFS)
 STATE       1      2      3      4      5      6      7      8      9
            27     81    136    190    245    299    354    408    517

 1-115.0   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)   ( 1)

 2-114.0   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)   ( 2)

 3-113.0   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)   ( 3)

 4-112.0   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)   ( 4)

 5-111.0   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)   ( 5)

 6-110.0   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)   ( 6)

 7-109.0   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)   ( 7)

 8-108.0   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)   ( 8)

 9-107.0   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)   ( 9)

10-106.0   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)   (10)

11-105.0   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)   (11)

12-104.0   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)   (12)

13-103.0   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)   (13)

14-102.0   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)   (14)

15-101.0   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)
```

```
********** RUSSELL  - PASS 2 - MONTH NO: 12 **********

STORAGE                        INFLOW STATE  (CFS)
 STATE      1      2      3      4      5      6      7      8      9     10
           21     63    105    147    189    231    273    315    357    399

 1-115.0  ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 2)   ( 1)   ( 1)   ( 1)
 2-114.0  ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 3)   ( 2)   ( 2)   ( 2)
 3-113.0  ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 4)   ( 3)   ( 3)   ( 3)
 4-112.0  ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 5)   ( 4)   ( 4)   ( 4)
 5-111.0  ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 6)   ( 5)   ( 5)   ( 5)
 6-110.0  ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 7)   ( 6)   ( 6)   ( 6)
 7-109.0  ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 8)   ( 7)   ( 7)   ( 7)
 8-108.0  ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 9)   ( 8)   ( 8)   ( 8)
 9-107.0  (10)   (10)   (10)   (10)   (10)   (10)   (10)   ( 9)   ( 9)   ( 9)
10-106.0  (11)   (11)   (11)   (11)   (11)   (11)   (11)   (10)   (10)   (10)
11-105.0  (12)   (12)   (12)   (12)   (12)   (12)   (12)   (11)   (11)   (11)
12-104.0  (13)   (13)   (13)   (13)   (13)   (13)   (13)   (12)   (12)   (12)
13-103.0  (14)   (14)   (14)   (14)   (14)   (14)   (14)   (13)   (13)   (13)
14-102.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (14)   (14)   (14)
15-101.0  (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)   (15)
```

D.2 SIMULATED RESERVOIR OPERATIONS

This section contains simulated reservoir operations of the system of reservoirs. The simulated operations were obtained by running the individual local inflow records through the 'optimal' policy. Note that in some instances, the inflow and the outflow are not at the same magnitude even though the reservoir level stays the same before and after release of water. The reason for this is that the outflow are representative flows set-forth by the policy.

			...........EAGER...........			.........RUSSELL..........			..................PLANT # 2..................				
YEAR	MTH	UNREG. INFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1953	1	74	345	115.00	328.	132	114.00	785.	1186.	213.00	1150.	36.	109531.
1953	2	9	25	114.00	531.	119	113.00	749.	1289.	213.00	1150.	139.	93953.
1953	3	13	26	113.00	532.	126	112.00	780.	1325.	213.00	1150.	175.	97820.
1953	4	9	16	112.00	539.	108	111.00	745.	1293.	212.00	1150.	143.	85170.
1953	5	635	444	112.00	439.	675	112.00	66.	1140.	212.00	1140.	0.	72703.
1953	6	434	398	112.00	369.	352	112.00	325.	1128.	212.00	1128.	0.	53963.
1953	7	306	411	112.00	376.	220	112.00	247.	929.	212.00	929.	0.	50153.
1953	8	706	233	112.00	270.	89	111.00	699.	1675.	212.00	1150.	525.	70686.
1953	9	282	720	113.00	259.	218	111.00	229.	770.	212.00	770.	0.	51672.
1953	10	313	479	113.00	454.	220	110.00	822.	1589.	213.00	1150.	439.	85946.
1953	11	221	321	113.00	332.	325	110.00	300.	852.	213.00	852.	0.	60856.
1953	12	104	305	113.00	296.	264	109.00	918.	1318.	213.00	1150.	168.	95064.
1954	1	2	221	112.00	742.	196	108.00	847.	1590.	213.00	1150.	440.	108531.
1954	2	3	252	112.00	261.	168	107.00	832.	1096.	213.00	1096.	0.	89066.
1954	3	13	85	111.00	589.	188	106.00	834.	1436.	213.00	1150.	286.	97820.
1954	4	134	202	111.00	186.	108	105.00	745.	1075.	212.00	1150.	130.	85170.
1954	5	872	566	112.00	47.	983	106.00	269.	1188.	212.00	1150.	38.	73431.
1954	6	486	800	113.00	63.	588	106.00	585.	1134.	212.00	1134.	0.	54257.
1954	7	30	256	113.00	292.	394	106.00	411.	734.	212.00	734.	0.	38118.
1954	8	127	164	113.00	193.	246	106.00	270.	590.	212.00	590.	0.	32375.
1954	9	322	11	112.00	577.	155	106.00	229.	1128.	212.00	1128.	0.	79950.
1954	10	156	20	111.00	559.	251	106.00	295.	1010.	213.00	768.	0.	54238.
1954	11	12	72	110.00	576.	161	105.00	781.	1369.	213.00	1150.	219.	85331.
1954	12	4	108	109.00	616.	373	105.00	357.	877.	213.00	877.	0.	79244.
1955	1	38	10	108.00	535.	121	104.00	754.	1326.	213.00	1150.	176.	109531.
1955	2	10	113	107.00	641.	102	103.00	749.	1400.	213.00	1150.	250.	93953.
1955	3	148	162	106.00	674.	98	102.00	726.	1548.	213.00	1150.	398.	97820.
1955	4	357	187	106.00	186.	184	101.00	811.	1364.	212.00	1150.	214.	85170.
1955	5	1012	575	107.00	47.	1427	103.00	30.	1089.	212.00	1088.	0.	69082.
1955	6	237	168	107.00	158.	310	103.00	325.	720.	212.00	720.	0.	32216.
1955	7	212	34	106.00	559.	503	103.00	576.	1347.	212.00	1150.	197.	63823.
1955	8	109	8	105.00	556.	289	103.00	270.	935.	212.00	935.	0.	55990.
1955	9	204	3	104.00	577.	21	102.00	721.	1503.	212.00	1150.	353.	81688.
1955	10	300	92	103.00	641.	69	101.00	704.	1645.	213.00	1150.	495.	85946.
1955	11	232	80	102.00	615.	119	101.00	136.	983.	213.00	983.	0.	71624.
1955	12	160	82	101.00	616.	79	101.00	63.	839.	213.00	839.	0.	66606.
1956	1	13	84	100.00	604.	40	101.00	47.	663.	213.00	663.	0.	58172.
1956	2	10	95	100.00	96.	45	101.00	62.	169.	210.00	917.	0.	72287.
1956	3	30	76	100.00	71.	44	101.00	27.	128.	207.00	765.	0.	59829.
1956	4	150	64	100.00	65.	158	101.00	166.	382.	204.00	1122.	0.	80631.
1956	5	552	616	101.00	47.	1638	103.00	639.	1238.	204.00	1150.	88.	71202.
1956	6	550	113	101.00	158.	253	103.00	185.	903.	204.00	903.	0.	40297.
1956	7	209	17	100.00	559.	131	102.00	727.	1496.	207.00	1150.	346.	62249.
1956	8	288	39	100.00	39.	37	101.00	699.	1036.	209.00	533.	0.	27423.
1956	9	244	9	100.00	60.	12	101.00	76.	380.	207.00	843.	0.	56218.
1956	10	5	16	100.00	41.	263	101.00	295.	341.	204.00	1074.	0.	77343.
1956	11	9	91	100.00	98.	141	101.00	136.	243.	201.00	940.	0.	64661.
1956	12	3	123	100.00	138.	48	101.00	63.	204.	198.00	805.	0.	67731.

			...........EAGER...........			.........RUSSELL..........			..................PLANT # 2..................				
YEAR	MTH	UNREG. INFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1957	1	130	105	100.00	121.	43	101.00	47.	297.	195.00	926.	0.	79090.
1957	2	141	84	100.00	96.	18	101.00	21.	258.	192.00	917.	0.	65894.
1957	3	143	56	100.00	43.	21	101.00	27.	213.	192.00	213.	0.	1736.
1957	4	94	168	100.00	152.	561	101.00	565.	812.	192.00	812.	0.	50732.
1957	5	752	1416	102.00	157.	1360	103.00	30.	939.	192.00	939.	0.	52858.
1957	6	210	420	102.00	369.	820	104.00	200.	779.	192.00	779.	0.	31178.
1957	7	776	654	102.00	626.	1660	106.00	273.	1675.	195.00	1150.	525.	59343.
1957	8	1131	346	102.00	347.	159	105.00	807.	2285.	198.00	1150.	1135.	66528.
1957	9	250	904	103.00	379.	1442	106.00	804.	1433.	201.10	692.	0.	41671.
1957	10	217	538	103.00	536.	464	106.00	413.	1166.	204.00	484.	0.	27483.
1957	11	160	382	103.00	371.	95	105.00	727.	1257.	207.00	559.	0.	34310.
1957	12	100	355	103.00	336.	66	104.00	708.	1144.	207.00	1144.	0.	92336.
1958	1	80	21	102.00	535.	350	103.00	940.	1554.	210.00	1150.	404.	107667.
1958	2	365	29	101.00	559.	90	102.00	749.	1673.	213.00	1150.	523.	93420.
1958	3	330	35	100.00	560.	553	102.00	513.	1403.	213.00	1150.	253.	97820.
1958	4	684	118	100.00	109.	96	101.00	745.	1538.	212.00	1150.	388.	85170.
1958	5	1313	860	101.00	173.	1172	102.00	472.	1957.	212.00	1150.	807.	73431.
1958	6	330	410	101.00	369.	846	103.00	200.	899.	212.00	899.	0.	41757.
1958	7	448	192	101.00	209.	464	103.00	411.	1068.	212.00	1068.	0.	58762.
1958	8	228	229	101.00	193.	380	103.00	378.	799.	212.00	799.	0.	46660.
1958	9	823	339	101.00	299.	723	103.00	886.	1808.	212.00	1150.	658.	81688.
1958	10	109	191	101.00	206.	830	103.00	767.	1082.	213.00	921.	0.	66971.
1958	11	30	369	101.00	371.	307	103.00	300.	700.	213.00	700.	0.	48361.
1958	12	3	398	101.00	375.	157	102.00	782.	1170.	213.00	1150.	20.	95064.
1959	1	2	341	101.00	328.	60	101.00	692.	1021.	213.00	1021.	0.	95946.
1959	2	2	202	101.00	206.	59	101.00	62.	271.	210.00	917.	0.	72287.
1959	3	2	157	100.00	674.	137	101.00	135.	811.	210.00	811.	0.	64789.
1959	4	270	108	100.00	109.	387	101.00	366.	745.	209.00	1033.	0.	74564.
1959	5	1154	797	101.00	173.	1423	103.00	30.	1356.	209.00	1150.	206.	72595.
1959	6	1062	1165	102.00	485.	1457	104.00	590.	2137.	212.00	1150.	987.	54809.
1959	7	229	386	102.00	376.	477	104.00	411.	1016.	212.00	1016.	0.	55553.
1959	8	273	480	102.00	501.	585	104.00	594.	1368.	212.00	1150.	218.	70686.
1959	9	248	9	101.00	577.	412	104.00	381.	1207.	212.00	1150.	57.	81688.
1959	10	375	5	100.00	559.	311	104.00	295.	1229.	213.00	1075.	0.	79704.
1959	11	337	6	100.00	20.	190	103.00	836.	1192.	213.00	1150.	42.	85331.
1959	12	235	13	100.00	20.	175	102.00	834.	1088.	213.00	1089.	0.	89455.
1960	1	104	65	100.00	52.	262	101.00	878.	1033.	213.00	1033.	0.	97212.
1960	2	258	17	100.00	14.	40	101.00	21.	293.	210.00	917.	0.	72287.
1960	3	257	38	100.00	43.	155	101.00	135.	435.	207.00	1063.	0.	87910.
1960	4	213	58	100.00	65.	237	101.00	233.	511.	207.00	511.	0.	30869.
1960	5	1348	526	101.00	47.	1539	103.00	30.	1425.	212.00	1150.	275.	72734.
1960	6	914	873	102.00	274.	981	104.00	200.	1388.	212.00	1150.	238.	55123.
1960	7	330	300	102.00	292.	378	104.00	411.	1034.	212.00	1034.	0.	58633.
1960	8	49	217	102.00	193.	80	103.00	699.	941.	212.00	941.	0.	56366.
1960	9	229	40	101.00	577.	200	103.00	229.	1035.	212.00	1035.	0.	72604.
1960	10	122	110	100.00	641.	88	102.00	704.	1467.	213.00	1150.	317.	85946.
1960	11	242	53	100.00	59.	207	101.00	836.	1136.	213.00	1136.	0.	84201.
1960	12	266	6	100.00	20.	223	101.00	231.	517.	213.00	517.	0.	37073.

YEAR	MTH	UNREG. INFLOW	EAGER			RUSSELL			PLANT # 2				
			INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1961	1	235	2	100.00	17.	124	101.00	140.	392.	210.00	1084.	0.	101919.
1961	2	213	22	100.00	14.	73	101.00	82.	289.	207.00	917.	0.	71222.
1961	3	321	11	100.00	14.	142	101.00	135.	470.	207.00	470.	0.	31547.
1961	4	277	10	100.00	22.	151	101.00	168.	465.	204.00	1122.	0.	80631.
1961	5	868	705	101.00	173.	1223	103.00	30.	1070.	204.00	1070.	0.	65539.
1961	6	313	475	101.00	475.	278	103.00	325.	1113.	204.00	1113.	0.	51464.
1961	7	15	337	101.00	376.	100	102.00	727.	1118.	207.00	488.	0.	21362.
1961	8	9	193	101.00	193.	79	101.00	699.	901.	207.00	901.	0.	52291.
1961	9	10	33	100.00	577.	48	101.00	76.	664.	207.00	864.	0.	41709.
1961	10	10	77	100.00	41.	149	101.00	177.	228.	204.00	767.	0.	51877.
1961	11	144	273	100.00	293.	312	101.00	300.	736.	204.00	736.	0.	48417.
1961	12	228	230	100.00	217.	172	101.00	189.	634.	204.00	634.	0.	44599.
1962	1	180	140	100.00	155.	215	101.00	202.	537.	201.00	1150.	91.	105183.
1962	2	34	108	100.00	96.	159	101.00	145.	276.	198.00	917.	0.	88025.
1962	3	51	153	100.00	157.	228	101.00	243.	451.	195.00	1150.	62.	91719.
1962	4	160	153	100.00	152.	79	101.00	100.	412.	192.00	1122.	0.	76760.
1962	5	1790	1412	102.00	157.	2248	103.00	639.	2586.	195.00	1150.	1436.	68276.
1962	6	608	502	102.00	475.	725	104.00	70.	1153.	195.00	1150.	3.	51567.
1962	7	97	370	102.00	376.	119	103.00	727.	1200.	198.00	488.	0.	19183.
1962	8	10	113	101.00	633.	110	102.00	807.	1450.	201.10	1150.	300.	67346.
1962	9	20	145	101.00	179.	173	102.00	229.	428.	198.00	1096.	0.	73583.
1962	10	81	149	100.00	641.	95	101.00	704.	1426.	201.00	1150.	276.	81715.
1962	11	47	259	100.00	254.	246	101.00	245.	546.	201.00	546.	0.	31790.
1962	12	153	217	100.00	217.	206	101.00	189.	559.	201.00	559.	0.	36652.
1963	1	6	174	100.00	190.	165	101.00	171.	366.	198.00	1084.	0.	96951.
1963	2	95	123	100.00	124.	160	101.00	145.	364.	195.00	1068.	0.	80626.
1963	3	79	294	100.00	271.	64	101.00	81.	431.	192.00	1063.	0.	82364.
1963	4	276	159	100.00	152.	344	101.00	366.	794.	192.00	794.	0.	49294.
1963	5	777	524	101.00	47.	854	102.00	269.	1093.	192.00	1093.	0.	63793.
1963	6	542	803	102.00	274.	931	103.00	200.	1016.	192.00	1016.	0.	43784.
1963	7	1114	706	103.00	192.	1199	104.00	589.	1895.	195.00	1150.	745.	59343.
1963	8	297	165	103.00	193.	423	104.00	378.	868.	195.00	868.	0.	46817.
1963	9	446	321	103.00	299.	597	104.00	534.	1279.	198.00	715.	0.	42542.
1963	10	293	270	103.00	289.	451	104.00	413.	995.	198.00	995.	0.	68348.
1963	11	163	188	103.00	215.	297	104.00	300.	677.	198.00	677.	0.	41632.
1963	12	51	115	102.00	616.	298	104.00	315.	982.	198.00	982.	0.	74312.
1964	1	114	312	102.00	328.	272	103.00	940.	1381.	201.00	649.	0.	51052.
1964	2	75	258	102.00	261.	247	102.00	873.	1210.	204.00	594.	0.	39857.
1964	3	104	167	101.00	674.	194	101.00	834.	1612.	207.00	1150.	462.	95047.
1964	4	476	221	101.00	239.	318	101.00	299.	1015.	208.00	580.	0.	37665.
1964	5	1087	664	102.00	173.	1341	103.00	30.	1289.	209.00	1150.	139.	72595.
1964	6	380	126	102.00	158.	364	103.00	325.	863.	209.00	863.	0.	39211.
1964	7	401	327	102.00	292.	305	103.00	247.	940.	209.00	940.	0.	50136.
1964	8	1022	771	103.00	214.	1081	104.00	381.	1617.	212.00	1150.	467.	70283.
1964	9	1016	1192	104.00	618.	1477	105.00	804.	2438.	212.00	1150.	1288.	81688.
1964	10	537	673	105.00	184.	845	105.00	767.	1488.	213.00	1150.	338.	85946.
1964	11	388	137	104.00	654.	436	105.00	409.	1451.	213.00	1150.	301.	85331.
1964	12	254	204	104.00	217.	405	105.00	399.	870.	213.00	870.	0.	69445.

YEAR	MTH	UNREG. INFLOW	EAGER			RUSSELL			PLANT # 2				
			INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1965	1	201	74	103.00	604.	277	104.00	940.	1744.	213.00	1150.	594.	109531.
1965	2	212	15	102.00	531.	308	104.00	311.	1055.	213.00	1055.	0.	85310.
1965	3	178	12	101.00	532.	171	103.00	834.	1544.	213.00	1150.	394.	97820.
1965	4	441	207	101.00	196.	382	103.00	366.	1003.	212.00	1150.	130.	85170.
1965	5	1067	640	102.00	173.	1252	105.00	30.	1269.	212.00	1150.	119.	73431.
1965	6	194	424	102.00	475.	539	105.00	585.	1254.	212.00	1150.	104.	55123.
1965	7	41	166	102.00	125.	260	105.00	247.	413.	209.00	1083.	0.	59294.
1965	8	269	184	102.00	193.	178	104.00	807.	1269.	209.00	1150.	119.	69881.
1965	9	419	211	102.00	179.	329	104.00	381.	980.	209.00	980.	0.	67290.
1965	10	401	156	101.00	641.	312	104.00	295.	1337.	210.00	1075.	0.	78728.
1965	11	298	138	100.00	654.	276	104.00	300.	1252.	213.00	559.	0.	36246.
1965	12	353	130	100.00	138.	156	103.00	792.	1283.	213.00	1150.	133.	95064.
1966	1	439	68	100.00	52.	54	102.00	692.	1182.	213.00	1150.	32.	109531.
1966	2	394	15	100.00	14.	14	101.00	666.	1074.	213.00	1074.	0.	87029.
1966	3	360	67	100.00	71.	16	101.00	27.	458.	213.00	458.	0.	32635.
1966	4	410	185	100.00	186.	55	101.00	33.	639.	212.00	909.	0.	65380.
1966	5	681	267	100.00	314.	634	102.00	66.	1060.	212.00	1060.	0.	67058.
1966	6	1066	619	101.00	63.	1383	103.00	590.	1719.	212.00	1150.	569.	55123.
1966	7	311	380	101.00	376.	309	103.00	247.	934.	212.00	934.	0.	50461.
1966	8	164	85	100.00	556.	128	102.00	807.	1527.	212.00	1150.	377.	70686.
1966	9	82	33	100.00	80.	61	101.00	721.	863.	212.00	863.	0.	59018.
1966	10	28	30	100.00	41.	151	101.00	177.	246.	210.00	844.	0.	60054.
1966	11	13	129	100.00	137.	226	101.00	245.	395.	207.00	1106.	0.	80283.
1966	12	13	221	100.00	217.	220	101.00	231.	461.	207.00	461.	0.	29834.
1967	1	13	60	100.00	52.	96	101.00	109.	173.	204.00	926.	0.	82817.
1967	2	107	93	100.00	96.	81	101.00	62.	266.	201.00	917.	0.	69091.
1967	3	144	56	100.00	43.	97	101.00	81.	268.	198.00	914.	0.	70542.
1967	4	187	111	100.00	109.	95	101.00	100.	376.	195.00	1122.	0.	77728.
1967	5	775	725	101.00	173.	1191	102.00	472.	1419.	198.00	1150.	269.	69112.
1967	6	819	521	101.00	475.	821	103.00	200.	1494.	201.10	1150.	344.	52519.
1967	7	403	422	101.00	459.	576	103.00	576.	1438.	204.00	1150.	288.	61534.
1967	8	50	187	101.00	193.	94	102.00	699.	942.	204.00	942.	0.	54289.
1967	9	46	35	100.00	577.	29	101.00	721.	1345.	207.00	715.	0.	45332.
1967	10	507	43	100.00	41.	27	101.00	59.	607.	207.00	607.	0.	39134.
1967	11	298	93	100.00	98.	37	101.00	27.	423.	204.00	1106.	0.	79316.
1967	12	291	88	100.00	99.	79	101.00	63.	453.	204.00	453.	0.	27978.
1968	1	236	34	100.00	17.	63	101.00	78.	331.	201.00	1084.	0.	98193.
1968	2	250	52	100.00	41.	35	101.00	21.	312.	198.00	1068.	0.	81692.
1968	3	84	43	100.00	43.	40	101.00	27.	154.	195.00	914.	0.	69433.
1968	4	225	286	100.00	283.	195	101.00	166.	674.	195.00	674.	0.	40397.
1968	5	638	359	100.00	314.	780	102.00	66.	1017.	195.00	1017.	0.	59268.
1968	6	284	402	100.00	369.	462	102.00	455.	1108.	195.00	1108.	0.	49342.
1968	7	349	214	100.00	208.	312	102.00	247.	805.	195.00	805.	0.	38383.
1968	8	238	43	100.00	39.	7	101.00	699.	976.	195.00	976.	0.	54199.
1968	9	361	551	100.00	538.	825	101.00	839.	1738.	198.00	971.	0.	62725.
1968	10	565	312	100.00	289.	589	101.00	531.	1385.	201.00	1150.	235.	81715.
1968	11	449	186	100.00	176.	236	101.00	245.	870.	201.00	870.	0.	58423.
1968	12	401	165	100.00	178.	155	101.00	147.	726.	201.00	726.	0.	51800.

			...........EAGER	....	....	.........RUSSELL	....	....	..................PLANT # 2	....	....	....	....
YEAR	MTH	UNREG. INFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1969	1	279	146	100.00	155.	244	101.00	233.	867.	198.00	1150.	91.	103941.
1969	2	209	112	100.00	124.	97	101.00	104.	437.	195.00	1068.	0.	80626.
1969	3	266	78	100.00	71.	97	101.00	81.	418.	192.00	1083.	0.	82364.
1969	4	550	256	100.00	239.	707	101.00	632.	1421.	192.00	1150.	271.	78557.
1969	5	287	336	100.00	314.	222	101.00	305.	905.	192.00	905.	0.	50479.
1969	6	214	287	100.00	264.	328	101.00	325.	803.	192.00	803.	0.	32430.
1969	7	41	289	100.00	292.	376	101.00	411.	745.	192.00	745.	0.	33954.
1969	8	223	694	101.00	214.	236	101.00	270.	707.	192.00	707.	0.	35042.
1969	9	1510	1105	102.00	618.	1533	102.00	804.	2932.	198.00	1150.	1782.	76419.
1969	10	694	368	102.00	371.	688	102.00	849.	1614.	201.00	1150.	464.	81715.
1969	11	155	287	102.00	254.	574	102.00	518.	926.	201.00	926.	0.	63068.
1969	12	38	306	102.00	296.	188	101.00	834.	1168.	204.00	526.	0.	34101.
1970	1	130	257	102.00	259.	180	101.00	171.	559.	201.00	1150.	91.	105183.
1970	2	326	107	101.00	814.	141	101.00	145.	1085.	201.00	1085.	0.	83808.
1970	3	248	37	100.00	560.	148	101.00	135.	943.	201.00	943.	0.	73900.
1970	4	313	10	100.00	22.	70	101.00	100.	435.	198.00	1122.	0.	78696.
1970	5	485	379	100.00	439.	625	102.00	66.	990.	198.00	990.	0.	58151.
1970	6	429	383	100.00	389.	1023	103.00	200.	998.	198.00	998.	0.	44106.
1970	7	446	286	100.00	292.	796	103.00	740.	1479.	201.10	1150.	329.	60808.
1970	8	111	191	100.00	193.	278	103.00	270.	574.	201.10	574.	0.	28357.
1970	9	232	110	100.00	60.	336	103.00	381.	673.	201.10	673.	0.	40631.
1970	10	141	276	100.00	289.	315	103.00	295.	725.	201.00	714.	0.	46032.
1970	11	347	243	100.00	254.	210	102.00	836.	1436.	204.00	1150.	286.	81844.
1970	12	229	211	100.00	217.	192	101.00	834.	1280.	207.00	526.	0.	35179.
1971	1	121	148	100.00	155.	190	101.00	202.	478.	204.00	1150.	91.	106425.
1971	2	75	177	100.00	179.	157	101.00	145.	389.	201.00	1068.	0.	82757.
1971	3	119	184	100.00	185.	99	101.00	81.	385.	198.00	1063.	0.	84583.
1971	4	416	261	100.00	239.	495	101.00	499.	1154.	201.10	1150.	4.	80993.
1971	5	873	510	101.00	47.	937	102.00	269.	1189.	201.10	1150.	39.	70394.
1971	6	436	460	101.00	475.	823	103.00	200.	1111.	204.00	469.	0.	16860.
1971	7	219	434	101.00	459.	490	103.00	411.	1090.	204.00	1090.	0.	58152.
1971	8	345	353	101.00	347.	195	102.00	807.	1498.	209.00	1150.	349.	69210.
1971	9	701	692	101.00	657.	744	102.00	686.	2045.	212.00	1150.	332.	81223.
1971	10	962	826	102.00	266.	1203	103.00	476.	1704.	213.00	1150.	554.	85946.
1971	11	384	395	102.00	371.	577	103.00	518.	1282.	213.00	1150.	132.	85331.
1971	12	169	318	102.00	336.	464	103.00	399.	904.	213.00	904.	0.	72513.
1972	1	151	324	102.00	328.	283	102.00	940.	1418.	213.00	1150.	268.	109531.
1972	2	145	289	102.00	261.	424	102.00	394.	801.	213.00	801.	0.	62321.
1972	3	41	217	102.00	214.	469	102.00	459.	714.	213.00	714.	0.	58711.
1972	4	168	201	102.00	196.	397	102.00	366.	730.	212.00	909.	0.	65380.
1972	5	1094	485	102.00	439.	742	103.00	66.	1599.	212.00	1150.	449.	73431.
1972	6	194	488	102.00	475.	649	103.00	585.	1254.	212.00	1150.	104.	55123.
1972	7	267	344	102.00	376.	484	103.00	411.	1054.	212.00	1054.	0.	57898.
1972	8	223	307	102.00	270.	381	103.00	378.	871.	212.00	871.	0.	51581.
1972	9	287	289	102.00	299.	652	103.00	686.	1272.	212.00	1150.	122.	81688.
1972	10	283	382	102.00	371.	531	103.00	531.	1195.	213.00	921.	0.	66971.
1972	11	183	307	102.00	293.	396	103.00	409.	884.	213.00	884.	0.	63486.
1972	12	126	271	102.00	257.	306	103.00	315.	698.	213.00	698.	0.	53648.

			...........EAGER	....	....	.........RUSSELL	....	....	..................PLANT # 2	....	....	....	....
YEAR	MTH	UNREG. INFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1973	1	30	246	102.00	259.	257	102.00	878.	1166.	213.00	1150.	16.	109531.
1973	2	30	115	101.00	641.	258	101.00	815.	1586.	213.00	1150.	436.	93953.
1973	3	51	132	100.00	646.	192	101.00	189.	886.	213.00	886.	0.	72919.
1973	4	166	94	100.00	109.	306	101.00	299.	574.	212.00	786.	0.	55228.
1973	5	757	421	100.00	439.	721	102.00	66.	1262.	212.00	1150.	112.	73431.
1973	6	261	495	100.00	475.	555	102.00	585.	1321.	212.00	1150.	171.	55123.
1973	7	466	279	100.00	292.	453	102.00	411.	1170.	212.00	1150.	20.	63823.
1973	8	193	206	100.00	193.	555	102.00	594.	980.	212.00	980.	0.	59032.
1973	9	159	221	100.00	179.	400	102.00	381.	720.	212.00	720.	0.	47683.
1973	10	413	256	100.00	289.	436	102.00	413.	1115.	213.00	921.	0.	66971.
1973	11	390	265	100.00	254.	338	102.00	354.	998.	213.00	998.	0.	72816.
1973	12	247	231	100.00	217.	319	102.00	315.	779.	213.00	779.	0.	61112.
1974	1	107	233	100.00	224.	340	101.00	940.	1271.	213.00	1150.	121.	109531.
1974	2	50	211	100.00	206.	263	101.00	270.	526.	210.00	1068.	0.	85954.
1974	3	16	186	100.00	185.	266	101.00	243.	446.	207.00	1063.	0.	87910.
1974	4	367	217	100.00	196.	582	101.00	565.	1128.	209.00	1128.	0.	81910.
1974	5	721	444	100.00	439.	955	102.00	269.	1429.	212.00	1150.	279.	73013.
1974	6	582	514	100.00	475.	818	103.00	200.	1257.	212.00	1150.	107.	55123.
1974	7	404	298	100.00	292.	468	103.00	411.	1108.	212.00	1108.	0.	61200.
1974	8	117	216	100.00	193.	390	103.00	378.	688.	212.00	688.	0.	39073.
1974	9	140	145	100.00	179.	193	103.00	229.	548.	212.00	548.	0.	34136.
1974	10	88	213	100.00	206.	151	102.00	822.	1116.	213.00	921.	0.	66971.
1974	11	289	221	100.00	215.	142	101.00	781.	1285.	213.00	1150.	135.	85331.
1974	12	180	215	100.00	217.	296	101.00	315.	712.	213.00	712.	0.	54976.
1975	1	119	42	100.00	52.	186	101.00	202.	372.	210.00	1084.	0.	101919.
1975	2	45	52	100.00	41.	155	101.00	145.	232.	207.00	917.	0.	71222.
1975	3	45	87	100.00	100.	124	101.00	135.	280.	204.00	914.	0.	72761.
1975	4	146	156	100.00	152.	413	101.00	432.	731.	204.00	731.	0.	47945.
1975	5	786	662	101.00	47.	874	102.00	269.	1082.	204.00	1082.	0.	66355.
1975	6	523	361	101.00	369.	788	103.00	200.	1092.	204.00	1092.	0.	50371.
1975	7	460	349	101.00	376.	502	103.00	576.	1412.	207.00	645.	0.	31052.
1975	8	291	229	101.00	193.	246	103.00	270.	754.	207.00	754.	0.	42243.
1975	9	43	141	101.00	179.	99	102.00	721.	944.	207.00	944.	0.	63827.
1975	10	80	137	100.00	641.	110	101.00	704.	1425.	210.00	1150.	275.	84644.
1975	11	103	153	100.00	137.	71	101.00	82.	321.	207.00	940.	0.	66597.
1975	12	164	167	100.00	178.	74	101.00	63.	405.	204.00	1048.	0.	82982.
1976	1	90	205	100.00	190.	84	101.00	78.	357.	201.00	1084.	0.	98193.
1976	2	113	232	100.00	234.	60	101.00	62.	409.	198.00	1088.	0.	81692.
1976	3	209	152	100.00	157.	49	101.00	27.	393.	195.00	1063.	0.	83473.
1976	4	270	163	100.00	152.	45	101.00	33.	456.	192.00	1122.	0.	76760.
1976	5	316	356	100.00	314.	351	101.00	305.	934.	192.00	834.	0.	52539.
1976	6	572	713	101.00	188.	927	102.00	200.	940.	192.00	940.	0.	39759.
1976	7	958	847	102.00	276.	1628	104.00	273.	1507.	195.00	1150.	357.	59343.
1976	8	201	619	103.00	137.	906	105.00	273.	611.	195.00	611.	0.	28284.
1976	9	252	370	103.00	418.	216	105.00	228.	898.	195.00	899.	0.	56692.
1976	10	167	334	103.00	371.	452	105.00	413.	951.	195.00	951.	0.	63763.
1976	11	285	354	103.00	371.	283	105.00	300.	955.	195.00	955.	0.	63516.
1976	12	190	319	103.00	336.	245	104.00	876.	1402.	198.00	1150.	252.	89135.

			...........EAGER...........			.........RUSSELL..........			..................PLANT # 2..................				
YEAR	MTH	UNREG. INFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	INFLOW	END OF MO. ELEV.	OUTFLOW	SPILL	VALUE OF GENERATION
1977	1	66	296	103.00	283.	230	103.00	878.	1237.	198.00	1150.	87.	103320.
1977	2	70	206	103.00	206.	89	102.00	749.	1025.	198.00	1025.	0.	77312.
1977	3	70	121	102.00	646.	234	101.00	888.	1604.	201.00	1150.	454.	92826.
1977	4	559	443	102.00	413.	464	101.00	432.	1405.	204.00	1150.	255.	81944.
1977	5	734	914	103.00	173.	1345	103.00	30.	936.	204.00	936.	0.	56024.
1977	6	492	617	104.00	63.	706	104.00	70.	625.	204.00	625.	0.	25452.
1977	7	179	229	104.00	209.	230	104.00	247.	635.	204.00	635.	0.	30071.
1977	8	6	234	104.00	270.	229	104.00	270.	546.	204.00	546.	0.	27221.
1977	9	218	244	104.00	299.	302	104.00	229.	746.	204.00	746.	0.	47257.
1977	10	247	307	104.00	289.	248	104.00	295.	831.	204.00	831.	0.	56697.
1977	11	359	130	103.00	654.	225	103.00	890.	1903.	207.00	1150.	753.	62912.
1977	12	260	64	102.00	577.	131	102.00	792.	1629.	210.00	1150.	479.	93447.
1978	1	146	50	101.00	569.	88	101.00	723.	1438.	213.00	1150.	288.	106910.
1978	2	261	35	100.00	559.	164	101.00	145.	965.	213.00	965.	0.	77209.
1978	3	187	28	100.00	14.	203	101.00	189.	390.	210.00	1063.	0.	89020.
1978	4	27	143	100.00	152.	407	101.00	432.	612.	209.00	786.	0.	54260.
1978	5	558	325	100.00	314.	463	101.00	508.	1379.	212.00	1150.	229.	73013.
1978	6	467	126	100.00	158.	427	101.00	455.	1080.	212.00	1080.	0.	51405.
1978	7	266	90	100.00	125.	251	101.00	247.	638.	212.00	638.	0.	32225.
1978	8	643	432	100.00	424.	451	101.00	486.	1553.	212.00	1150.	403.	70686.
1978	9	672	392	100.00	418.	530	101.00	534.	1624.	212.00	1150.	474.	81688.
1978	10	715	316	100.00	289.	366	101.00	413.	1417.	213.00	1150.	267.	85946.
1978	11	411	83	100.00	98.	157	101.00	136.	645.	213.00	645.	0.	43789.
1978	12	356	30	100.00	20.	114	101.00	105.	481.	213.00	481.	0.	33776.
1979	1	404	73	100.00	86.	169	101.00	171.	661.	213.00	661.	0.	57908.
1979	2	313	20	100.00	14.	133	101.00	145.	472.	210.00	1068.	0.	85954.
1979	3	234	20	100.00	14.	17	101.00	27.	275.	207.00	914.	0.	73870.
1979	4	252	10	100.00	22.	63	101.00	33.	307.	204.00	899.	0.	70479.
1979	5	610	202	100.00	188.	439	101.00	508.	1306.	204.00	1150.	156.	71202.
1979	6	593	282	100.00	264.	630	101.00	585.	1442.	207.00	1150.	292.	53763.
1979	7	34	201	100.00	209.	18	101.00	82.	325.	204.00	1083.	0.	58063.
1979	8	95	78	100.00	116.	288	101.00	270.	481.	204.00	481.	0	22779.
1979	9	130	265	100.00	299.	335	101.00	381.	810.	204.00	810.	0.	52351.
1979	10	94	258	100.00	289.	348	101.00	295.	678.	204.00	678.	0.	44006.
1979	11	22	243	100.00	254.	349	101.00	354.	630.	204.00	630.	0.	39663.
1979	12	30	209	100.00	217.	212	101.00	231.	478.	204.00	478.	0.	30313.
1980	1	22	151	100.00	155.	153	101.00	140.	317.	201.00	1084.	0.	98193.
1980	2	0	145	100.00	151.	186	101.00	187.	338.	198.00	1068.	0.	81692.
1980	3	0	187	100.00	185.	275	101.00	243.	428.	195.00	1063.	0.	83473.
1980	4	169	333	100.00	326.	547	101.00	565.	1061.	195.00	1061.	0.	72166.
1980	5	399	167	100.00	188.	233	101.00	305.	892.	195.00	892.	0.	50357.
1980	6	377	139	100.00	158.	161	101.00	195.	730.	195.00	730.	0.	29193.
1980	7	265	102	100.00	125.	106	101.00	82.	473.	195.00	473.	0.	17894.
1980	8	446	335	100.00	347.	436	101.00	486.	1279.	198.00	483.	0.	20955.
1980	9	488	411	100.00	418.	551	101.00	534.	1440.	201.10	692.	0.	41671.
1980	10	490	623	100.00	619.	594	101.00	649.	1758.	204.00	1150.	608.	82707.
1980	11	357	250	100.00	254.	314	101.00	300.	910.	204.00	910.	0.	62720.
1980	12	307	175	100.00	178.	226	101.00	231.	716.	204.00	716.	0.	52062.

REFERENCES

1. Loucks, D. P., Stedinger, J. R., and Haith, D. A: Water Resources Planning and Analysis. Prentice-Hall Inc., Englewood Cliffs, N. J., 1981.

2. Gablinger, M., and Loucks, D. P: "Markov Model for Flow Regulation", Journal of the Hydraulics Division, ASCE, vol. 96, No. HY1, pp. 165-181, Jan. 1970.

3. Butcher, W. S: "Stochastic Dynamic Programming for Optimum Resevoir Operation", Water Resources Bulletin, vol. 7, No. 1, pp. 115-123, Feb. 1971.

4. Klemes, V: "Discrete Representation of Storage for Stochastic Reservoir Optimization", Water Resources Research, Vol. 13, No. 1, pp. 149-158, Feb. 1977.

5. Torabi, M., and Mobasheri, F: "A Stochastic Dynamic Programmin Model for the Optimum Operation of a Multi-purpose Reservoir", Water Resources Bulletin, Vol. 9, No. 6, pp. 1089-1099, Dec. 1973.

6. Cooper L., and Cooper, M. W: Introduction to Dynamic Programming, Pergamon Press, 1981.

7. Hillier, S. F., and Lieberman, G. J: Introduction to Operations Research, Holden-Day Inc., San Francisco, 1980.

8. Jacoby, H., and Loucks, D. P: "Combined Use of Optimization and Simulation Models in River Basin Planning", Water Resources Research, Vol. 8, No. 6, pp. 1401-1414, Dec. 1972.

9. Houck, M. H., and Cohon J. L: "Sequential Explicitly Linear Programming Model. A Proposed Method for Design and Management of Multipurpose Reservoir Systems", Water Resources Reseach, Vol. 14, No. 2, pp. 161-169, April 1978.

10. Kuiper, J., and Ortolano, L: "A Dynamic Programming Simulation Strategy for the Capacity Expansion of Hydroelectric Power Systems", Water Resources Research, Vol. 9, No. 6, pp. 1497-1510, Dec. 1793.

11. Sigvaldason, O. T: "A Simulation Model for Operating a Multipurpose Multireservoir System", Water Resources Research, Vol. 12, No.2, pp. 263-278, April 1976.

12. Dudley, N., and Burt, O. R: "Stochastic Reservoir Management and System Design for Irrigation", Water Resources Research, Vol. 9, No. 3, pp. 507-522, June 1973.

13. Askew, A. J: "Chance-constrained Dynamic Programming and the Optimization of Water Resources System", Water Resources Research, Vol. 10, No. 6, pp. 1099-1106, 1974b.

14. Sniedovich, M., and Davis, D. R: "Comments on 'Chance-constrained Dynamic Programming and Optimization of Water Resources Systems' by A. J. Askew", Water Resources Research, Vol. 11, No. 6, pp. 1037-1038, 1975.

15. Rossman, L. A: "Reliability-Constrained Dynamic Programming and Randomized Release Rules in Reservoir Management", Water Resources Research, Vol. 13, No. 2, pp. 247-255, April 1977.

16. Hall, W. A., Butcher, W. S., and Esogbue, A: "Optimization of the Operation of a Multipurpose Reservoir", Water Resources Research, pp. 471-521, June 1968.

17. Mawer, P. A., and Thorn, D. A: "Improved Dynamic Programming Procedures and Their Practical Application to Water Resources Systems", Water Resources REseach, Vol. 10, No. 2, pp. 183-190, April 1974.

18. Norman, J. M., and White D. J: " A Method for Approximate Solutions to Stochastic Dynamic Programming Problems Using Expectation", Operations Research, Vol. 16, pp. 296-306, April 1968.

19. Porteus, E: "An Adjustment to the Norman-White Approach to Approximating Dynamic Programs", Operations Research, Vol. 27, pp. 1203-1207, Nov.-Dec. 1979.

20. Askew, A. J: "Optimum Reservoir Operating Policies and the Imposition of Reliability Constraint", Water Resources Research, Vol. 10, No. 1, pp. 51-56, Feb. 1974.

21. Bellman, R. E., and Dreyfus, S. E: Applied Dynamic Programming, Princeton, N. J.: Princeton University Press, 1962.

22. Howard, R: Dynamic Problem Systems, Vol. 1: Markov Models, Wiley.

23. Prekopa, A., Tamas, R., and Istvan, Z: "Serially Linked Reservoir System Design Using Stochastic Programming", Water Resources Research, Vol. 14, No. 4, pp. 672-678, 1978.

24. Loucks, D. P., and Falkson, L. M: "A Comparison of Some Dynamic, Linear and Policy Iteration Methods for Reservoir Operations", Water Resources Bulletin, Vol. 6, No. 3, pp. 384-399, May-June 1970.

25. Moran, P. A. P: "Theory of Storage", Metheun, London, 1959.

26. Doran, D.G, Savarenskiy: "An Efficient Transition Defination for Discrete State Reservoir Anlysis: The Divided Interval Technique", Water Resources Research, Vol. 11, No. 6, pp. 867-873, 1975.

27. Nemhauser G. l: Intorduction to Dynamic Programming, Jonh Wiley & Sons, Inc., New York, 1966.

28. Askew A. J: "Use of Risk Premiums in Chance-Constrained Dynamic Programming", Water Resources Research, Vol. 11, No. 6, pp. 862-866, Dec. 1975.

29. Schweig, Z., and Cole, J. A: "Optimal Control of Linked Reservoirs", Water Resources Research, Vol. 4, No. 3, pp. 479-498, June 1968.

30. Kemeny, J. G., and Snell J. L: Finite Markov Chains, Van Nostrand Co., Inc., Princeton, N. J., 1960.

31. Rosenthal, R. E: "Optimal Reservoir Management: Problems and Models", Presented at the ORSA/TIMS Annual Meeting, Colorado Springs, Colorado, Nov. 10-11-12, 1980.

32. Cochord, D. D: "A Model for Solving Multiperiod Multireservoir Water Resources Problems With Stochastic Inflows", Ph.D. Thesis, 1981.

33. Personal Communication with Mr. David Cormie, Planning Engineer, Manitoba Hydro, Winnipeg, Manitoba.