A United States Contribution to the International Hydrological Decade

IHD 1965 1974

HEC-IHD-0700

Hydrologic Engineering Methods For Water Resources Development

Volume 7
Flood Control by Reservoirs

February 1976

Approved for Public Release. Distribution Unlimited.

IHD-7

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1976	IHD Volume 7

4. TITLE AND SUBTITLE
Flood Control by Reservoirs

5. FUNDING NUMBERS

6. AUTHOR(S)
Leo R. Beard

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616-4687

8. PERFORMING ORGANIZATION REPORT NUMBER
IHD-7

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release. Distribution of this document is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This is Volume 7 of the 12 volume report prepared by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers as a contribution to the International Hydrological Decade.

Basic principles of reservoir operation for flood control are presented and procedures for establishing operation criteria are described. Topics include determination of reservoir release rates, regulation of the reservoir design flood, consideration for determining outlet and spillway regulation, determination of rule curves, and procedures for analyzing multiple-reservoir operation. The applicability of computer simulation for establishing operational criteria is discussed and several computer programs are described in the appendices.

14. SUBJECT TERMS
International Hydrological Decade, Flood Control, Reservoir Operation, Rule Curves

15. NUMBER OF PAGES
590

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

Hydrologic Engineering Methods for Water Resources Development

Volume 7
Flood Control by Reservoirs

February 1976

US Army Corps of Engineers
Institute for Water Resources
Hydrologic Engineering Center
609 Second Street
Davis, CA 95616

(530) 756-1104
(530) 756-8250 FAX
www.hec.usace.army.mil

IHD-7

FOREWORD

This volume is part of the 12-volume report entitled "Hydrologic Engineering Methods for Water Resources Development," prepared by The Hydrologic Engineering Center (HEC) as part of the U. S. Army Corps of Engineers' participation in the International Hydrological Decade. This volume discusses the basic principles that are applied in reservoir operation for flood control, and describes methods and procedures that are consistent with these principles. Emphasis is placed on selected practical methods and procedures for operating reservoirs for flood-control rather than on the underlying theory. Although many of the methods and procedures described herein have been used successfully by the Corps of Engineers, the volume should not be construed to represent the official policy or criteria of the Corps.

This volume was prepared primarily by Leo R. Beard, HEC Director until July 1972. Messrs. Bill S. Eichert (present HEC Director), Edward F. Hawkins, James McHughes, John C. Peters, and Dale R. Burnett reviewed and provided valuable assistance in preparing this volume.

CONTENTS

CONTENTS

CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction

CHAPTER 1. INTRODUCTION

Section 1.01. Purpose

The purposes of this volume are to present basic principles of reservoir operation for flood control and to describe procedures for establishing operational criteria. Topics include determination of reservoir release rates, regulation of the reservoir design flood, considerations for determining outlet and spillway regulation, determination of rule curves, and procedures for analyzing multiple-reservoir operation. The applicability of computer simulation for establishing operational criteria is discussed, and several computer programs are described in the appendixes.

Section 1.02. Basic Principles

Basic principles applied in reservoir operation for flood control are summarized briefly as follows:

a. The reservoir storage reserved for flood control should be utilized in such a manner as to maximize benefits over the life-time of the reservoir. For completed projects reservoir space allocated to flood control should be utilized to assure the protection for which the project was designed and upon which downstream interests have based their developments.

b. Reduction in flood control space requirements can sometimes be made on the basis of seasonal variation in flood potential or, if long-term forecasts are dependable (as in the case of snowmelt floods in some regions), space can be adjusted in relation to the forecast.

c. Reservoir space provided for flood control should be held empty during times when full flood potential exists, except for temporary storage of flood waters to prevent downstream flooding.

d. Whenever water is stored in flood control space, releases should be made at maximum rates that do not cause substantial damage downstream, subject to limiting controls on the rate-of-change of release and subject to unforeseen emergency conditions.

e. Reduction in target release rates when the flood hazard is low is discouraged, because such intermittent protection encourages development in low areas that can inhibit important flood releases in the future.

f. Maintenance of channel capacities and proper management of flood plains downstream of reservoirs is especially important for maintaining reservoir release capability.

g. The operation of very large outlet gates and particularly the operation of spillway gates can be extremely hazardous and should be strictly regulated by the use of emergency release rules.

The methods and guides presented in the following chapters are intended to be consistent with these principles.

Chapter 2

Controlled Reservoir Releases

CHAPTER 2. CONTROLLED RESERVOIR RELEASES

Section 2.01. Release Considerations

As discused in Volume 1, it is generally most economical and effective to make maximum releases to empty flood storage consistent with downstream conditions in order to minimize the need for valuable reservoir flood control space. Maximum feasible target flows at any downstream location are usually those that do not produce serious flood damage by inundation. The stage (elevation) at which serious damage begins can be determined from topographic map studies and field inspections. The flow corresponding to this stage is determined from a rating curve that can be constructed from observed flood stages and flows. The maximum nondamaging flow can vary seasonally, for example where damages are primarily agricultural. Where flow measurements are not available, water surface profiles for various flows may be computed, using methods described in Volume 6, and a stage-discharge curve can then be constructed. The best information on water surface profiles and inundated areas is that obtained during and immediately following actual floods where the peak flow is known and high-water marks are obtained along the damage reach.

If good observational data are not available for estimating maximum flows that are not seriously damaging, it can often be inferred that the flow exceeded in half of the years (i.e., the 2-year flood as determined from a flow frequency study) is approximately the maximum flow that is not seriously damaging. This is because those who are damaged soon learn to avoid frequent damage if it is serious. It should be noted, however, that reservoir control often reduces the frequency of such flows, and the tendency to use flood-prone areas unwisely must be controlled by regulations, particularly when the flood-control effectiveness of reservoirs depends on the availability of downstream channel capacity.

In a planning study in which the storage and release capacity and operation rules for a flood control reservoir are being determined, allowance must be made for imperfection in operation as discussed in Volume 1. Experience in the western United States has shown that for design purposes, the target flow at damage locations should be about 80 percent of the actual flow above which significant damages occur. Then, in actual operation, every effort should be made to utilize effectively all of the flow capacity. If this is done, the effectiveness of actual operation can reasonably approach the design objectives.

Where a reservoir is operated to regulate floods at locations a considerable distance downstream, allowance must be made for local runoff that will occur downstream of the dam and above the damage area. The release from the reservoir is determined as the difference between the target flow and the maximum local runoff forecasted to occur during the times when a portion of the current releases will reach the damage area. Maximum forecasted local runoff in the application is the "best forecast" amount plus a contingency allowance. This contingency allowance usually ranges from 25 to 100 percent of the local runoff during rain floods, because forecast accuracy for rapidly changing flow is rather poor. The amount of contingency depends on the consequences of exceeding target flows. If these are serious, as where levees exist, the contingency allowance should be high in order to avoid a preventable disaster.

The importance of coordinating releases to forecasted local inflows at a downstream damage location depends to some extent on the relation of flood control storage to release rate. Where storage is large and the amount of water that can be released during the flood inflow period is a small part of the design flood volume, it may not be worthwhile to take an unnecessary chance of exceeding safe flows downstream. On the other hand, where the release during floods is large and constitutes a major part of the design flood volume, failure to make maximum feasible releases during flood inflow periods could be disastrous.

Section 2.02. Use of Index Flows to Forecast Local Runoff

Experience has demonstrated that forecasts of runoff based on measured rainfall are not highly dependable and that the use of forecasted rainfall for flood operations is subject to major uncertainty. Where forecasts of local runoff downstream of a reservoir must be made for release scheduling, it is usually best to use river-stage reports from an index location within the local tributary area as an indicator of the total runoff. If index-station flows at the time of a particular reservoir release correlate with local runoff that reaches the damage center as late or later than the reservoir release does, a relationship between index flow and total local flow can be developed, along with reliability criteria, for use in directly establishing safe releases. This approach is valid even if the index flows are only a small fraction of the total local flows. A simple method is as follows:

a. Plot observed hydrographs for the index station and corresponding hydrographs of local runoff at the damage center for as many historical floods as possible. A schematic representation of a local flow area and an index area is shown in fig. 2.01a.

b. Determine a time of flood wave travel, t, from the reservoir to the damage center. Shift the local flow hydrographs a time period t earlier. This is illustrated in fig. 2.01b.

c. Shift the index-flow hydrographs so that peaks are coincident with the peaks of the translated local flow hydrographs. The length of time an index hydrograph is shifted is the "time of advance warning," T, as illustrated in fig. 2.01b. If T is negative, the index flow occurs too late to provide a good warning, but index flow can still be used to some advantage in the same manner. Adopt a "representative" value of T for subsequent steps in the procedure.

d. For each flood, plot simultaneous values at frequent intervals, of the two translated hydrographs from steps "b" and "c". The two translated hydrographs are shown dashed in fig. 2.01b, and plotted points are shown in fig. 2.01c. Draw a line enveloping the highest values of damage-center local flows so that the line is smooth and passes through the origin, as in fig. 2.01c.

e. Construct a "release curve" from this "envelope curve" by plotting the difference between the target flow and the envelope value of local flow against the index flow, as in fig. 2.01d. Fig. 2.01d can

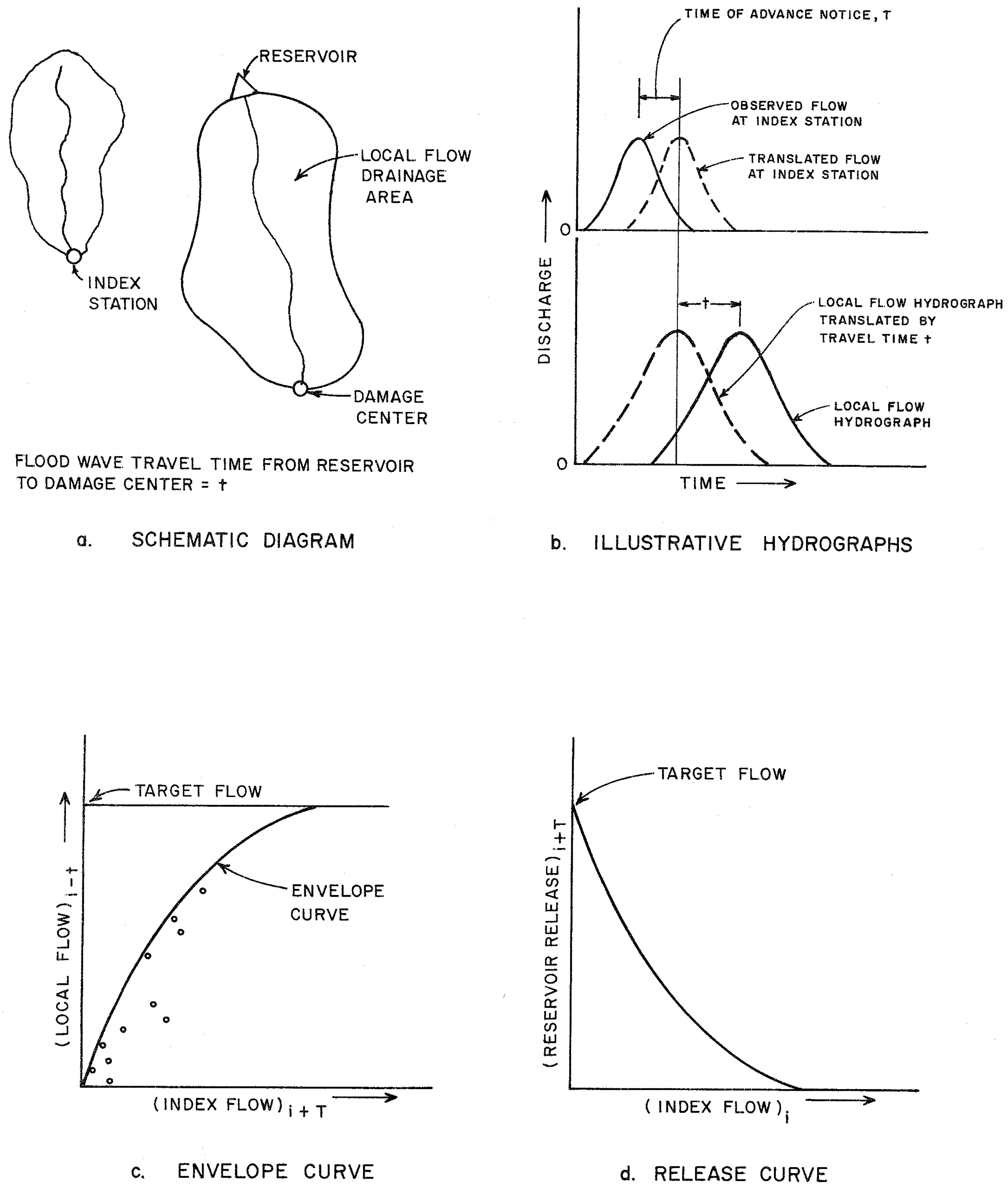


Fig. 2.01. Development of reservoir release rate

then be used to determine the flood control release to make a time period T following a given index flow.

In order to understand this procedure, it is important to remember that:

<u>a</u>. There is a delay, t, between the time that releases are made and the time that they reach the damage center. It is therefore necessary to match current releases with local flows expected to occur at the damage center at a time t later. A refinement to the procedure would be to account for routing effects by obtaining the translated local flows by a reverse routing process rather than pure lagging.

<u>b</u>. Maximum correlation between some index-station flows and local flows is obtained if local flows are offset in time so that the peak local and peak index flows coincide. If this offset time is greater than t, there will be some advance warning time using index flows to forecast local flows t time periods later. If this offset time is less than t, maximum correlation between local and index flows must be sacrificed in order to forecast early enough, so index flows are correlated with local flows that occur t later, even though higher correlation could be obtained with some different offset.

Where records are not available for the index station or for computing local runoff, an approximate relation can be obtained in the same manner if balanced hypothetical floods for the index station and local runoff were computed for several sizes of floods using procedures described in Volume 5. An error allowance for forecasting local flow from index flow should be added to the local flow. The amount would depend on the suitability of the index station and the consequences of exceeding target flows at the damage center, and would range typically between 25 and 100 percent of the forecasted local flows.

Where more than one downstream damage center must be protected on a forecast basis by a reservoir, this entire process is repeated for each damage center, and the smallest current allowable release is adopted.

Section 2.03. Computer-Aided Forecast Procedures

In the index approach just described, reservoir releases are based on runoff that is occurring at an "index" station, and use is not made of precipitation information. Computer-aided forecast procedures currently (1975) available in the United States employ sophisticated precipitation-runoff models that can utilize precipitation forecasts in determining streamflow forecasts. Three computer programs that are used on an operational basis for forecasting streamflows are described in references 1, 4, and 11.

In order to determine reservoir releases for planning studies where flows throughout the basin are known, or for real-time flood operations where forecasted flows are developed by an external procedure, the procedures employed in computer program HEC-5C, Simulation of Flood Control and Conservation Systems, have been found to be useful. Exhibit 2 of Appendix 1 illustrates the procedure.

Chapter 3

Regulation of Reservoir Design Flood

CHAPTER 3. REGULATION OF RESERVOIR DESIGN FLOOD

In cases where a specific observed or hypothetical reservoir design flood has been adopted as a basis for establishing flood control space, the amount of space required is determined by performing a routing (an operation study) of that flood. Routings can be performed by manual methods or by using a computer program such as HEC-5C. The initial storage in the reservoir used in such a routing should be the maximum storage that could reasonably be anticipated at the start of a major flood. In general, this would be storage at the top of the conservation pool, which includes storage required for all purposes other than flood control (including a reserve for sedimentation). No storage should exist in the flood control space at the start of a reservoir design flood, because this flood should include all periods of heavy runoff that would cause storage in the flood control space and affect the maximum reservoir stage during that flood.

Releases made during the reservoir design flood are controlled by outlet capacity and by target flows downstream of the reservoir. During those periods when the controlling constraint is downstream of the reservoir, the operation study is performed by adding the inflow volume during any computation interval to the storage at the start of that interval and subtracting the average release during that interval that would be permitted by downstream controls. During times when releases are controlled by outlet capacity or are otherwise a unique function of storage, routing is performed by use of storage-indication curves, because outflow changes during the computation interval and must be estimated at the start of the interval. The general routing procedure is as follows:

a. Compute the average reservoir inflow, including rainfall on the lake, for each computation interval of the flood.

b. If outflow is strictly a function of storage during any portion of the flood, prepare a storage-indication curve by plotting outflow against storage indication. Storage-indication is equal to half of the outflow plus all of the storage, where storage is expressed in volume units that represent one unit of outflow continuing for one computation interval of time. This is illustrated in table 3.01 and fig. 3.01.

c. Where outflow is strictly a function of storage, start with the storage indication value corresponding to the specified initial storage, subtract the corresponding outflow and add the average inflow for the computation interval to obtain storage indication for the end of the computation interval. A value of outflow for the end of the interval is then read from the storage-indication curve. This step is repeated for each interval, starting with the new storage-indication value, as illustrated in table 3.02. Fig. 3.02 illustrates the routing graphically.

d. Where outflow depends on conditions downstream, determine the average outflow for each current interval in accordance with the regulations, subtract from initial storage for the interval and add average inflow for the interval to obtain storage at the end of the interval. Storage must be expressed in volume units corresponding to one unit of outflow (and inflow) continuing for one interval. This step is repeated for each interval of the flood.

e. The outflow hydrograph obtained in this manner should be routed to downstream damage locations and combined with local runoff to evaluate effects of design-flood regulation. Generally the outflow determination for downstream conditions requires an iterative process of trial releases and routing to determine the maximum release that can be made without causing flooding. Examples of a hand computation and computer solution for an operation study for a single reservoir operating for two downstream control points is shown in Exhibit 2 of the HEC-5C Users Manual (Appendix 1).

Table 3.01. Computation of storage indication

Elevation	Storage		Outflow	Storage-Indication
(meters)	(million m^3)	(cms-2hr)	(cms)	(cms-2hr)
128	778	108,000	0	108,000
130	864	120,000	2,000	121,000
132	950	132,000	8,000	136,000
134	1,037	144,000	18,000	153,000
136	1,123	156,000	30,000	171,000
138	1,210	168,000	44,000	190,000

If the results of the reservoir operation study for a given design are not satisfactory, either because flows are too high or reservoir storage is not fully utilized, the reservoir size, outlet capacity or operation method should be changed, and a new routing performed. This

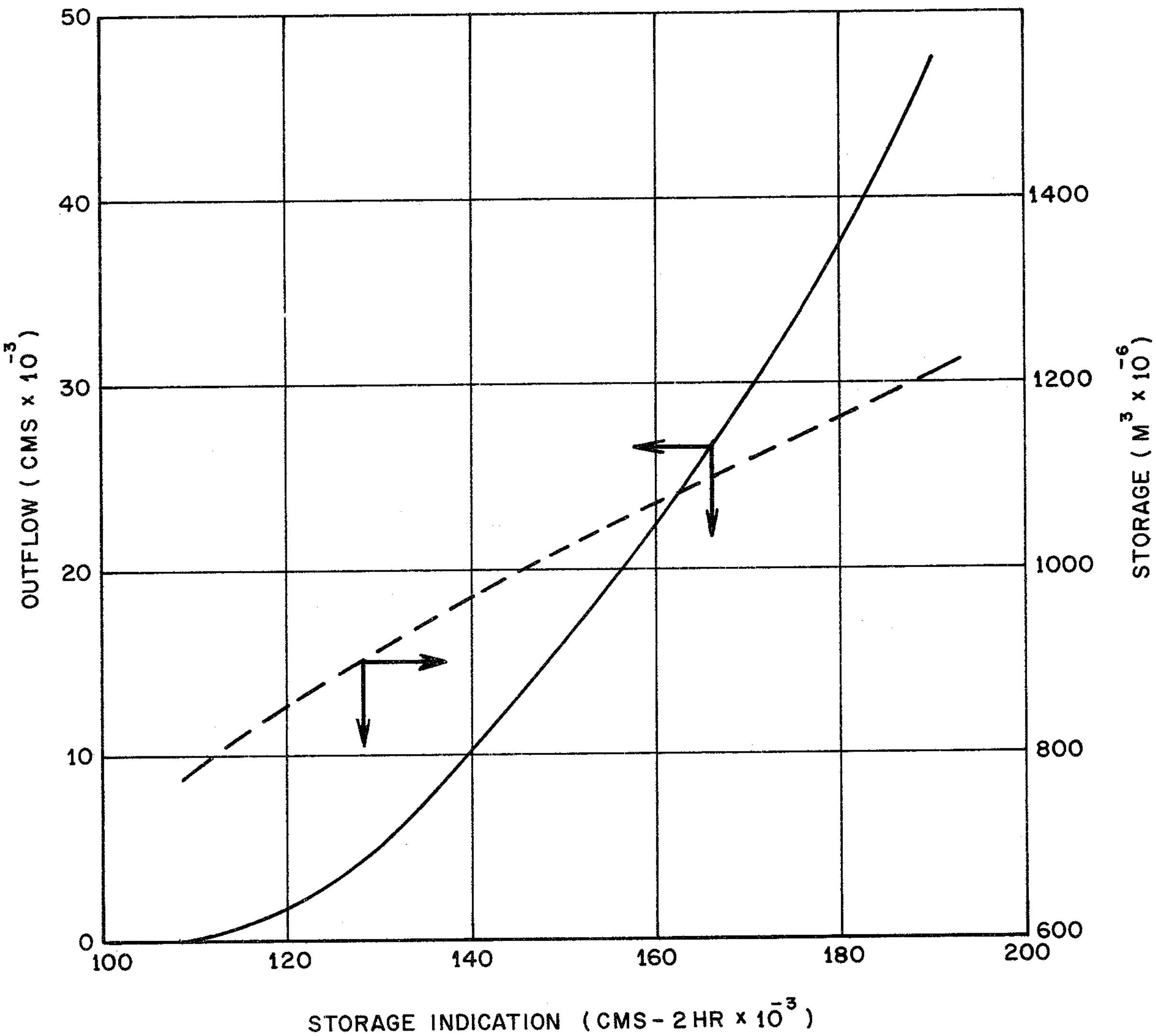


Fig. 3.01. Storage indication curve

Table 3.02. Reservoir routing

Time (hours)	Average Inflow (cms)	End-of-Period Storage Indication (cms-2 hr)	End-of-Period Outflow (cms)	End-of-Period Storage (million m^3)
		108,000	0	778
0-2	20,000	128,000	4,500	906
2-4	30,000	153,500	18,500	1,040
4-6	50,000	185,000	40,000	1,188
6-8	45,000	190,000	44,000	1,210
8-10	30,000	176,000	34,000	1,146

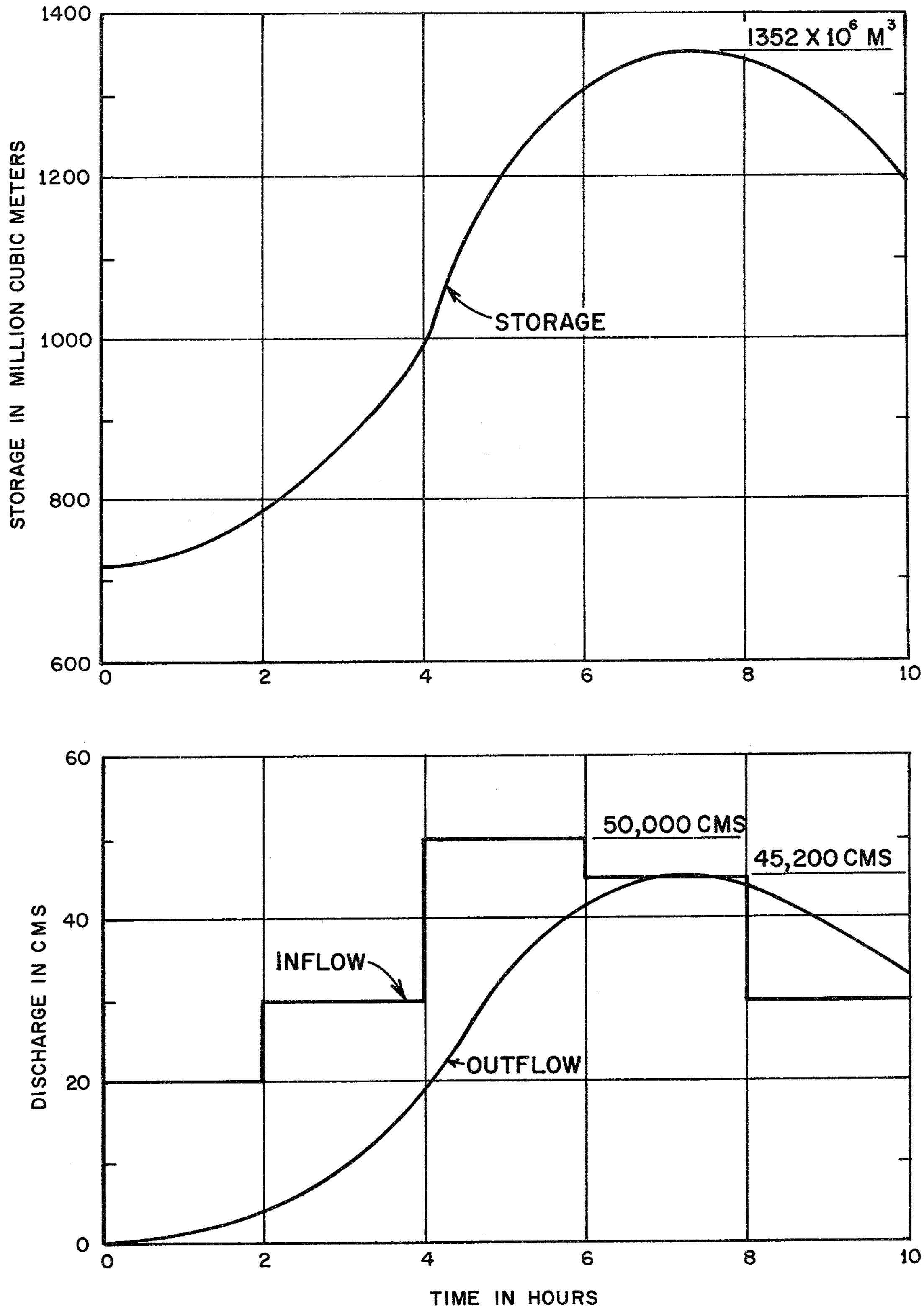


Fig. 3.02. Operational hydrographs of reservoir routing - uncontrolled spillway

process is repeated until a design is obtained that will provide a satisfactory degree of protection at minimum cost. In this procedure, a graphical representation of pertinent flows such as is illustrated in fig. 3.02 can be helpful in estimating how changes in release schedules would change storage requirements or how changes in storage capacity would change the capability to control releases. Changes in downstream flow volumes must correspond to changes in the volume of water stored or released from the reservoir.

Chapter 4

Regulation of Expected Floods

CHAPTER 4. REGULATION OF EXPECTED FLOODS

The degree of flood protection provided by a reservoir may vary seasonally or stochastically with varying hydrologic conditions. For example, when flood control requirements conflict seriously with other project functions, it may be advisable to compromise and reduce the degree of flood protection during certain periods of the year. As another example, an extended period of drought could result in substantial empty space within the conservation pool at the start of a major flood, in which case a higher degree of protection than usual would be provided. In order to evaluate any plan of operation, it is necessary to integrate the effects of all combinations of conditions and potential flood magnitudes that can prevail.

A complete evaluation of a plan of operation could theoretically be made if the operation of the reservoir were studied in detail under conditions prevailing during hundreds of years, presuming that all of the important combinations of initial conditions, downstream conditions and inflow conditions would be adequately represented in such a long period of time. However, it is not ordinarily feasible to perform such extensive computations, and some means must therefore be employed for approximating the results that would be obtained.

The most common method of evaluation is to route all major historical floods through the reservoir for one or more conditions of initial storage. One assumed condition might be that the reservoir flood space is empty at the beginning of the flood. Another procedure would be to base the starting storage on the results of monthly operation studies.

Where reservoir conditions at the start of each flood are not essentially constant as in the case of a reservoir operated for flood control only, it is sometimes satisfactory to select a typical flood pattern for inflows and one for local flows downstream and to route eight or ten sizes of floods (ratios of the typical flood hydrographs) through the reservoir and downstream, using techniques described in the preceding chapter. The frequency of occurrence of each regulated flood is considered to correspond to the frequency of occurrence of the corresponding unregulated flood. This rule is satisfactory as long as the pattern used is reasonably typical of the various flood patterns that occur at the location. Where different types of floods occur, such as snowmelt, general rain floods and cloudburst floods, it would be necessary to perform this operation for each type of flood. Separate frequency curves of unregulated flows would be required for each type of flood.

Where reservoir conditions at the start of each flood can be materially different, the above set or sets of flood routings should be repeated for each of various starting conditions. This would give a frequency curve of regulated flows for each starting condition. These must then be combined into a single frequency curve of regulated flows as follows:

a. Determine from a monthly multipurpose operation study the proportion of time that each starting condition (range of initial storage) will prevail during the flood season.

b. For each of various specified magnitudes of regulated flows, multiply the frequency indicated for each starting condition by the proportion of time that the starting condition prevails.

c. Add these products to obtain the frequency of the specified flow magnitude.

This procedure for obtaining a frequency curve is illustrated in Section 8.06 of Volume 3.

The computer program HEC-5C described in Appendix 1, can be used to perform monthly multipurpose reservoir routings and short interval flood routings during the same computer run. The program can also be used for performing reservoir system flood operation studies for up to nine ratios of any number of flood patterns, and can compute regulated frequency curves and expected average annual flood damage with and without the reservoir systems.

Chapter 5

Outlet Capacities

CHAPTER 5. OUTLET CAPACITIES

Outlets and gates provided at reservoirs should be adequate to perform the services for which the reservoir is to be operated. These should include routine operation requirements, potential changes in operation functions and objectives, and requirements for project servicing and safety. In the last category are emergency gates for closing outlets for repairs to the main service gates, and gates which provide outlet capacity near the bottom of the reservoir to drain the reservoir to the extent necessary for emergency repairs.

The outlet capacity usable for functional operation purposes is that which can reasonably be depended upon when needed. It must be ascertained that gates can be operated safely at partial or full opening, as might be necessary, under all hydraulic heads that can prevail. If the discharge capacity of hydroelectric turbines is to be counted upon for other purposes, it is necessary that they be operable when needed, regardless of variations in power load.

The discharge capacity of outlets is computed in accordance with the general equation:

$$Q = CAH^{1/2}$$

where:

Q = discharge rate

C = coefficient of discharge and unit conversion

A = cross-sectional area

H = vertical distance from static water level to centroid of A or to downstream tailwater, if higher

Values for the coefficient C are obtainable from standard hydraulics handbooks, but model tests for evaluating C should be made where unusual conditions exist and discharge determinations are critical, particularly for partial gate openings. Reference 8 provides information on calculation of rating curves for outlet works. Where possible, outlet discharge rating curves should be checked by prototype measurements downstream as soon after project construction as is feasible.

Where very large release capacities are required for flood control it might not be economically feasible to follow the normal procedure of providing outlet capacity for full flood-control releases when the reservoir stage is at the top of the conservation pool. If full release capacity is not provided, it should be remembered that reduced outlet capacity must be accompanied by increased storage capacity, or else the flood control effectiveness will be reduced. The proper balance among outlet capacity, storage capacity, and degree of flood protection provided can be obtained through studies of costs and benefits and consideration of other factors such as safety and minimum protection standards. Such studies would include comprehensive flood routings as discussed in Chapter 4.

There are occasions where local inflows above downstream damage locations are so large as to severely restrict the releases that can safely be made from the reservoir during critical flood periods. In such cases, outlet capacity substantially below downstream channel capacities might be adequate. In order to select the best release capacity, comprehensive flood routings discussed above should include typical sequences of floods long enough to assure that expected sequences of floods can be adequately regulated.

In the case of a flood control reservoir emptying into a downstream flood control reservoir, the outlet capacity of the upstream reservoir should be sufficient to assure that its flood control space can be emptied during the period when high tailwater exists due to water being stored in the flood control space at the downstream reservoir, under any reasonable distribution of inflows to the two reservoirs. This will assure that the reservoir system can operate efficiently by making full required releases from the downstream reservoir whenever water is stored in flood control space at either reservoir.

In the case of two flood control reservoirs on separate tributaries above the same damage center, the outlet capacity of each should be large enough to supply target flows at the damage center with minimum expected simultaneous release from the other reservoir. Again, this provision is necessary to assure the capability of making full flood control target flows at the damage location whenever water is in flood control space at either reservoir. This is subject to provisions discussed above for cases where local runoff below the reservoirs and above the damage center is so large as to warrant smaller outlet capacities.

Chapter 6

Spillway Operation

CHAPTER 6. SPILLWAY OPERATION

Section 6.01. Considerations for Spillway Operation

The primary purpose of a spillway is to prevent overtopping of the dam by flood flows in excess of those which the project is designed to regulate, up to the spillway design flood. There are other purposes for which a spillway may be used, however. For example, gates may be added to an existing spillway to permit storage of water above the spillway crest level during periods when it is safe to do so. It is sometimes desirable to close gates on the outlet works to take advantage of the limited capacity of the spillway under low heads and thus prevent downstream damage. This is only feasible, of course, if the flood does not greatly exceed project design magnitudes. Whenever the spillway is used for such secondary purposes, however, every care must be exercised to assure that the gates can and would be operated so as to make the full capacity of the spillway and outlets available when needed for protection of the structure.

The size and characteristics of a spillway are based on economic and operation studies of a spillway design flood. In the case of projects where exceeding the spillway capacity would result in a major disaster, it is important to provide a large enough spillway to pass the probable maximum flood (described in Volume 5) without major structural failure. In other cases, a smaller spillway design flood might be satisfactory. The final design of the spillway should be such that it will safely pass the spillway design flood occurring at a time when the reservoir is as full as could occur in advance of such a flood, adhering to the specific rules by which the project would be operated under such conditions. The spillway operation must not be dependent on communications that are subject to failure or on expert analysis that might not be available at the time.

During floods that make use of the spillway and result in downstream flows that are damaging, the following precautions are necessary:

a. Outlet and spillway gates should not be opened so rapidly that damaging flows downstream will be larger than would occur without the project.

b. Opening of gates must start early enough to allow an orderly opening of the gates to their full capacity without storing water above the maximum safe level in the reservoir.

c. Damaging flows should not be released before it is certain that the flood cannot be completely controlled, but should be released at a specified rate as an emergency measure as early as is feasible after it is certain the flows of that magnitude or larger are inevitable and would have occurred by that time without the project.

Induced surcharge operation may be used to exercise partial control over outflow rates after the reservoir has filled to the static-full-pool level. Induced surcharge storage is storage above the static-full-pool. Regulation is accomplished by raising all gates by small increments, forcing into surcharge storage all inflow in excess of the discharge capacity of the spillway with the gates at selected openings. The elevation attained and volume of induced surcharge used will vary with the volume and rate of reservoir inflow in individual floods and the exact schedule of gate operations in each case. The maximum elevation of induced surcharge that is practicable to provide for in the design of projects involving gated spillways usually is limited to approximately 1 to 3 meters.

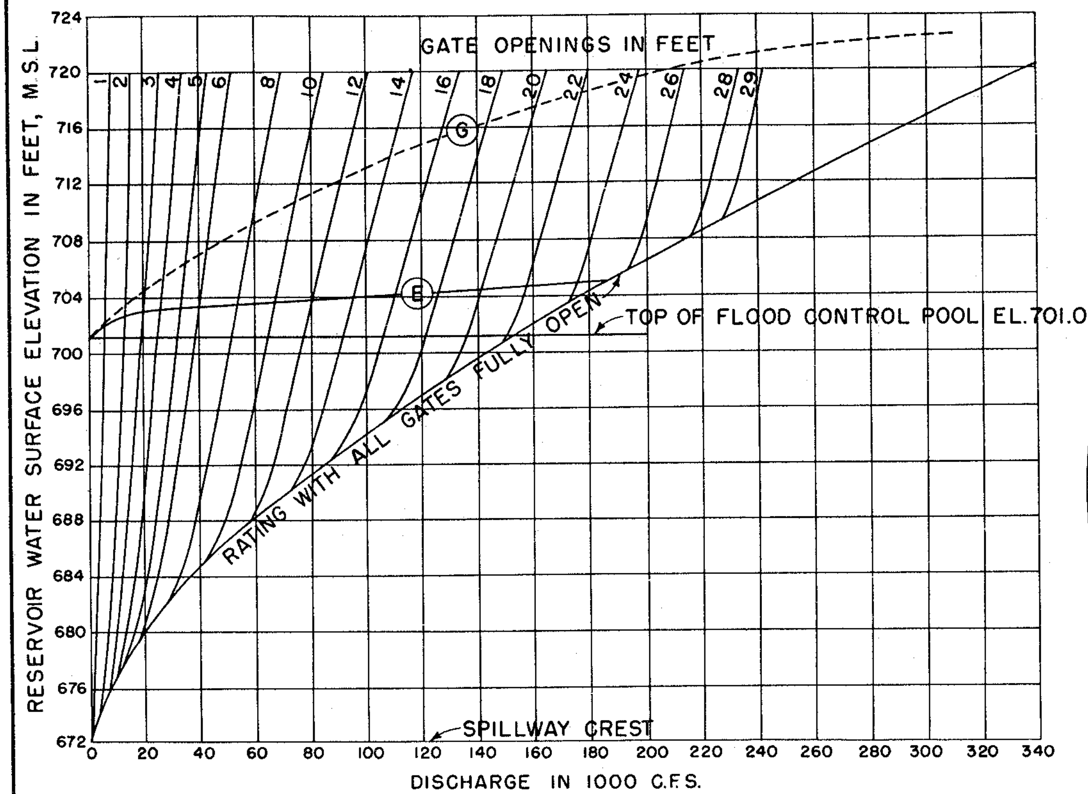
Section 6.02. Development of Emergency Release Schedules

In order to assure that the project operation will be able to comply with necessary precautions under extreme flood conditions, it is advisable to provide an emergency release diagram that uses only information on reservoir data immediately available to the operator. Such an operation diagram is illustrated in fig. 6.04 and is developed as follows:

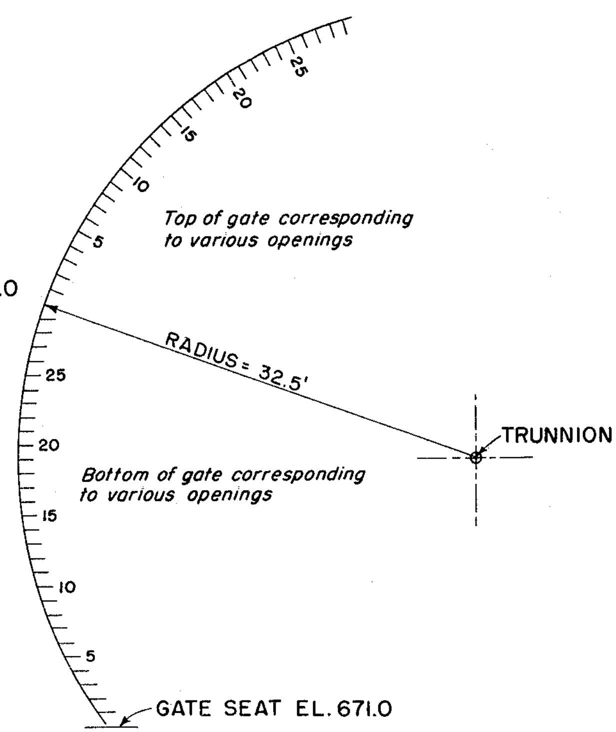
a. Develop a set of spillway-rating curves which shows the discharge that would occur as all spillway gates are raised collectively by successive increments of about 1 foot (.3 meter) until fully opened. A set of curves is shown in fig. 6.01.

b. Construct an "induced surcharge envelope curve" from a point corresponding to the nondamaging flood control release at the static-full-pool elevation to the free discharge capacity of the spillway corresponding to the elevation at which all gates must be fully opened. This is illustrated by curve E, fig. 6.01. A straight-line connection would assure the minimum rate of increase in spillway discharge under critical flood conditions, and may be the proper selection in some cases. However, curvature as illustrated in fig. 6.01 permits a lower release

Fig. 6.01



SPILLWAY RATING CURVES



TAINTER GATE DIAGRAM

NOTES:

Spillway equipped with seven 40ft. x 29ft. tainter gates.
All gates are assumed to open uniformly.
Gate openings represent vertical distance of lower edge above gate seat.
Curves of partial gate openings were estimated from model tests of similar structures.
Curve (G) corresponds to top of the gates at various openings.
Curve (E) represents a limiting relation of gate opening and reservoir level.
When reservoir level corresponding to a given gate setting is below the (E) curve, outflow is regulated by the size of gate opening not to exceed natural flow conditions at the dam site.

GATED SPILLWAY DISCHARGE CHARACTERISTICS

rate in the lower surcharge ranges which would be the most frequently utilized. The minimum permissible slope of the line at the higher elevations is governed by the rate of increase in spillway discharge that may be considered acceptable during infrequent and extraordinary floods.

c. Analyze recession characteristics of inflow hydrographs to obtain a recession constant that will be used in predicting a minimum inflow volume that can be expected when only reservoir elevation and the rate of rise of reservoir elevation are known. For conservative results the assumed recession curve should be somewhat steeper than the average observed recession and normally can be patterned after the spillway-design flood recession. The recession constant can be obtained by plotting the recession curve as a straight line on semilog paper, with the flow on a logarithmic scale and time on an arithmetic scale. The recession constant, T, is defined as the time required for the discharge to decrease from any value, say Q_A, to a value Q_B, where Q_B equals $Q_A/2.7$.

d. A relationship to compute the volume of water that must be stored for a hydrograph receded from an initial flow to a constant outflow can be derived from continuity considerations. Consider fig. 6.02,

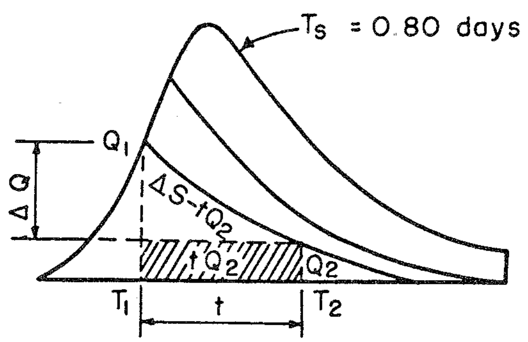


Fig. 6.02. Schematic hydrograph

which schematically illustrates terms to be used in solving for the volumes to be stored, S_A. In the fig. 6.02, Q_1 represents the inflow and Q_2 represents the constant outflow. The recession constant, T_s , may be defined as

$$T_s = \frac{\Delta S}{\Delta Q} = \frac{\frac{S_A}{2} + Q_2 t}{Q_1 - Q_2} = \frac{S_A + 2Q_2 t}{2(Q_1 - Q_2)} \qquad (6\text{-}1)$$

then,

$$t = T_2 - T_1 = -T_s \log_e \frac{Q_2}{Q_1} = T_s \log_e \frac{Q_1}{Q_2} \qquad (6\text{-}2)$$

Substituting (6-2) into (6-1) and rearranging

$$S_A = 2T_s \left(Q_1 - Q_2 - Q_2 \log_e \frac{Q_1}{Q_2}\right)$$

$$= 2T_s \left[Q_1 - Q_2 \left(1 + \log_e \frac{Q_1}{Q_2}\right)\right] \qquad (6\text{-}3)$$

For each of various inflow rates and for each of various outflow rates, compute the volume of water that must be stored, S_A, using equation 6-3. Then determine pool levels by subtracting S_A from the storage value for the given outflow as defined by the "induced surcharge envelope curve." The computations are illustrated in table 6.01. The pool levels thus determined represent the maximum pool levels that should be permitted for the corresponding inflow and release rates.

e. Obtain a family of regulation curves by plotting the pool levels corresponding to various outflows using inflow as a parameter. The family of curves is shown in fig. 6.03.

TABLE 6.01

Computations for Spillway Gate Regulation Schedule

Spillway gates: 40 x 26 ft
Spillway crest elev: 835
T_s=0.67

Equation: $S_A=2T_s[Q_1-Q_2(1+\log_e Q_1/Q_2)]$, where at a given instant Q_1= Inflow (c.f.s.), Q_2= Outflow (c.f.s.), S_A= Available storage (acre-ft.)= Limiting Surcharge storage (S_s)—Actual storage (S_I), and T_s= Adopted inflow recession constant (days)

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
Q_1 (1,000 c.f.s.)	Q_1/Q_2	$1+\log_e Q_1/Q_2$	$Q_2\times$col. 3 (1,000 c.f.s.)	K= col. 1−col. 4 (1,000 c.f.s.)	S_A= $2T_s\times$col. 5 (1,000 acre-ft.)	S_I= S_s−col. 6 (1,000 acre-ft.)	Pool elevation
	Q_2=0				S_s=660.5		
				0	0.0	660.5	859.5
10	----------	----------	0.0	10	13.4	647.1	858.8
20	----------	----------	----------	20	26.8	633.7	858.1
30	----------	----------	----------	30	40.2	620.3	857.3
40	----------	----------	----------	40	53.6	606.9	856.6
	Q_2=10				S_s=675.9		
10	1.00	1.000	10.0	0.0	0.0	675.9	860.3
20	2.00	1.693	16.9	3.1	4.2	671.7	860.1
30	3.00	2.099	21.0	9.0	12.1	663.8	859.7
40	4.00	2.386	23.9	16.1	21.6	654.3	859.2
50	5.00	2.609	26.1	23.9	32.0	643.9	858.6
	Q_2=20				S_s=687.8		
20	1.00	1.000	20.0	0.0	0.0	687.8	860.9
30	1.50	1.405	28.1	1.9	2.5	685.3	860.8
40	2.00	1.693	33.9	6.1	8.2	679.6	860.5
50	2.50	1.916	38.3	11.7	15.7	672.1	860.1
60	3.00	2.099	42.0	18.0	24.1	663.7	859.7
70	3.50	2.253	45.1	24.9	33.4	654.4	859.2
	Q_2=30				S_s=700.3		
30	1.00	1.000	30.0	0.0	0.0	700.3	861.5
40	1.33	1.285	38.6	1.4	1.9	698.4	861.4
50	1.67	1.513	45.4	4.7	6.3	694.0	861.2
60	2.00	1.693	50.8	9.2	12.3	688.0	860.9
70	2.33	1.846	55.4	14.6	19.6	680.7	860.5
80	2.67	1.982	59.5	20.6	27.6	672.7	860.1
90	3.00	2.099	63.0	27.0	36.2	664.1	859.7
	Q_2=40				S_s=715.4		
40	1.00	1.000	40.0	0.0	0.0	715.4	862.2
50	1.25	1.223	48.9	1.1	1.5	715.9	862.1
60	1.50	1.405	56.2	3.8	5.1	710.3	862.0
70	1.75	1.560	62.4	7.6	10.2	705.2	861.7
80	2.00	1.693	67.7	12.3	16.5	698.9	861.4
100	2.50	1.916	76.6	23.3	31.2	684.2	860.7
120	3.00	2.099	84.0	36.1	48.4	667.0	859.8
140	3.50	2.253	90.1	49.9	66.9	648.5	858.9

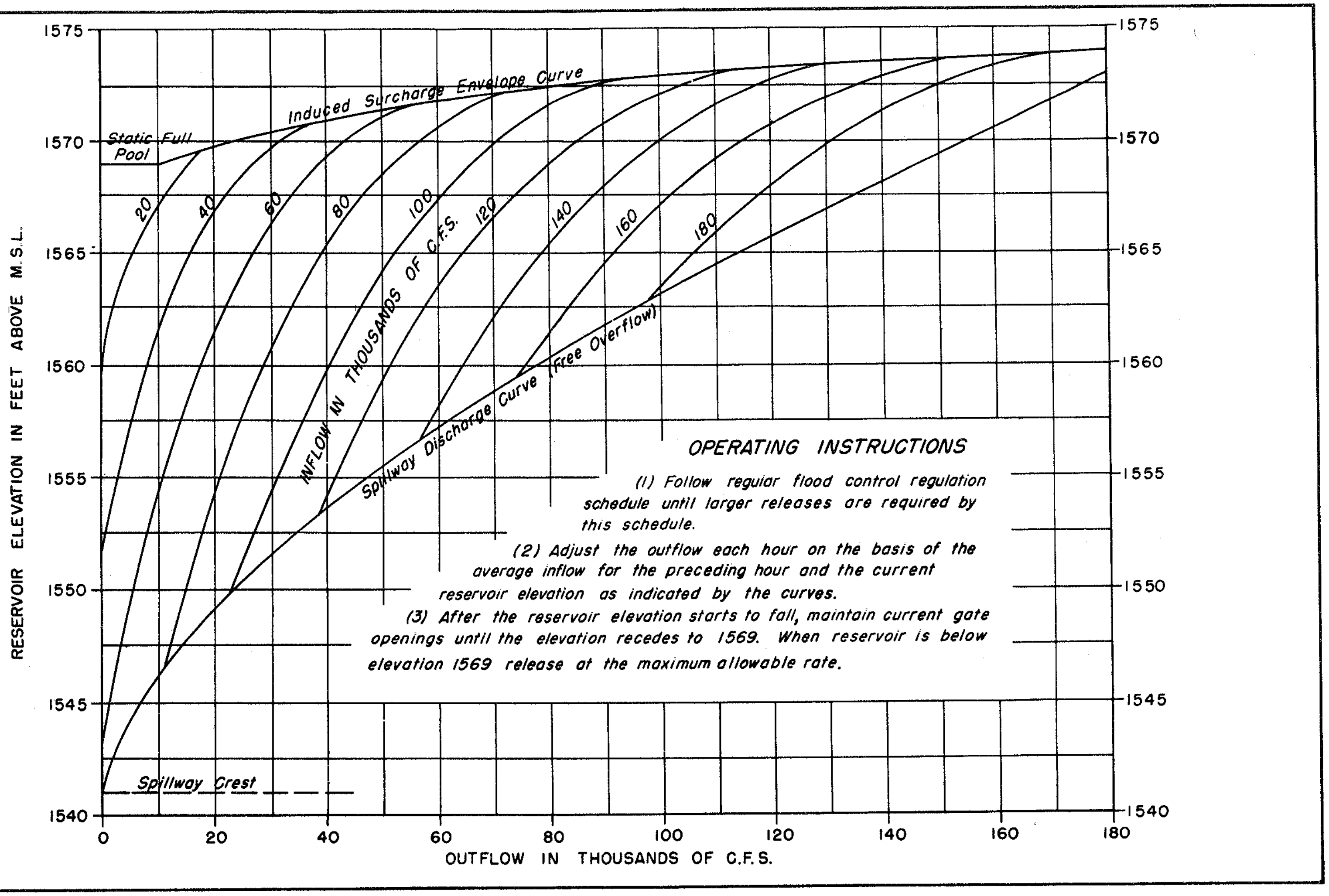


Fig. 6.03. Spillway gate regulation curves based on inflow

f. A family of curves such as those shown in fig. 6.03 are appropriate for use in a central office, but relationships to be used as an emergency operation schedule for damtenders are more directly usable if the rate of rise of reservoir level is substituted for the inflow. This is readily accomplished by obtaining the difference between the volume of inflow and outflow for a selected time interval and expressing the volume as a rate of rise for any particular reservoir elevation. A typical family of curves is shown in fig. 6.04. The time interval to be used as a basis for determining rate of rise should be based on a consideration of the reservoir and drainage basin characteristics, with 1 to 3 hours being typical. Adjustment in gate openings at 1- or 2-hour intervals is adequate for most projects.

A computer program Spillway Gate Regulation Curve, described in Appendix 5, has been developed for computing gate regulation schedule curves for a reservoir utilizing area-capacity curves, an induced surcharge envelope curve, and a constant recession constant, T_s.

Section 6.03. Initial Reservoir Level

The spillway discharge capacity and peak reservoir level likely to be attained during the spillway design flood will be governed by,

a. The spillway design flood inflow hydrograph.

b. The reservoir level at the beginning of the spillway design flood inflow.

c. The plan of reservoir regulation.

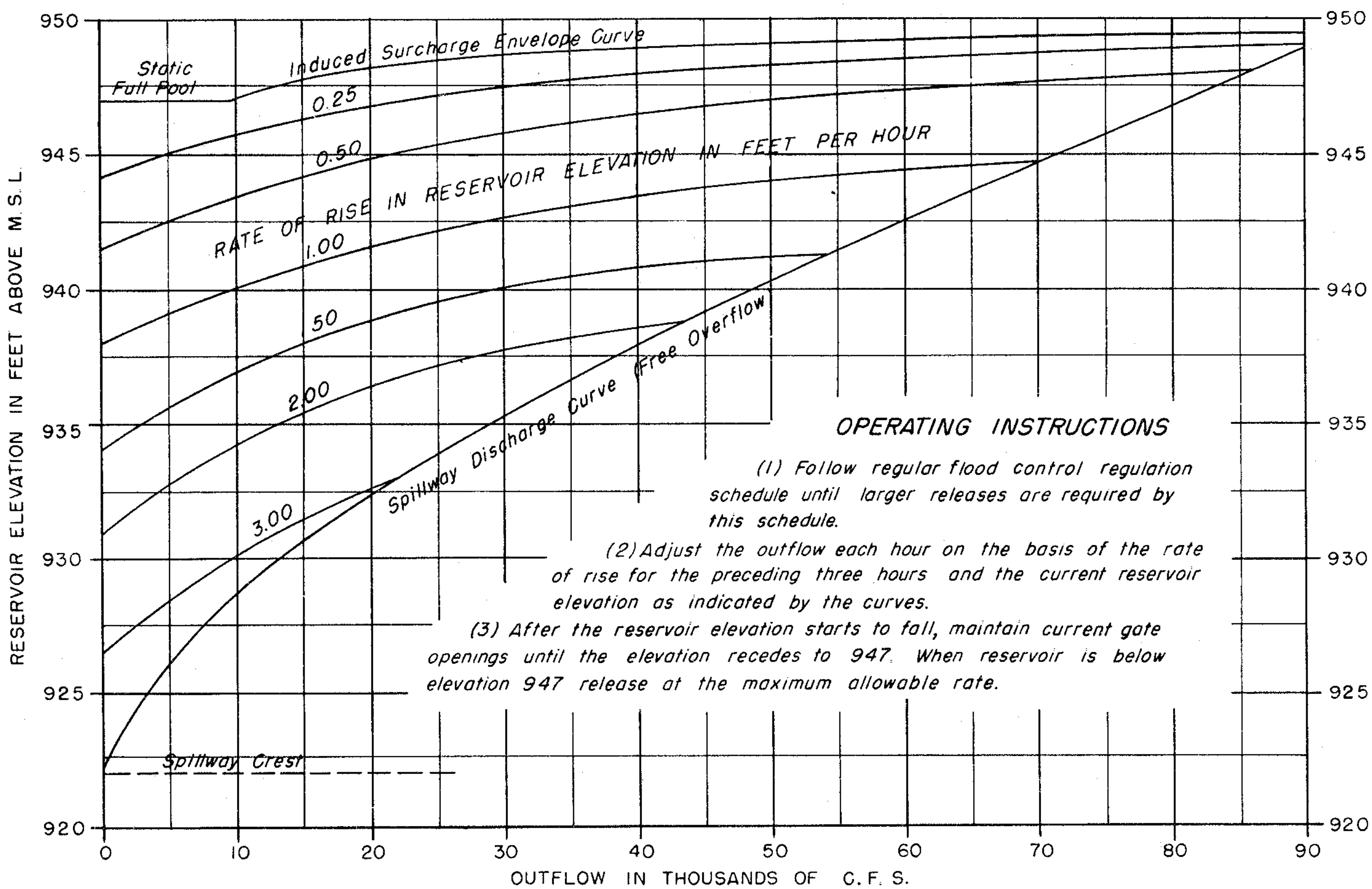


Fig. 6.04. Spillway gate regulation curves based on rate of rise

If the flood control space in the reservoir below the "normal full pool elevation" (top of flood control pool) is relatively large in proportion to the spillway design flood volume, the initial pool level assumed in flood routing studies can have a major influence on estimates of spillway discharge requirements and surcharge heights. Some considerations in selecting initial stages are quoted below from Corps of Engineers manuals.

As a general rule there is no reliable rational way of estimating the initial reservoir level that is likely to prevail at the beginning of the spillway design flood, except when the storage space is so small as to assure frequent filling. If a long period of streamflow records is available, hypothetical reservoir regulation studies will provide some index to reservoir elevation probabilities, but even these computed relations may be greatly altered in the future if changing conditions result in substantial alterations in the reservoir regulation plan (as is often the case). In addition, reallocations of flood control space to some other use in the future may result in higher pool levels at the beginning of the spillway design flood. In any case, an unusual sequence of floods can result in filling all or a major portion of the flood control space in a reservoir immediately before the beginning of the spillway design flood.

In view of the uncertainties involved in estimating initial reservoir levels that might reasonably be expected to prevail at the beginning of the spillway design flood, it has been common practice in studies prepared by the Corps of Engineers to assume the reservoir is initially filled to the "normal full pool level" if routing of representative major floods of record, or the hypothetical Standard Project Flood (occurring 5 days in advance of the spillway design flood), shows that such a level (or higher) might prevail at the time the spillway design flood occurs. If the spillway design flood estimate is associated with a particular season, the determination of initial pool level would consider flood conditions on comparable dates.

In many instances the assumption of initial reservoir levels corresponding to arbitrarily selected percentages of the flood control capacity will serve to demonstrate the effects that alternative assumptions would have on maximum reservoir surcharge levels, and may eliminate the need for more detailed studies of probable initial pool levels when the effects are relatively small or moderate. In this connection, it is usually desirable to assume, for one routing of the spillway design flood that the design flood control capacity is 50 percent filled at the beginning of inflow. There are several reasons for concluding that the flood control design storage capacity of a reservoir is likely to be at least 50 percent filled at the beginning of the spillway design flood, regardless of the size of the capacity involved. Normally there will be a relatively large number of floods capable of filling at least one-half the design flood control space, and most reservoir regulation plans call for optimum control of these moderate floods. In some cases, reservoir capacities originally assigned to flood control are reassigned in part to conservation or similar uses, further increasing the likelihood that at least 50 percent of the original design capacity will be filled at the beginning of the spillway design flood. It is also probable that hydrologic and meteorological conditions required for development of the maximum probable floods will be preceded by small or moderate flood runoff that would partially deplete available flood control capacities.

A comparison of surcharge elevations computed under alternative assumptions discussed in the previous paragraph usually will reveal whether or not more detailed analysis should be made to establish the most logical starting pool level to be assumed in routing the spillway design flood. If the design flood control capacity is relatively small, there will be little difference between estimated maximum surcharge levels; on the other hand, if the flood control capacity is unusually large in comparison with normal flood runoff quantities, the assumption that the reservoir will be only half filled at the beginning of the spillway design flood would be reasonable in most circumstances. The apparent likelihood that either of these initial pool levels (full or half full) would prevail at the beginning of the spillway design flood can be taken into consideration when the final decisions are reached regarding freeboard requirements for the dam, based on comparison of the effects of alternative assumptions, and other pertinent information.

Section 6.04. Routing the Spillway Design Flood

In establishing the capacity for a spillway of a major dam, a spillway design flood routing should be made and operation rules for such a routing must be adhered to strictly.

A computer program has been developed which will compute a spillway rating curve for an assumed design head and then make a flood routing of the spillway design flood to determine the maximum water surface. A concrete ogee spillway with vertical walls or a broad-crested weir can be accomodated. The routing can be for a gated or an uncontrolled spillway, and discharge from a conduit or sluice can be included. The program, Spillway Rating and Flood Routing, is described in Appendix 4.

Routing a spillway design flood through a reservoir controlled by a gated spillway is achieved by determining the change in storage during each time period as the difference between inflow and outflow volumes, and adding this change of storage to the total stoarge at the end of the preceding time period. Outflow for a period is determined with a relationship such as that shown in fig. 6.03, using the reservoir elevation at the end of the previous period and the average inflow for the previous period. When a free spillway discharge is reached, the Modified Puls method can be used to continue the routing.

Chapter 7

Seasonal Operation Variations

CHAPTER 7. SEASONAL OPERATION VARIATIONS

Section 7.01. General

At almost all locations, floods of any specific type are seasonal in nature and it may not be necessary to provide all of the flood control space for that type of flood during part of the year. In formulating regulations, the seasonal variation in potential of each type of flood that is important to the design should be examined, and criteria should be adopted for the use of flood control space for other purposes when appropriate and desirable.

Section 7.02. Seasonal Rain-Storm Variations

Since rain floods usually occur within a few hours or few days of the rain storms that cause them, the seasonal distribution of rain floods can be ascertained by a study of the seasonal distribution of rain storms, with due consideration given to seasonal variations in ground conditions. As an example, the results of a study of rainfall frequencies and maximum recorded rainfall amounts are summarized in fig. 7.01, and data on outstanding early-season and late-season storms are summarized in table 7.01 for central and northern California, USA. It is apparent that storms in this region are most frequent in the months of December, January, and February, but major storms and floods have occurred in November and March, and moderate to large storms and floods have occurred

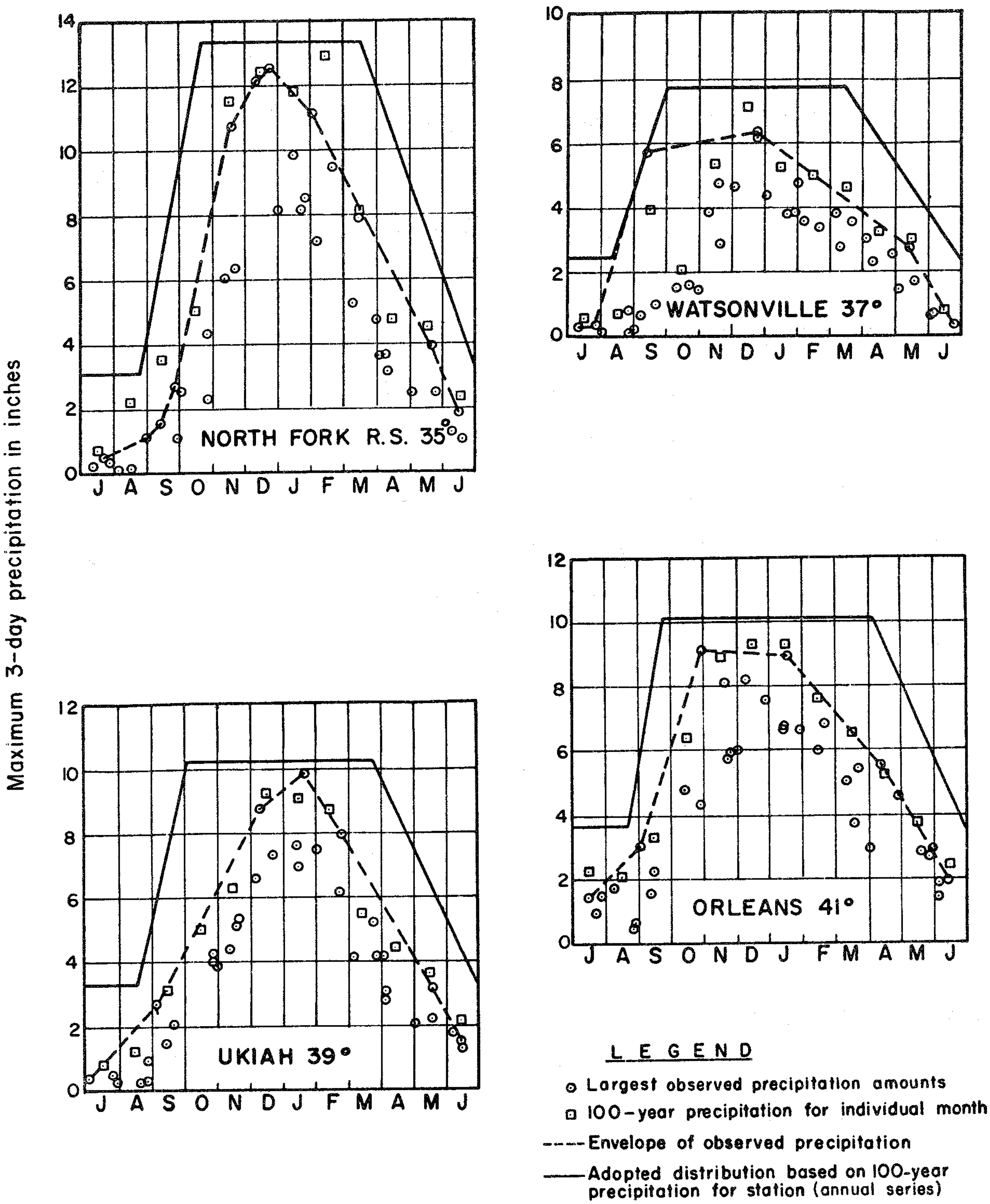


Fig. 7.01. Observed and adopted seasonal distribution of maximum 3-day precipitation

Table 7.01. Maximum observed 3-day precipitation early-season and late-season storms in California

Station	Lat.	Long.	10-yr precip. (in.)	100-yr precip. (in.)	3-day precipitation (in.)	3-day precipitation % of 100-yr
					Storm of 26 May 1906	
Magalia	39-48	121-35	15.5	22.8	8.77	38
Emigrant Gap	39-18	120-40	12.8	18.6	6.70	36
Summerdale	37-29	119-39	13.0	19.8	7.42	37
					Storm of 11 May 1915	
Kennett	40-44	122-24	16.4	26.3	13.81	52
Magalia	39-48	121-35	15.8	23.2	12.53	54
Emigrant Gap	39-18	120-40	12.8	18.6	9.90	53
Kentfield	37-57	122-33	8.0	11.4	6.62	58
					Storm of 13 Sept. 1918	
Red Bluff	40-10	122-14	4.6	6.51	7.12	109
Blue Canyon	39-17	120-42	14.5	15.0	5.55	37
Antioch	38-00	121-47	3.3	4.88	6.59	135
San Jose	37-21	121-54	4.0	6.16	6.22	101
					Storm of 6 April 1926	
Dry Canyon Res	34-28	118-32	6.4	11.9	8.5	71
Colbys	34-18	118-07	15.6	30.8	18.3	59
Hoegee's Camp	34-13	118-02	20.9	40.6	25.6	63
Raywood Flats	34-03	116-49	13.8	23.4	14.1	60
					Storm of 25 Sept. 1939	
Squirrel Inn #2	34-14	117-14	15.5	26.6	9.02	34
Mt. Wilson	34-13	118-04	16.0	30.6	11.60	38
Los Angeles	34-03	118-15	6.3	11.2	5.62	50
Fullerton	33-51	117-55	6.0	10.6	5.97	56
					Storm of 30 Oct. 1945	
McCloud	41-15	122-08	9.3	13.6	9.20	68
Shasta Dam	40-43	122-25	14.8	23.7	10.30	43
Upper Mattole	40-15	124-12	12.6	17.2	10.29	60
L. Spaulding	39-19	120-39	12.2	17.7	8.96	51
					Storm of 27 Oct. 1950	
Elk Valley	42-00	123-43	13.5	19.6	15.95	81
Gasquet R. S.	41-52	123-58	13.4	19.0	22.09	116
Orick	41-20	124-02	9.9	14.8	17.79	120
Lakeshore	40-53	122-23	15.8	23.2	14.02	60

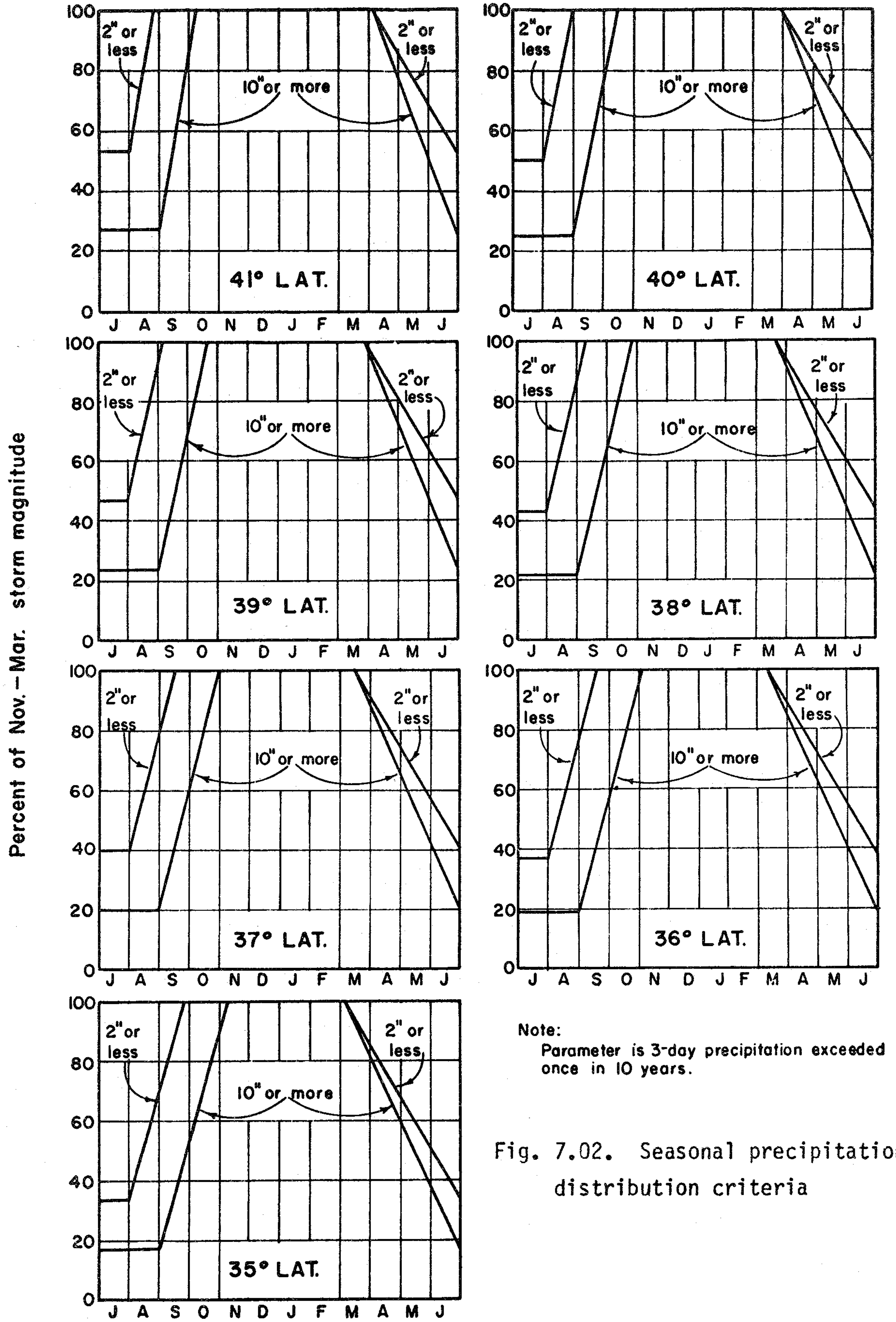
Table 7.01. Maximum observed 3-day precipitation early-season and late-season storms in California (cont.)

Station	Lat.	Long.	10-yr precip. (in.)	100-yr precip. (in.)	3-day precipitation (in.)	3-day precipitation % of 100-yr
					Storm of 19 May 1957	
Brush Cr. R. S.	39-41	121-22	15.0	23.9	8.15	34
Bullards Bar P.H.	39-25	121-09	10.9	16.3	7.81	48
Gold Run	39-10	120-52	9.4	14.2	7.32	52
Giant Forest	36-34	118-46	12.8	20.1	7.45	37
					Storm of 2 April 1958	
Lehman Ranch	38-36	121-01	5.3	7.58	5.65	75
Drytown	38-26	120-52	5.5	8.19	6.20	76
Hogan Dam	38-08	120-48	6.0	8.59	5.65	66
Oakdale	37-52	120-52	3.5	5.01	7.25	145

as early as September and as late as May. Weather maps indicate that these last events can be associated generally with the same type of extra-tropical cyclonic disturbances that cause the general winter storms, except that the September 1939 storm is known to be of tropical origin. Important rain floods are unknown in the months of June, July, and August in this region, except for small-area floods resulting from cloudbursts. These, of course, must also be considered in design and operation, but are usually important only in very small basins. Seasonal-variation criteria for central and northern California, based on the information contained in fig. 7.01 and table 7.01, are summarized in fig. 7.02. These criteria are useful as a general guide, but are subject to modification where special conditions warrant. Application methods are described in the next section.

Section 7.03. Seasonal Rain-Flood Variations

The seasonal variation of rain floods can be computed, by hydrograph analysis, from the seasonal variation of rain storms. If a particular flood has been used as a primary basis of project design, loss-rate curves used in deriving that project design flood from the project design storm can be applied to various percentages of the project design storm to delineate the seasonal variation of flood potential. If an official project design flood does not exist, a hypothetical flood could be developed for this specific purpose. Loss rates used in the early part of the rain-flood season should ordinarily be higher than those used in the middle and late parts of the season. Each alternative



Note:
Parameter is 3-day precipitation exceeded once in 10 years.

Fig. 7.02. Seasonal precipitation distribution criteria

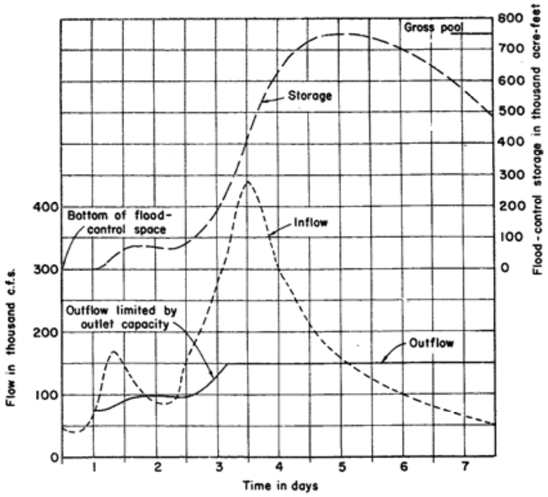
flood would be routed through the reservoir under contemplated operation conditions to determine the amount of reservoir space required. Typical routings are illustrated in fig. 7.03.

The reservoir space requirements thus obtained should be provided on the various dates shown by fig. 7.02 to correspond to the percentage of the design storm used. In this example, based on a latitude of 40° and a 10-year basin-mean storm precipitation of 10 inches in 3 days, fig. 7.02 indicates that the basin can experience full storm potential as early as 15 October and as late as 1 April. Fig. 7.02 also indicates that as much as 80 percent of the full storm potential can be experienced as early as 2 October and as late as 27 April, and as much as 60 percent as early as 18 September and as late as 23 May. Space requirements determined in fig. 7.03 are plotted against these corresponding dates in fig. 7.04 in order to determine maximum space requirements shown in fig. 7.05.

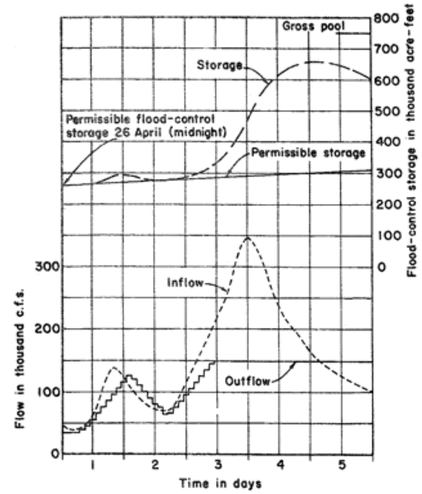
In cases where flood control space is reduced because of dry ground, as discussed in Chapter 6, the required flood-control space for dry ground conditions on these various dates can be established in the same manner, as illustrated in fig. 7.03, except that different loss-rate curves are used, as described in Chapter 8.

Section 7.04. Snowmelt-Season Limitations

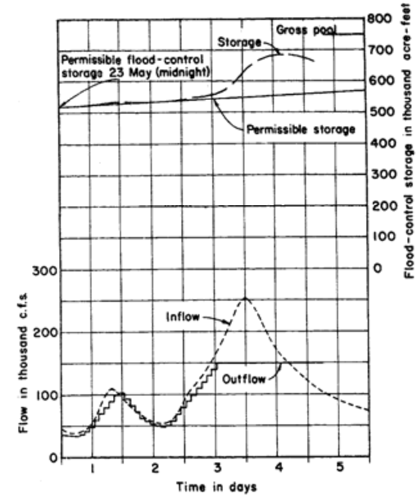
Where snow accumulates during the winter and melts mostly during the spring, the use of reservoir space for the control of snowmelt floods can almost always be based on forecasts of runoff volume expected by the end of the snowmelt season. The operation is designed to control the



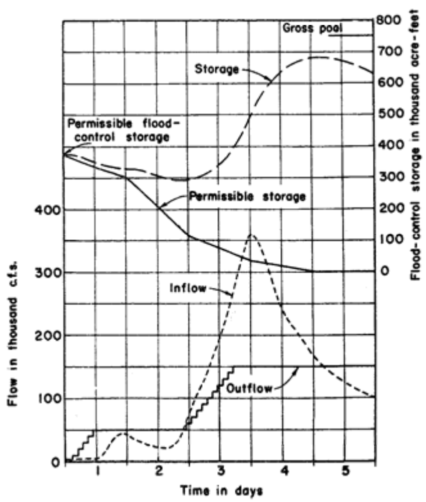
STANDARD PROJECT FLOOD
(STANDARD PROJECT STORM ON WET GROUND)



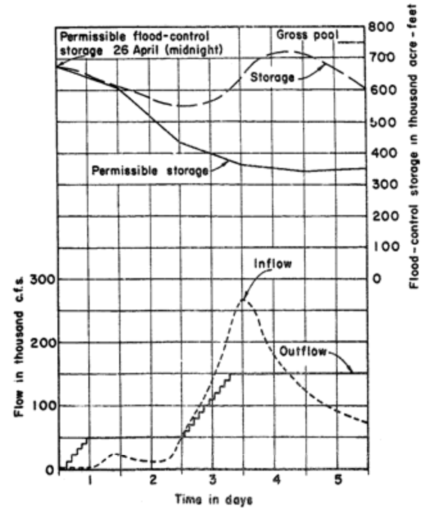
80 PERCENT OF STANDARD PROJECT STORM ON WET GROUND



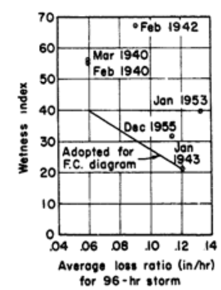
60 PERCENT OF STANDARD PROJECT STORM ON WET GROUND



STANDARD PROJECT STORM ON DRY GROUND



80 PERCENT OF STANDARD PROJECT STORM ON DRY GROUND



NOTE:
Dry ground conditions are defined as those observed during 1943 storm. Inset at left shows comparison of loss rates observed during major floods studied

Fig. 7.03. Hypothetical flood routings

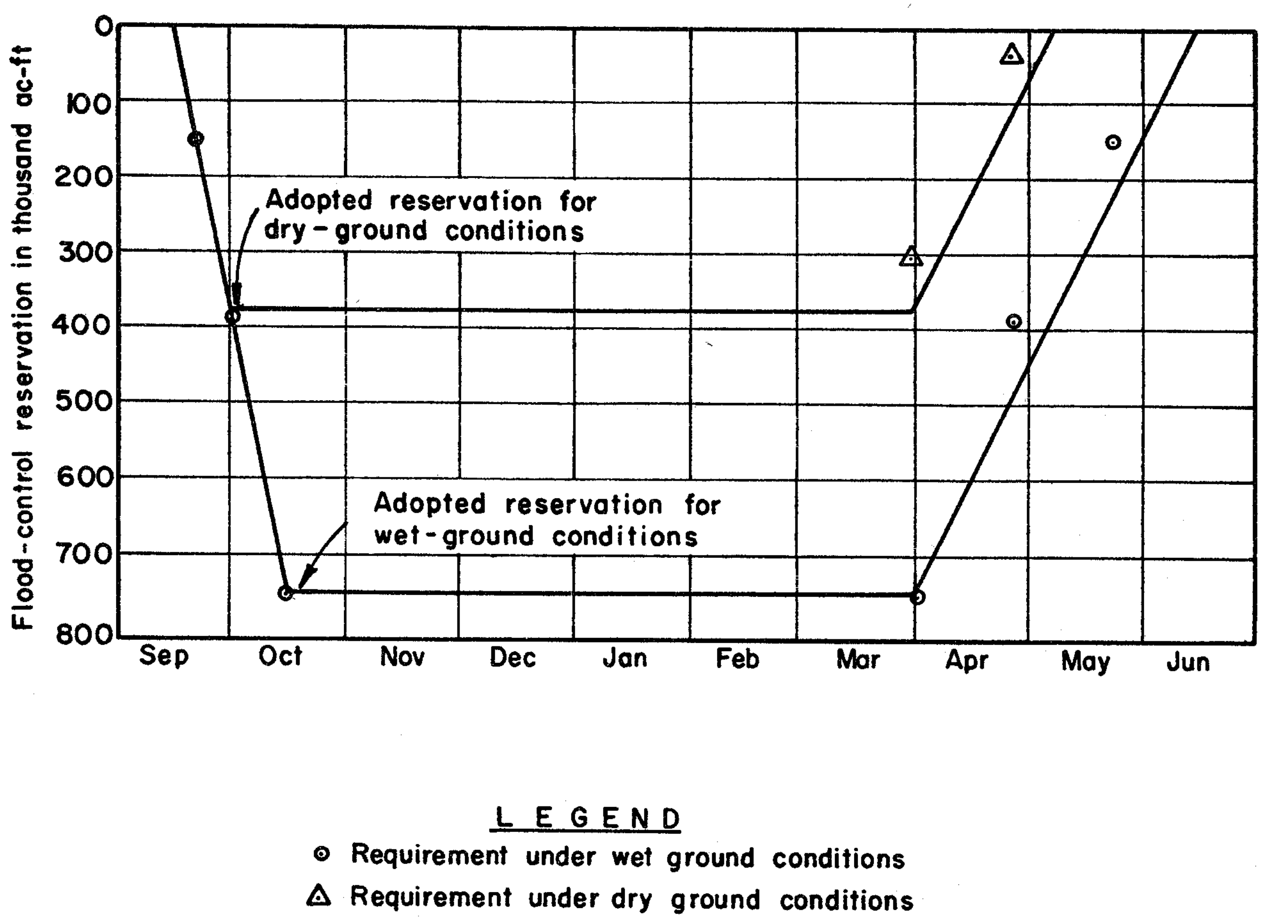
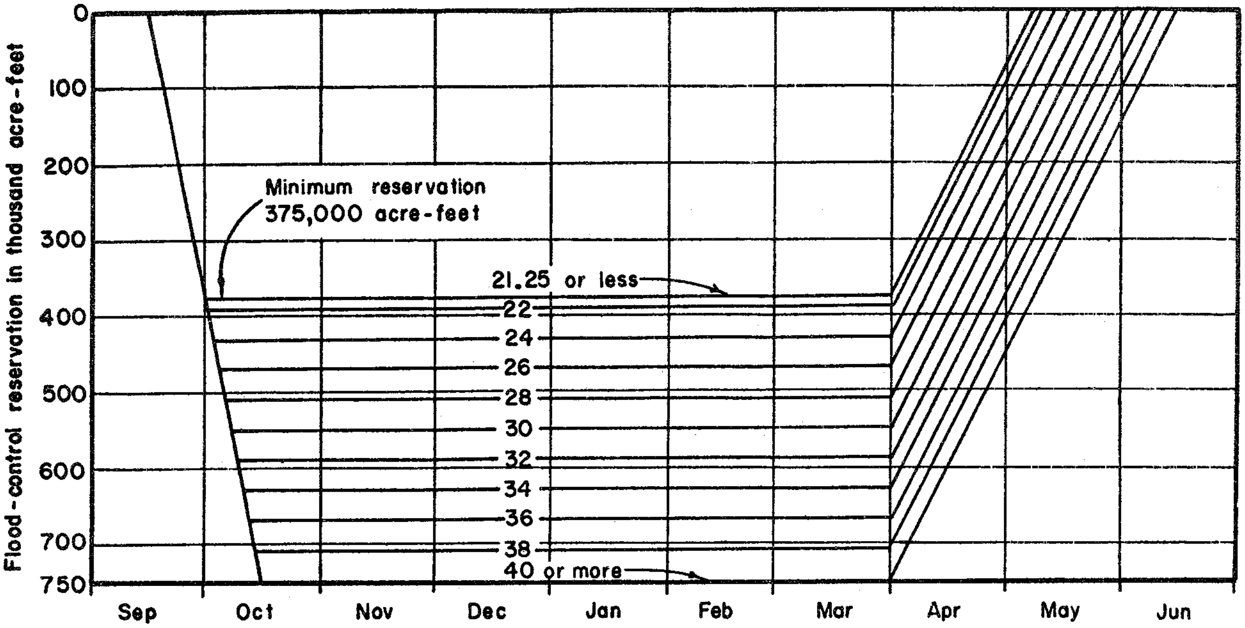


Fig. 7.04. Seasonal flood control space requirement



USE OF DIAGRAM

1. Parameters are preceding 60-day basin-mean precipitation expressed as a percentage of normal annual precipation.

2. Except when releases are governed by the emergency release diagram, all storage in excess of that indicated by this diagram shall be released as rapidly as possible, subject to the following conditions:

a. That releases do not exceed 50,000 cfs or maximum rate of inflow for the flood, whichever is greater.

b. That releases do not exceed 150,000 cfs at any time.

c. That flows in a downstream damage reach do not exceed 180,000 cfs at any time.

d. That releases are not increased more than 10,000 cfs or decreased more than 5,000 cfs in any 2-hour period.

NOTE: After 31 March, reservation for any given parameter decreases 10,000 acre-feet per day.

Fig. 7.05. Flood-control diagram

forecasted flood, with appropriate contingency allowances, and yet completely fill the reservoir whenever possible.

The limiting amount of space dedicated to the control of snowmelt floods can ordinarily be determined by routings of design and maximum recorded floods. It is usually found that full snowmelt space may be utilized during the early months of the snowmelt season but that it is ordinarily safe to reduce the maximum space during the later months, because the full space could never be effectively utilized at these later dates. Important exceptions to this rule occur in cases where reservoir capacity is small relative to runoff volume or where a reservoir is located at high elevations where melting occurs later. The standard project snow-melt flood usually involves early high melt rates, and does not ordinarily require large amounts of reservoir space late in the season, because snow pack conducive to high melt rates is not great enough to sustain high runoff late in the season. Accordingly, some major observed flood will ordinarily govern during the later months.

Section 7.05. Drawdown Limitations

The multiple use of reservoir space will require drawdown of reservoir stages at the beginning of the flood season or when any flood-potential index values used might result in increased space requirement. In formulating flood control regulations for the multiple use of reservoir space, consideration should be given to the effects of necessary drawdown of reservoir stages when inflows are below flood stage. If some damages are caused by releases during the drawdown periods, a claim might be made that they have been caused unnecessarily, and consequences might result that would seriously impair future operation. Accordingly, drawdown rates should be maintained at nondamaging rates insofar as possible, and the regulations should make full allowances for the time required to evacuate space at these safe rates, with liberal allowance for possible inflow rates at the time. Drawdown requirements are usually determined by routing the design flood preceded by maximum observed runoff considered to be reasonably consistent with design-flood conditions.

Chapter 8

Conditional Rain-Flood Reservation

CHAPTER 8. CONDITIONAL RAIN-FLOOD RESERVATION

Section 8.01. Nature and Limitations

Experience has indicated that rain storms and rain floods in many cases cannot be forecasted accurately enough nor sufficiently in advance for firm use of forecasts in reservoir operation criteria. While continuous efforts should ordinarily be made to forecast rain floods whenever and wherever appropriate in connection with reservoir operation, it is often considered to be unsafe to depend on the evacuation of reservoir space on the basis of a rainstorm or rain-flood forecast. However, there are times when ground conditions are such that the rain-flood potential is materially below normal and others when the potential is materially above normal, and it is often possible to increase overall project accomplishments by varying the required flood-control space with the conditions of the ground. If the ground is dry at the beginning of a storm, loss rates will in most cases be high, and the resulting flood will be less severe than otherwise, even though the ground becomes progressively wetter during the storm. However, as soon as a storm occurring on dry ground is over, the ground is wet, and provision should be made immediately to evacuate such additional space as is considered necessary to control a flood resulting from the project design storm occurring on the wetter ground.

When it is proposed, in formulating regulations, to reduce the space requirement because of dry ground, it must be ascertained that space can be subsequently evacuated in time to provide the additional space required when the ground becomes wet. This is possible only in cases where release rates are adequate to evacuate space during a series of moderate floods that might precede the main design flood period. Whether this is possible can be determined roughly by estimating the critical duration of design runoff, which is defined herein as the time between the beginning of storage of flows in excess of flood releases and the time of maximum reservoir stage. If the critical duration of runoff is a few days or less, the reservoir is most likely to be filled by a single rain flood of a few days duration, and since ground conditions at the beginning of that flood would ordinarily influence the flood magnitude, space requirement could be a function of ground conditions. On the other hand, if the critical duration of runoff is greater than a few days, the reservoir is most likely to be filled by a sequence of floods, and although the ground may be dry at the beginning of the sequence, it becomes wet after the first storm or two, and the remaining storms occur on wet ground. Consequently, ground conditions probably would not greatly influence space requirements where critical durations are long. If the critical duration exceeds 5 days, it is ordinarily not wise to permit conditional storage in the rain-flood space.

Section 8.02. Selection of Index

A practical index of ground conditions is the preceding 60-day basin-mean precipitation. Although this index is not the most accurate measure of ground wetness and has theoretical weaknesses, practical operation advantages discussed below normally override these handicaps. Nonetheless, since each basin has its own peculiarities, it may be desirable to select alternative indexes in some cases. The 60-day precipitation index for each reservoir area is computed from daily reports provided by the network of precipitation stations covering that area. Since the number of stations usable is limited, this computation is only approximate, and efforts should be made to obtain reports from as many well-distributed stations as feasible. Where precipitation is primarily orographic, precipitation amounts vary systematically with the topography of each basin. Consequently a simple arithmetic mean of all reporting stations may differ significantly from the true basin mean. A more satisfactory system is to use the ratio of the normal annual precipitation at each station to the normal annual basin-mean precipitation. Under this system, the sum of the short-term precipitation values at all reporting stations is divided by the sum of the normal annual precipitation values for the same stations to obtain the average proportion of normal annual precipitation that fell on the basin during the period, and this average proportion is multiplied by the normal annual basin-mean precipitation to estimate the short-term basin-mean value. Under this system, temporary failure of some of the stations to report or permanent changes in the location of stations which make up the network will not significantly affect the computation of basin-mean precipitation. Volume 4 of this report contains a more complete discussion on the computation of basin-mean precipitation.

Studies have been made of various other indexes such as preceding runoff for various durations, preceding precipitation since the beginning of the season or for various durations, preceding precipitation with greater weight given to the more recent amounts, and various other more complex indexes. A typical correlation study relating runoff to storm precipitation and ground-wetness index resulted in the following correlation coefficients:

Ground-Wetness Index	Correlation Coefficient
Preceding 15-day precipitation	.53
Preceding 30-day precipitation	.55
Preceding 60-day precipitation	.64
Weighted 15-, 30-, 60-day precipitation	.62
Preceding precipitation since 1 October	.62
Preceding 15-day runoff	.62
Preceding 30-day runoff	.66
Preceding 60-day runoff	.65
Weighted 15-, 30-, 60-day runoff	.64
Preceding runoff since 1 October	.61
Precipitation minus runoff depth since 1 Oct.	.59

In general, preceding runoff appears to be the most accurate index, but preceding precipitation is almost as accurate. It is considered that the precipitation index is more generally satisfactory, because its influence is registered earlier. The duration of preceding precipitation used for the index should be sufficiently long so that fluctuations of the index will not cause excessive operational hardships such as forcing release of valuable water at frequent intervals. While it may be theoretically desirable, it is not satisfactory to give greater weight to the most recent quantities, because this would result in unnecessarily rapid fluctuations of the index and consequent difficulty in operation.

Considering all aspects of this problem, 60-day precipitation has been found to be a generally satisfactory index.

Section 8.03. Variation of Space Requirement

When including provisions in the operation regulations to use flood control space for conservation purposes during periods of dry ground conditions, it is necessary to select some measure of the effect of ground conditions on space requirements. The selected index (for example, preceding 60-day precipitation as discussed in the preceding paragraph) must be related to loss-rate criteria, and these criteria in turn must be applied to a design or other hypothetical storm in order to determine the space required to control the resulting flood. This is accomplished by plotting infiltration index or some other measure of loss rates against an observed ground wetness index for historical floods as illustrated in fig. 7.03. A line enveloping loss rates on the lower side would then be selected for project design, as shown in fig. 7.03, because project operation must be adequate to control floods when the more adverse observed ground conditions occur.

An index value for dry ground conditions should then be selected, and a corresponding loss-rate curve derived, usually from hydrograph analysis of a specific recorded flood. These loss rates could then be applied to the design storm and to various percentages of the design storm to determine space requirements under dry ground conditions for various times of the year.

Space requirements for intermediate conditions between dry and wet ground can be interpolated linearly for all practical purposes. It is best to select a firm minimum space for dry ground conditions equal to at least half of the maximum space required for wet ground conditions during the main part of the rain-flood season. An illustration of the construction of a diagram using these principles, based on data in figs. 7.03 and 7.04, is shown in fig. 7.05.

Before adopting a flood-control diagram derived as above, all important historical floods should be routed and the space requirement and wetness index plotted on the diagram at appropriate points before the start of flood flows requiring storage. Parameters determined from hypothetical considerations should then be adjusted if necessary to provide at least as much storage as that required by the historical floods. If the hypothetical parameters require excessive storage reservation in comparison with that required by historical floods resulting from storms approaching design magnitude, they should be adjusted to require a reasonable margin of storage above that required by such historical floods.

Section 8.04. Effect on the Control of Rain Floods

The conditional use of flood control space reduces the flood control accomplishment to some extent unless a compensating increase in maximum flood control space is made. When rain-flood parameters are used, the diagram provides for control of a specific design storm on whatever ground conditions might exist rather than of a specific design flood. If a 50-year protection is to be provided by conditional use of space, for example, the maximum space needed is that required to control a flood from the 50-year storm on very wet ground. If 50-year protection is to be provided by firm use of flood control space, on the other hand, the maximum space needed is that required to control 50-year runoff, and this would be somewhat less.

Chapter 9

Conditional Snowmelt-Flood Reservation

CHAPTER 9. CONDITIONAL SNOWMELT-FLOOD RESERVATION

Section 9.01. Snowmelt Forecast

Inasmuch as seasonal snowmelt runoff volumes can ordinarily be forecasted months in advance with a reasonable degree of reliability, an excellent opportunity exists for both providing adequate flood control space as needed, and for subsequently providing conservation storage in the reservoir whenever possible.

Forecasts of the total runoff can be made at the beginning of each month (and at intermediate dates, where warranted) largely on the basis of field measurement of snow on the ground by means of a snow course network. The accuracy of these total volume forecasts increases progressively as the season advances. Before the middle of the snowpack accumulation season, the possible error is very large, because it must include not only an estimate of the runoff expected from snow on the ground but also a forecast of the additional snow that may fall in the last half of the season. By the end of the accumulation season, this second source of error has become comparatively small, and the overall accuracy increases markedly.

After most of the snow has melted, other types of information become available, such as the magnitude and rate of decrease of the snow-covered area, magnitude and rate of change of the runoff yield per degree-day of temperature at key weather stations, and finally, rate of recession of the snowmelt runoff at stream gaging stations. By use of these additional types of data, forecasts can be made of the remaining runoff which have considerably greater accuracy than could be achieved by simply subtracting the observed runoff volume since the start of the snowmelt season from the total forecast volume.

Section 9.02. Latitude of Operation

Since the accuracy of snowmelt forecasts generally increases as the season progresses, it is desirable that regulations should provide for deferring flood releases until a surplus of water above that needed for conservation or power purposes is assured or until the available space plus project releases throughout the remainder of the critical melt period is required to control the anticipated floodwaters plus a contingency allowance. In this way, releases that might impair project objectives would be based on the best available forecast, since forecast reliability continuously improves during the snowmelt season. If after initiating flood releases, the runoff forecast is diminished, flood releases can then be stopped or reduced, and the effect of the earlier forecast error can be largely or completely nullified. Thus the latitude available in operating for snowmelt floods is equal to the flood release rate (excess above release for other purposes) multiplied by the amount of time until the reservoir is expected to fill. This latitude of operation ordinarily makes it possible to control anticipated floods without seriously risking the possibility of not filling the reservoir for conservation or power purposes.

Section 9.03. Forecasted Space Requirement

In constructing a flood control diagram for the control of snowmelt floods, the space requirement corresponding to a specified volume of remaining runoff after a given date is determined by routing of historical runoff between that date each year and the date that reservoir storage would be maximum. The space requirement is then plotted against the total observed runoff for the forecast period. A set of curves thus derived is illustrated in fig. 9.01. These curves can be used to determine space requirement corresponding to any specified volume of remaining runoff.

Section 9.04. Standard Error of Estimate

In formulating parameter lines for snowmelt operation, allowance must be made for forecast errors and other contingencies. A measure of normal forecast error can be obtained by examining past forecast experience and computing the "standard error of forecast" from the actual historical forecasts. If a new forecast method is to be used, the standard error should be obtained by applying the procedure to historical data, taking care not to use data that would not be available at the date of forecast. The standard error of forecast is computed by adding the squares of forecast errors and dividing by the number of statistical degrees of freedom, F (approximately equal to the number, N, of forecast errors used). The square root of the quotient thus obtained is the standard error of forecast, S_e.

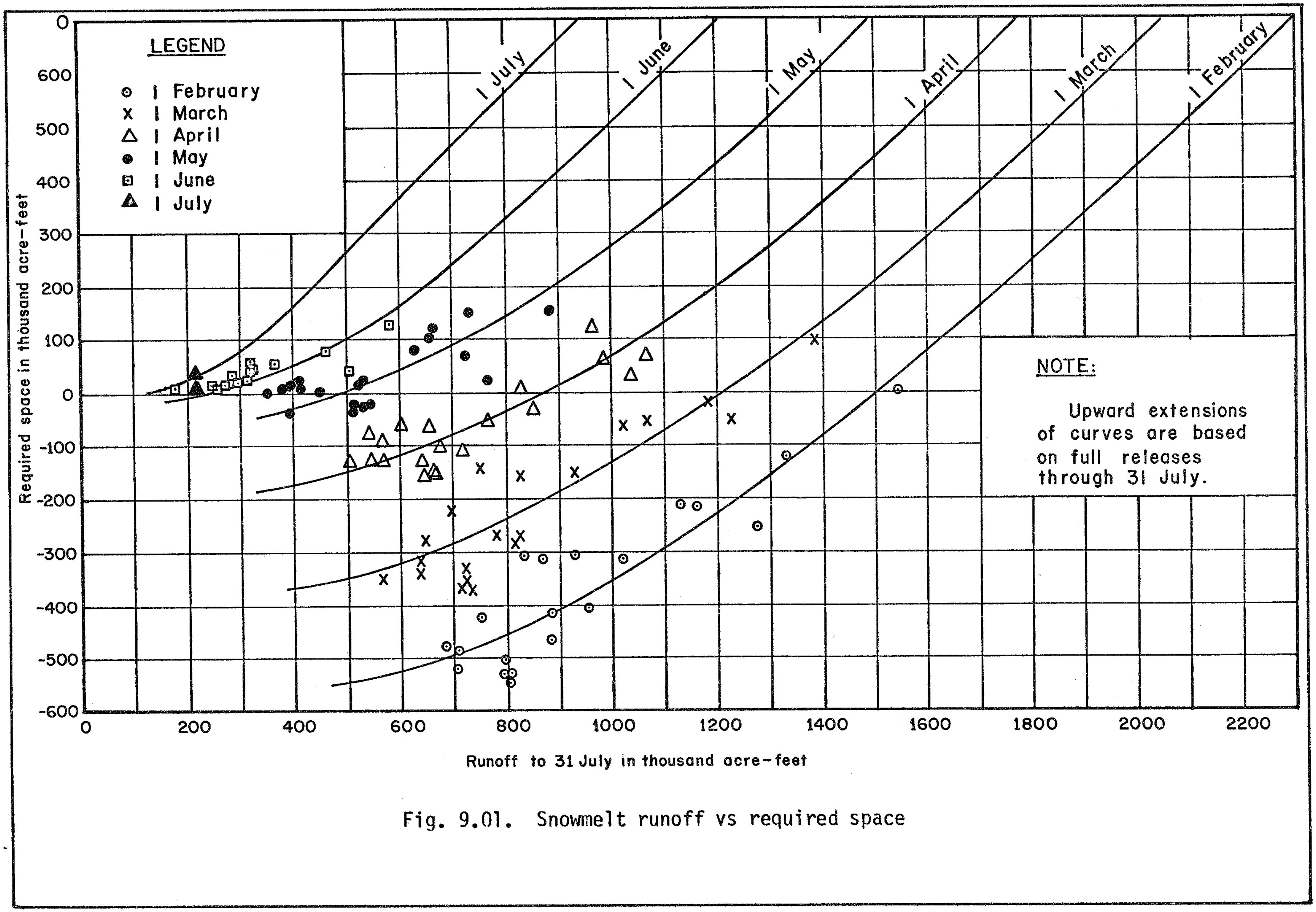


Fig. 9.01. Snowmelt runoff vs required space

If X' is the forecast and X the observed quantity, the equation would be as follows:

$$S_e^2 = \frac{\Sigma(X' - X)^2}{F} \qquad (9\text{-}1)$$

In addition to the forecast error of total runoff volume, there is an uncertainty of future weather conditions and as to whether runoff will be unusually early or late. In the event of an unusually early runoff, more flood control space is required because there is less time for making releases. A measure of this uncertainty is the standard error of the space-runoff relationship, which is the standard deviation of points about the lines in fig. 9.01, measured in the horizontal direction. This stanard error, called herein the "standard error of timing," can be combined with the standard error of forecast by taking the square root of the sum of the squares of these two quantities. The result is called herein the "standard error of estimate." Table 9.01 and fig. 9.02 illustrate the typical relation between the various types of errors and the forecast rate.

Section 9.05. Error Allowance

The multiple (k) of that standard error of estimate to be added as an error allowance will depend on the seriousness of losing control of a snowmelt flood, the importance of filling the reservoir for conservation, and the latitude of operation discussed above. Commonly, twice the standard error of estimate is used, because this assures control in a high percentage of years and ordinarily represents a reasonable compromise between

Table 9.01. Forecast verification data natural April-July flows

(Values in thousand acre-feet)

Year	Recorded flow	1 February Forecast	1 February Error	1 March Forecast	1 March Error	1 April Forecast	1 April Error	1 May Forecast	1 May Error
1932	569					557	- 12		
1933	362					390	28		
1934	138								
1935	501								
1936	598					646	48		
1937	545					630	85	630	85
1938	850					700	-150	700	-150
1939	220					280	58	225	3
1940	516					400	-116	400	-116
1941	600					550	- 50	560	- 40
1942	665					500	-165	550	-115
1943	541					570	29	570	29
1944	346					380	34	380	34
1945	507					500	- 7	425	- 82
1946	448					550	102	500	52
1947	254					325	71	300	46
1948	526					260	-266	410	-116
1949	439					500	61	440	1
1950	569					575	6	610	41
1951	351					250	-101	250	-101
1952	967					1050	83	1000	33
1953	482	600	118	460	- 22	400	- 82	430	- 52
1954	378	390	12	370	- 8	400	22	380	2
1955	348	500	152	430	82	300	- 48	360	12
1956	642	900	258	800	158	620	- 22	675	33
1957	420	385	- 35	335	- 85	355	- 65	345	- 75
1958	827	460	-367	490	-337	830	3	790	- 37
Average			157		115		68		51
Extreme			-367		-337		-266		-150

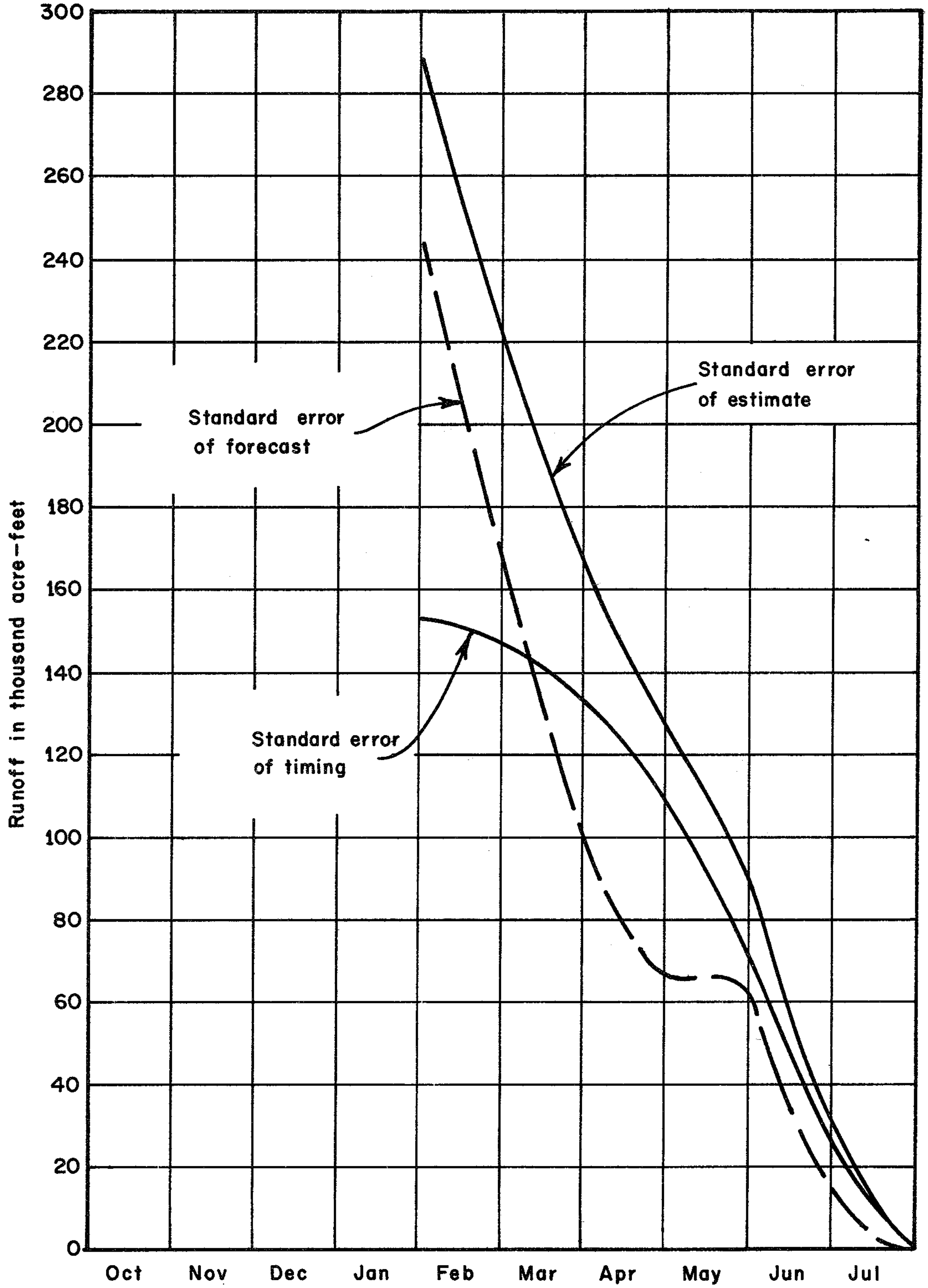


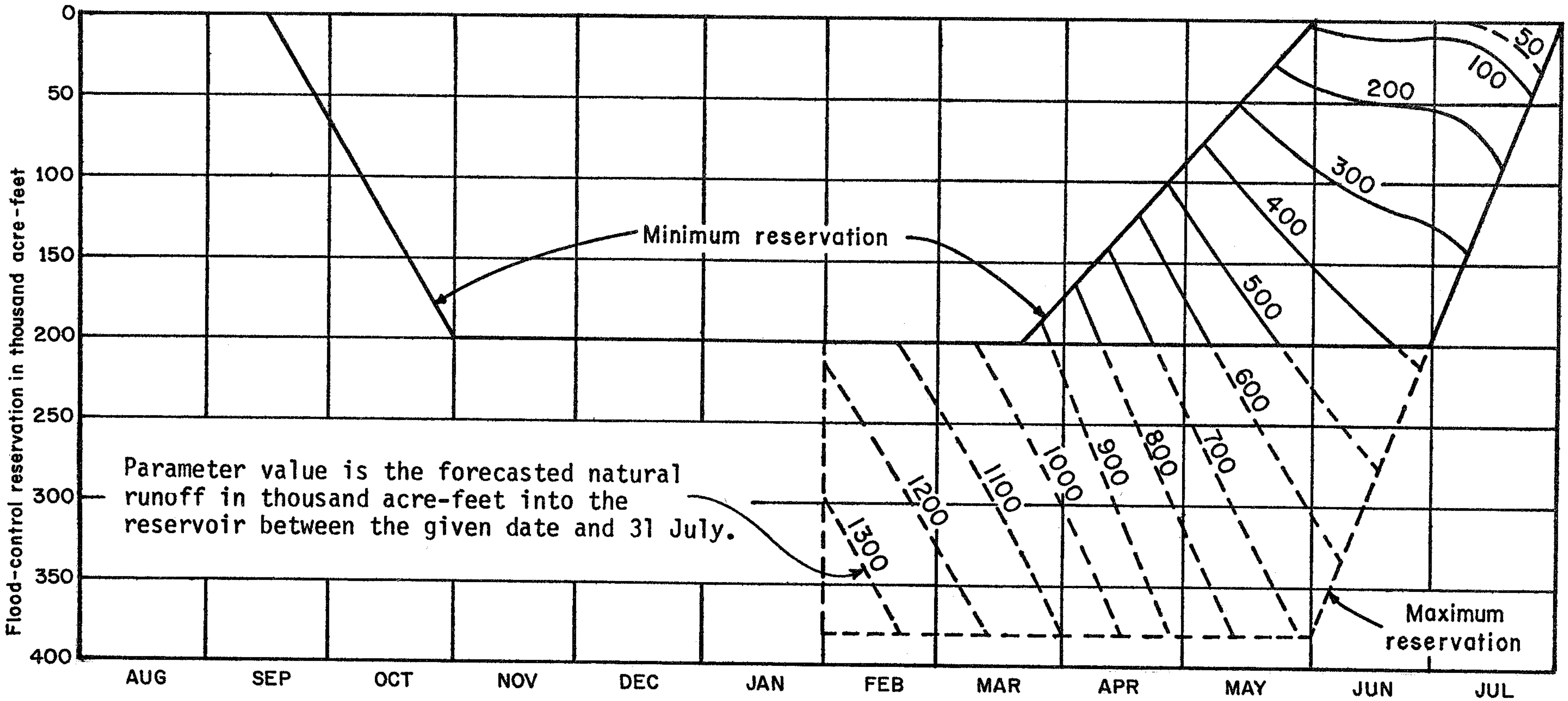
Fig. 9.02. Standard errors of estimating snowmelt runoff

flood control and conservation accomplishments, but each case should be studied individually.

Section 9.06. Formulation of Criteria

The intervening area on the flood control diagram (fig. 9.03) between the minimum rain-flood space limits and the maximum snowmelt flood space limits represents conditional flood control space. Parameter lines occupying this space are computed as illustrated in table 9.02 by assuming a given forecast on a given date, adding the adopted error allowance, and determining from this sum the required space, using curves similar to those shown in fig. 9.01. Resulting parameters are then plotted within the range of conditional flood control space as illustrated in fig. 9.03.

In some river basins, during flood periods there are substantial diversions out of the river which can significantly reduce flooding downstream. Since such diversions can vary from year to year, it may be desirable to include a provision in the regulations for adjusting the snowmelt space requirements for the difference between scheduled and normal diversions upstream of the critical channel reach that are expected to occur between the given date and the earliest date that the reservoir can fill under full flood control releases. Experience has shown that scheduled diversions cannot be fully depended upon, and it may be well to provide for only about 80 percent of the computed difference.



NOTES:

1. Space corresponding to dash-line portion of diagram would be required only if flood-control storage capacity exceeding 200,000 acre-feet is found to be economically feasible.

2. When space available for flood control is less than that indicated by the diagram, water shall be released as rapidly as possible without causing flows at downstream damage center to exceed 5,000 c.f.s.

3. With certain restrictions, required space in the reservoir may be reduced when empty space is available in upstream reservoirs.

Fig. 9.03. Preliminary flood-control diagram

TABLE 9.02

COMPUTATION OF SNOWMELT PARAMETERS

(Quantities in thousand ac-ft)

Forecast to 31 July	1 February		1 March		1 April		1 May		1 June		1 July	
	Forecast plus error	Space required	Forecast plus error	Space required	Forecast plus error	Space required	Forecast plus error	Space required	Forecast plus error	Space required	Forecast plus error	Space required
0	574		444		332		254		188		62	
50	624		494		382		304	- 50	238	- 8	112	- 1
100	674		544		432	- 170	354	- 42	288	5	162	10
200	774		644		532	- 145	454	- 18	388	42	262	54
300	874		744		632	- 110	554	18	488	91	362	127
400	974		844	-222	732	- 70	654	65	588	150	462	220
500	1074	-312	944	-170	832	- 25	754	118	688	225	562	322
600	1174	-247	1044	-110	932	25	854	175	788	305	662	422
700	1274	-175	1144	- 47	1032	85	954	240	888	395	762	522
800	1374	-100	1244	19	1132	150	1054	315	988	488	862	622
900	1474	- 23	1344	88	1232	220	1154	400	1088	580	962	722
1000	1574	55	1444	164	1332	300	1254	475	1188	680	1062	
1100	1674	135	1544	245	1432	385	1354	565	1288	780	1162	
1200	1774	219	1644	330	1532	475	1454	670	1388			
1300	1874	304	1744	420	1632	565						
1400	1974	395	1844	512								
1500	2074	488										
1600	2174											
1700	2274											

NOTE: Parameter development based on a reservoir outflow of 4500 c.f.s., which allows for operational contingencies that might prevent the full and continuous use of 5000 c.f.s. channel capacity plus 500 c.f.s. proposed aqueduct diversion.

Section 9.07. Effect on the Control of Snowmelt Floods

It should be recognized that when flood control space is reserved on a forecast or conditional basis, the space provided will occasionally be inadequate for flood control or too large to fill for conservation purposes, because of forecast and model imperfections. This should be reflected in the project frequency curves by discounting the amount of flood control space that can be depended upon when evaluating benefits.

Chapter 10

Multiple-Reservoir Operation

CHAPTER 10. MULTIPLE-RESERVOIR OPERATION

Section 10.01. General

Various problems arise when more than one reservoir in a system is operated for flood control or when reservoirs operated for other purposes can influence inflows to or releases from a reservoir operated for flood control. Where different reservoirs in a system subject to flood control regulations are operated for flood control by different agencies, the regulations should be worded so that coordination of the flood control operation is assured without requiring any party to operate beyond his capacity or to the undue detriment of other functions. Each operator should be given maximum flexibility of operation consistent with attainment of flood control objectives. The general procedures for coordinating flood control operation and for making allowances for incidental flood control effects by reservoirs operated for other purposes are discussed in the following paragraphs.

Section 10.02. Incidental Regulation by Conservation Reservoirs

In cases where reservoirs not operating for flood control are located upstream from a flood control reservoir, it is generally best to establish a basic flood control diagram for the flood control reservoir on the assumption that no upstream storage space will exist and, if appropriate, to provide criteria allowing for the assured beneficial effects of these upstream reservoirs. Beneficial effects are assured when:

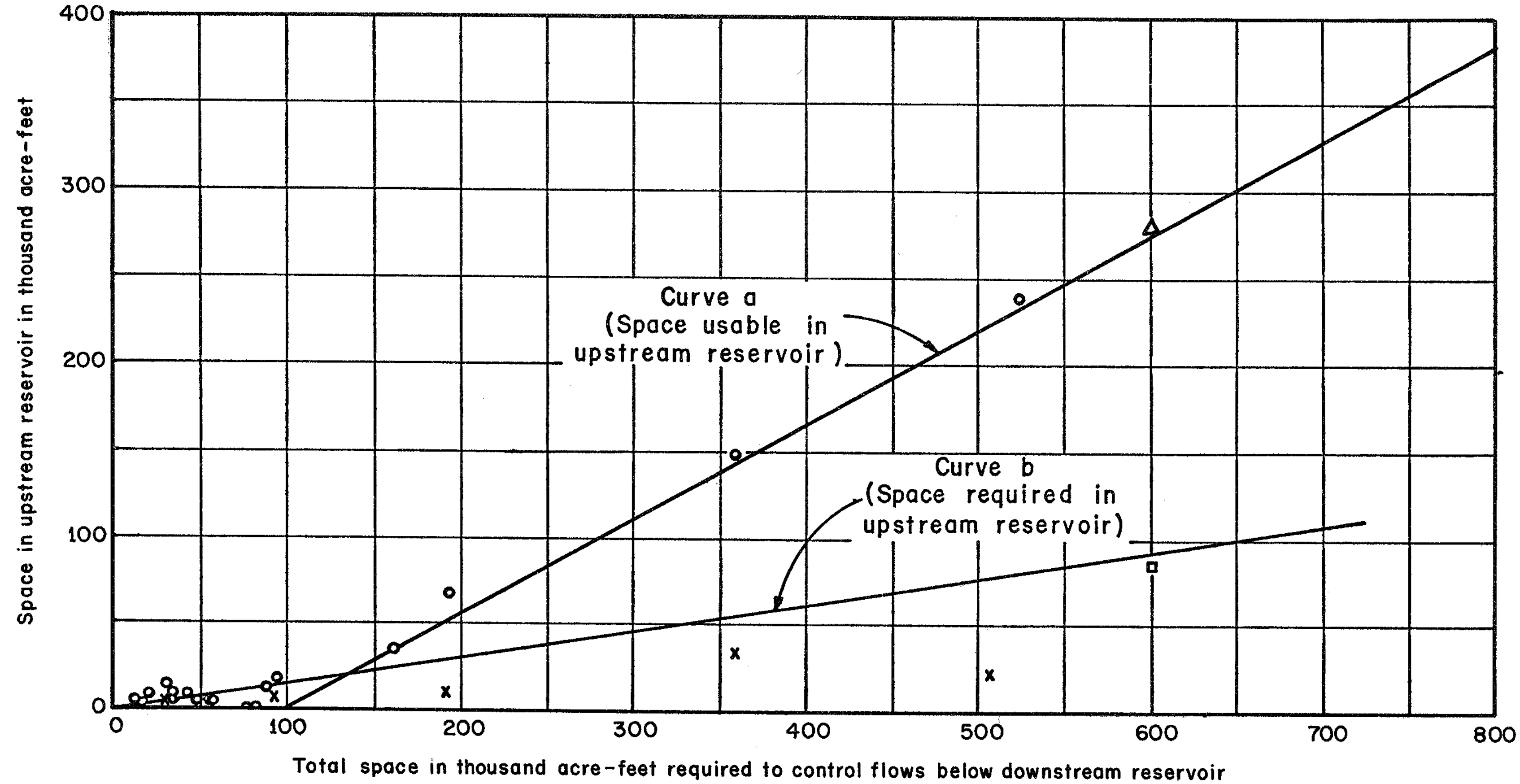
a. Empty space exists at the beginning of a flood.

b. Dependable release criteria guarantee that excess water will be stored in that reservoir.

c. If a flood capable of filling the flood control reservoir occurs, a sufficient proportion of the runoff will occur above the upstream reservoir to fill it.

Water storable at the upstream reservoir can be estimated as illustrated by curve a of fig. 10.01, the development of which is described in section 10.03. A conservative enveloping technique that would represent minimum runoff at the upstream reservoir should be used. In order to allow for unforseen contingencies, it may be wise to take credit for not more than about 80 percent of the portion of the actual and usable upstream storage space not governed by flood control regulations. Where storage quantities in upstream reservoirs can change rapidly, adequate communication should exist in order to assure that the space believed to be available actually does exist at the time.

In the case of a conservation reservoir located downstream from the flood control reservoir, no flood control allowance for the empty space can ordinarily be made, since flood control releases are not required at the downstream reservoir when water is stored within that space. The downstream reservoir will usually fill early and then provide no storage during the main part of the flood.



LEGEND

Design flood	observed flood	
△	o	Space usable in upstream reservoir, with minimum releases.
□	x	Space required in upstream reservoir, with maximum releases.

Fig. 10.01. Division of flood-control space reservoirs in series

Section 10.03. Flood Control Reservoirs in Series

Where two flood control reservoirs exist on the same stream, division of the required flood control space between the two reservoirs can be governed by criteria developed as follows. In a case of more than two reservoirs in series, the principles would similarly apply to each reservoir in turn, beginning with the farthest reservoir downstream.

a. Route the project design flood with a maximum proportion of runoff occurring above the upper reservoir, and all pertinent observed floods, to determine in each case:

(1) Space required at the lower reservoir to control the flood to nondamaging releases from the lower reservoir assuming no control at the upper reservoir.

(2) Space required at the upper reservoir to control the flood to nondamaging flows between the two reservoirs.

b. Plot a-(2) vertically against a-(1) horizontally and envelop all values, preferably with a straight line. Curve b in fig. 10.01 was obtained in this way.

c. Route the project design flood with maximum proportion of runoff occurring between the two reservoirs, and all pertinent observed floods, to determine in each case:

(1) Space required at the lower reservoir to control the flood to non-damaging releases from the lower reservoir, assuming no control at the upper reservoir.

(2) Space usable (water storable) at the upper reservoir if minimum permissible releases are maintained at the upper reservoir.

d. Plot c-(2) vertically against c-(1) horizontally and envelop on the lower side, preferably with a straight line. Curve a in fig. 10.01 was obtained in this way.

Space required in the upper reservoir is that indicated by curve b of fig. 10.01. Space required in the lower reservoir is the difference between total required space and that available in the upper reservoir, except that credit for space in the upper reservoir will be limited to that indicated by curve a. For example, if the total storage requirement for the two reservoirs were 600,000 acre-feet, a storage of about 90,000 acre-feet (curve b) would be required for the upper reservoir and 275,000 acre-feet (curve a) would be usable at the upper reservoir. If, in fact, the upstream reservoir had an available storage of 200,000 acre-feet, the storage required at the lower reservoir would be 600,000 - 200,000 or 400,000 acre-feet.

If channel capacity constraints between the two reservoirs are such that a relatively large amount of storage is required at the upstream reservoir to prevent flooding between the reservoirs, it is possible that curve b (fig. 10.01) will plot above curve a. In this case, curve b would dictate the storage in the upper reservoir, and required storage at the lower reservoir would equal the total storage minus the usable storage at the upper reservoir. The combined storage of the two reservoirs would exceed the "total" storage.

Where no damages occur between the two reservoirs, and with unlimited outlet capacity at the upper reservoir, curve b in fig. 10.01 will show a zero space requirement for the upper reservoir. In this case, minimum releases would normally be made at the upper reservoir and maximum space would be reserved in the lower reservoir. However, releases from the two reservoirs should be scheduled so that whenever flood control space is occupied, the remaining empty space will generally be divided between the two reservoirs, insofar as possible within the range of proportion determined in subparagraphs b and d above. However, in cases where releases from the downstream reservoir are controlled by the outlet capacity at that dam, an effort should be made to maintain the stage as high as feasible and necessary in the lower reservoirs in order to maintain higher head on the outlets and thus make higher flood releases possible.

Section 10.04. Flood Control Reservoirs in Parallel

Where two flood control reservoirs exist on separate streams tributary to a single stream where flood damages occur, and where it is economically and hydrologically feasible to fully coordinate the operation of the two reservoirs, division of the required flood control space between the two reservoirs can be governed by criteria developed as follows:

a. Route the project design flood with maximum proportion of runoff occurring above reservoir A, and all pertinent recorded floods, with maximum feasible nondamaging releases from reservoir A and the remainder of nondamaging releases from reservoir B, to determine minimum space requirement at reservoir A. Plot space required at A versus total space required, and envelop the plotted points, preferably with a straight line.

b. Route the project design flood with maximum proportion of runoff occurring above reservoir B, and all pertinent recorded floods, with maximum feasible nondamaging releases from reservoir B and the remainder of nondamaging releases at reservoir A to determine space usable at reservoir A. Plot space usable at A versus total space required and envelop on the lower side, preferably with a straight line.

c. The proportion of total required space that should be located in reservoir A is intermediate between these two envelope curves, and should generally remain a flexible amount where operational flexibility is desirable. The difference between the total required space and that usable in reservoir A is the minimum required in reservoir B. Similarly, the difference between the total required space and that required in reservoir A is that usable in reservoir B.

d. Releases from the two reservoirs should be scheduled so that whenever flood control space is occupied, the remaining empty space will be divided between the two reservoirs, insofar as possible, within the range of proportion indicated in c above.

Section 10.05. Index Levels and the Equivalent Reservoir Concept

In simulating the operation of a reservoir system, it has been found useful to employ concepts of "index levels" and "equivalent reservoirs" for determining release priorities among reservoirs. Index levels are integer numbers assigned to certain elevations in a reservoir. The levels are assigned in such a way as to control the "balancing" of the reservoir system. A system is "in balance" when all reservoirs are at the same index level. The level of a given reservoir at a given point in time is obtained by linear interpolation in a table of index levels versus storage for the reservoir. In balancing levels among reservoirs, priority for releases is governed by the criteria that reservoirs at the highest levels at a given point in time are given first priority for making releases. Exhibit 4 in Appendix 1 illustrates how index levels can be chosen to control operation rules for a reservoir system. Procedures in section 10.03 and 10.04 can be useful in establishing the amount of storage in each reservoir for each index level.

In determining the priority of reservoir releases among parallel reservoirs, or among subsystems of a reservoir system, the concept of an "equivalent reservoir" is used. For example, consider a situation in which two parallel reservoirs are upstream from a third, as shown in fig. 10.02. Table 10.01 shows level-storage characteristics for a reservoir equivalent to the three reservoirs.

Suppose that it is desired to determine the amount of release to make from reservoirs 1 and 2 and that storages in reservoirs 1, 2 and 3 at the end of the previous time period are 35, 12.5 and 3, respectively. For these storages, the equivalent reservoir storage is 50.5 and the equivalent level is 3.97. The levels of reservoirs 1, 2 and 3 are 4.5, 3.5 and 2.5, respectively. A criteria that could be used to control releases is that releases will be made from an upstream reservoir (reservoir 1 or 2) if its level is above the greater of the level of reservoir 3 or the

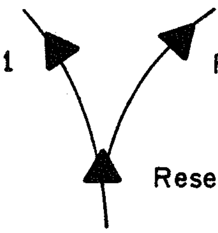


Fig. 10.02. Reservoir configuration for equivalent reservoir example

Cumulative Storage - Acre Feet				
Index Level	Reservoir 1	Reservoir 2	Reservoir 3	Equivalent Reservoir
5	40	20	8	68
4	30	15	6	51
3	20	10	4	34
2	10	5	2	17
1	0	0	0	0

Table 10.01. Equivalent reservoir level-storage characteristics

equivalent reservoir level (reservoirs 1, 2 and 3). Therefore, a release would be made from reservoir 1 and not from reservoir 2 because the level of reservoir 1 is above the equivalent reservoir level and the level of reservoir 2 is below the equivalent reservoir level. The actual releases would of course be governed by physical and other constraints that must be met.

Computer program HEC-5C, which is described in detail in Appendix 1, uses both the index level and equivalent reservoir concepts in simulating operation of reservoir systems.

Chapter 11

Operation Compromise for Rainfloods

CHAPTER 11. OPERATION COMPROMISE FOR RAINFLOODS

Section 11.01. Operation Conflicts

There is practically no case of multiple use of reservoir space where the accomplishment of one objective does not interfere to some extent with the accomplishment of other objectives. Since there is in all cases a conflict of interest, there is sometimes the temptation to depart from flood control regulations in the interest of other objectives, particularly irrigation and power generation. The temptation to infringe on flood control space is sometimes strong, because usually losses to other functions are obvious, and losses to flood control (although potentially much greater) may not occur or indeed probably will not occur in any particular case. Consequently, a very rigid attitude against infringement on flood control space must be maintained at all times. However, when the flood control rules are formulated, it must be recognized that there are certain periods in the year when the probability of floods is low and the value of space for other purposes is particularly high, and consideration should be given to reducing the flood control requirements during these periods and increasing them at other times.

Section 11.02. Early Filling Requirements

In many cases, provision of the full flood control space until the end of the rain-flood season will prevent the use of such space during the non-flood season for other purposes. Generally this occurs where there is very little runoff after the end of the flood season. In these cases a reduction in the required flood control space toward the end of the season can be considered, but the reduction should be minor if assured flood protection is to be obtained. There have been many disastrous consequences of too-early reservoir filling. A suggested rule to follow is to diminish normal flood control requirements only where the additional space is required and more beneficial for other purposes, but to provide on any date at least two-thirds of the flood control space that would be required for that day by normal flood control criteria. A means of compensating for such reduction of space requirement is suggested below.

Section 11.03. Delayed Drawdown

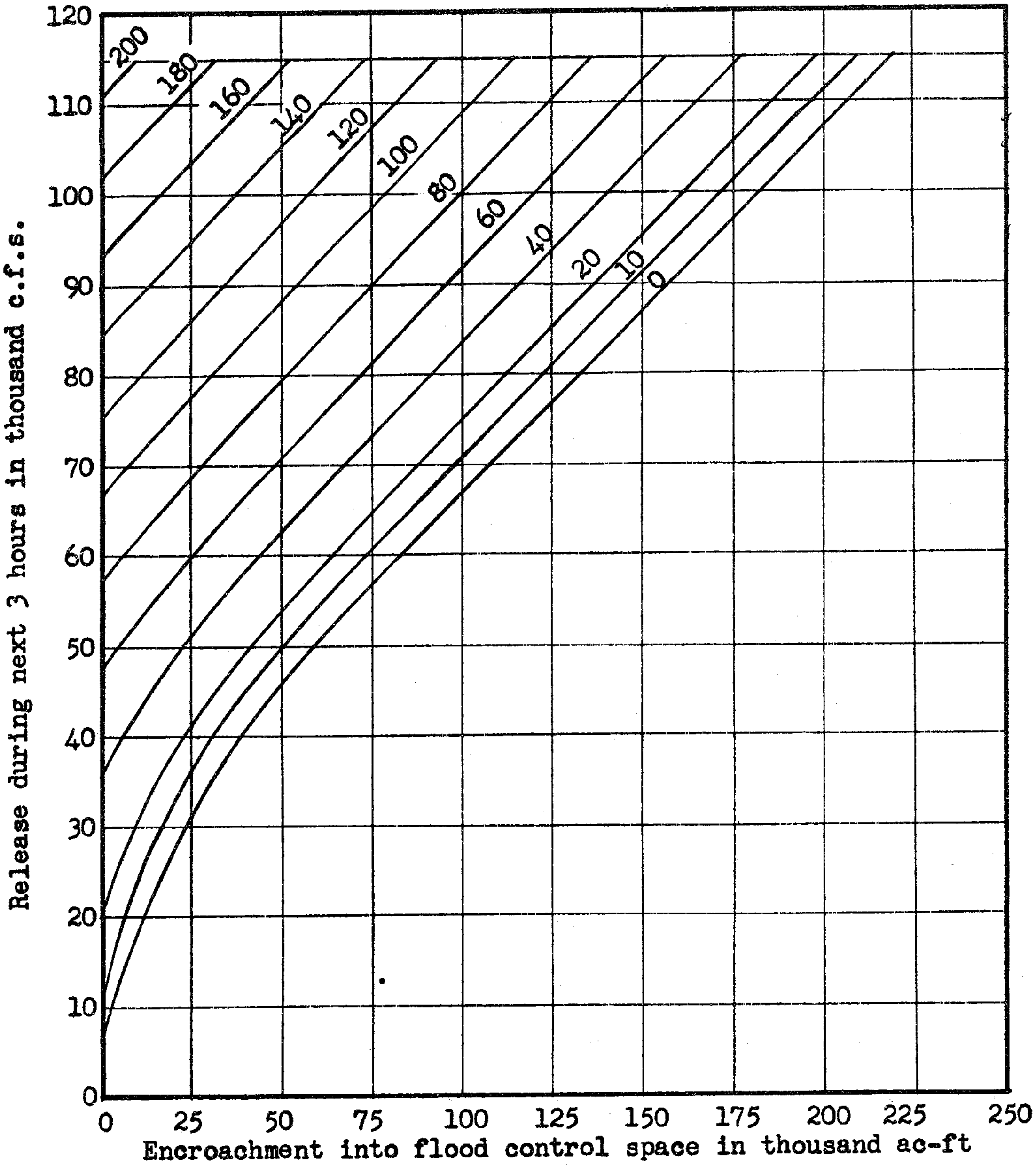
For the beginning of a flood season, it may be desirable to incorporate in the diagram a moderate reservoir drawdown provision that would result in emptying the flood control space at a later date than that required for full flood protection, in order to increase the effective use of the released water. Decisions to do this should be based on principles and considerations discussed in the preceding paragraph. Reduction should generally not be made unless important conservation benefits are thereby obtained and should not be made to the extent that would seriously impair assured flood protection.

Section 11.04. Transition Operation

The nature of flood control rules is ordinarily such that flood releases are often not required until it is estimated that full releases should be continued until the flood terminates. This minimizes the possibility of wasting water unnecessarily. If transition criteria between normal conservation operation and flood control operation are considered necessary, they should be incorporated into the rules, and the required flood control space would thereby be increased. Where releases over and above normal conservation uses can be utilized, consideration should be given to releasing at intermediate rates during periods when a surplus of water is apparent and maximum flood control releases are not yet required. (In the case of snowmelt runoff that can be forecast far in advance, this can be accomplished by a separate set of parameters based on releases at a specified intermediate rate between any given date and the date the reservoir is expected to fill.)

After flood waters have been stored in a reservoir where high release rates are employed, it is necessary to plan the reduction of the releases so that they will be reduced to conservation rates by the time the flood control space has been evacuated, without exceeding the safe rate of reduction. This can be done by constructing a set of curves similar to those shown in fig. 11.01 as follows:

a. Determine a safe rate of reduction of flood release for various release rates. This should usually be such that the rate of fall of downstream river stages will be somewhat less than the maximum observed rate



NOTES:

1. For use only when peak inflow is past or no large increase in inflow is anticipated.
2. Parameter values are current inflow in thousand c.f.s.
3. Do not change release more than 10,000 c.f.s. during any 2-hour period.

Fig. 11.01. Criteria for reduction of flood releases

of fall of preproject river stages after floods. For example, fig. 11.01 is based on the following schedule:

Range of release (cfs)	Rate of change of release per 3 hours	Rate of change of river stage (ft/3 hours)
5,000 - 25,000	5,000 cfs	2.2 - 1.2
25,000 - 60,000	6,000 cfs	1.4 - 1.1
60,000	10%	1.1 - 1.7

b. For selected periods of time prior to the time that releases are reduced to conservation rates, compute the volume of water that would be released in accordance with the adopted release reduction schedule (see column 3 of table 11.01.)

c. Select a rate of inflow recession which is somewhat less than the most rapid observed rate of inflow recession after floods. This is expressed as the time in days required for the flow to recede from a value Q to a value equal to Q/2.718, and is designated as T_S. The curves of fig. 11.01 are based on a value of T_S = .542 days.

d. The volume under a logarithmic recession curve during a period of t days after an initial inflow Q is given by the following equation:

$$V = 1.98\, T_S\, Q\, (1 - e^{-t/T_S}) \qquad (11\text{-}1)$$

in which:

V = volume under the recession curve in acre-feet

T_S = the recession time constant in days (see c above)

Q = the initial inflow in c.f.s.

t = time in days after the initial inflow

Table 11.01

COMPUTATION OF RELEASE REDUCTION CRITERIA

(Volumes in thousand acre-feet)

Remaining hours of release	Release: Next 3 hrs in thous cfs	Release: Remaining volume	Remaining inflow volume when current inflow (thousand cfs) is equal to: 20	40	60	80	100	120	140	160	180	200
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
48	115.0	219.4	21.0	41.9	62.9	83.8	104.8	125.8	146.7	167.7	188.6	209.6
45	103.5	190.9	20.8	41.6	62.5	83.3	104.1	124.9	145.7	166.6	187.4	208.2
42	93.1	165.2	20.6	41.3	61.9	82.6	103.2	123.8	144.5	165.1	185.8	
39	83.8	142.1	20.4	40.8	61.3	81.7	102.1	122.5	142.9	163.4		
36	75.4	121.3	20.1	40.3	60.4	80.6	100.7	120.8				
33	67.9	102.6	19.8	39.6	59.4	79.2	99.0	118.8				
30	61.1	85.8	19.4	38.7	58.1	77.4	96.8					
27	55.0	70.7	18.8	37.6	56.4	75.2						
24	49.0	57.0	18.1	36.2	54.3							
21	43.0	44.9	17.2	34.4	51.7							
18	37.0	34.2	16.1	32.2								
15	31.0	25.0	14.7	29.4								
12	25.0	17.4	12.9									
9	20.0	11.2	10.7									
6	15.0	6.2	7.9									
3	10.0	2.5										
0	7.5	0										

	Flood-control storage when current inflow (thousand cfs) is equal to: 20	40	60	80	100	120	140	160	180	200
(1)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
48	198.4	177.5	156.5	135.6	114.6	93.6	72.7	51.7	30.8	9.8
45	170.1	149.3	128.4	107.6	86.8	66.0	45.2	24.3	3.5	
42	144.6	123.9	103.3	82.6	62.0	41.4	20.7	0.1		
39	121.7	101.3	80.8	60.4	40.0	19.6				
36	101.2	81.0	60.9	40.7	20.6	0.5				
33	82.8	63.0	43.2	23.4	3.6					
30	66.4	47.1	27.7	8.4						
27	51.9	33.1	14.3							
24	38.9	20.8	2.7							
21	27.7	10.5								
18	18.1	2.0								
15	10.3									
12	4.5									
9	0.5									

Using this equation, compute the volume of inflow (V) for each of several assumed values of initial inflow (Q) and for values of t corresponding to periods of release given in column 1, table 11.01 (see columns 4 to 13, table 11.01.)

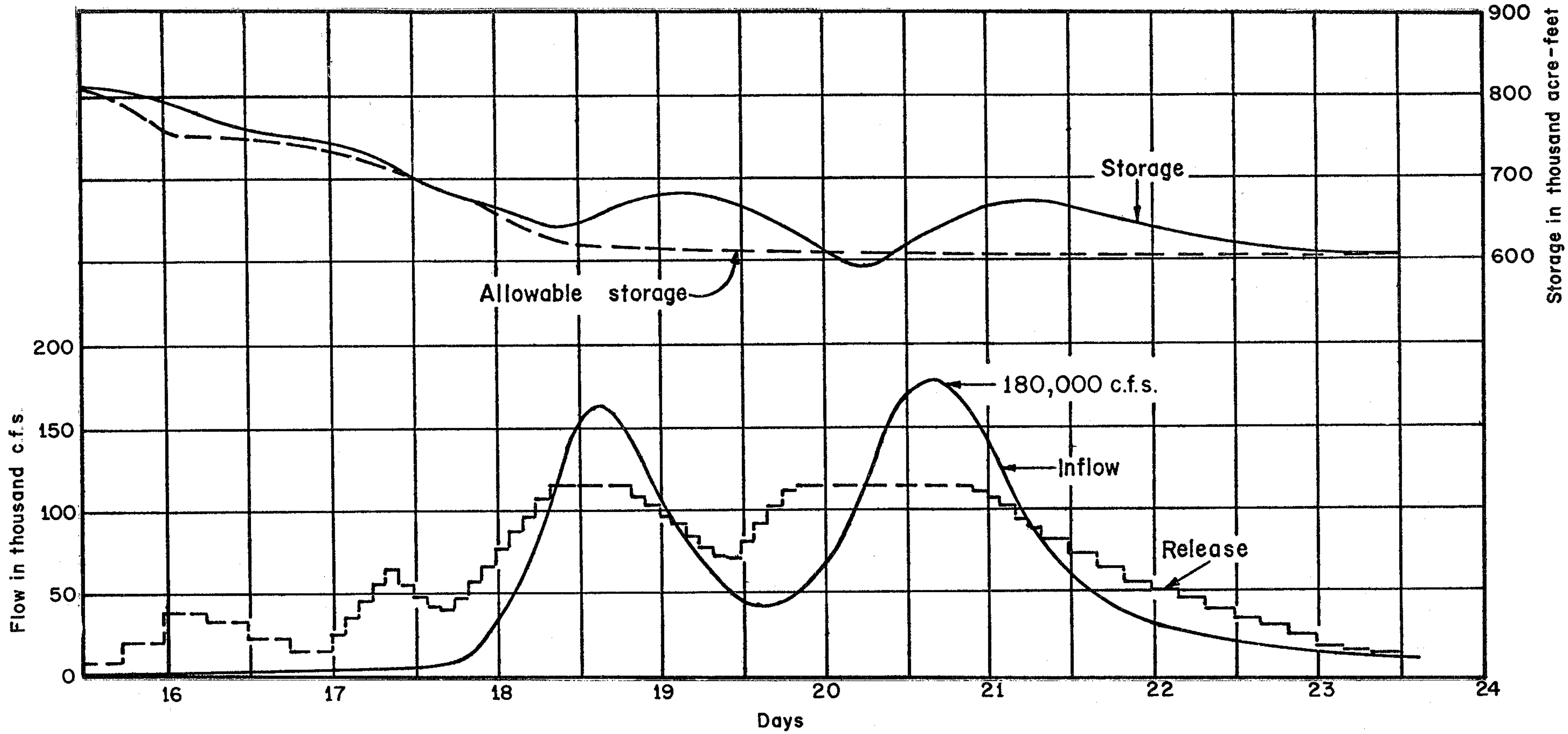
f. For corresponding periods of time, subtract these inflow volumes from the release volumes (column 3 of table 11.01) to obtain values of flood control storage (see columns 14 to 23 of table 11.01).

g. Release during the next 3 hours (column 2 of table 11.01) is plotted against flood control storage (columns 14 to 23, table 11.01) for each of the assumed values of initial inflow to obtain the curves of fig. 11.01. The parameter values of the curves are equal to the assumed initial inflow.

In using the curves constructed as described above, whenever the indicated release corresponding to the current inflow and current flood control storage is less than the current release, the release should be reduced to the indicated value. This process is repeated each interval (every 3 hours, in this case) until the release has been reduced to conservation rates. Fig. 11.02 illustrates the use of release-reduction criteria.

Section 11.05. Means of Compensating for Space Reduction

Whenever regulations provide less flood control space at any particular time than would be required for complete control of design rain floods with seasonal adjustment (in order to increase the overall accomplishments of the project), compensating changes in constructing the



Notes:

Gross pool, 1,010,000 acre-feet.
Bottom of flood control reservation, 610,000 acre-feet

Fig. 11.02. Hypothetical operation of recorded flood

diagram should be made, if feasible, or benefits claimed for the control of floods should be correspondingly reduced. A suggested procedure is as follows:

a. Construct a flood control diagram in accordance with principles discussed above so that assured control of the project design storm or flood is obtained. It is recognized that the element of chance is considered in constructing flood control diagrams, but the diagram should be such that the difference between accomplishments with the diagram and accomplishments obtained by providing the maximum flood control space inviolate at all times is not greater than 5 percent and preferably in the order of 1 or 2 percent.

b. Reduce required space during the period in question by not more than one-third (i.e., allow reservoir to be drawn down by a later date or to begin filling on an earlier date, but provide at any date at least two-thirds of the space required on that date by the normal flood control criteria).

c. Increase all ordinates of empty space by a constant ratio so that the area of the flood control diagram is equal to the original corresponding area.

Chapter 12

Use of Computer Programs

CHAPTER 12. USE OF COMPUTER PROGRAMS

Many of the computations needed for developing operation rules and criteria for flood control reservoirs can be accomplished by use of electronic computer programs contained in the various volumes of this report.

The computer program HEC-1, which is described in Appendix 1 of Volume 1, is capable of computing design floods and typical floods used for evaluating project accomplishments.

Computer program HEC-5C, which is described in detail in Appendix 1 of this volume, is intended for simulation of the sequential operation of a system of reservoirs of any configuration for short interval historical or synthetic floods or for long duration non-flood periods or for combinations of the two. The program may be used:

a. To determine flood control and conservation storage requirements of each reservoir in a system.

b. To determine the influence of a system of reservoirs on the spatial and temporal distribution of runoff in a basin.

c. To evaluate operational criteria for both flood control and conservation for a system of reservoirs.

d. To determine the average annual flood damages, system costs, and system net benefits for flood damage reduction.

e. To determine, by simulating selected alternative systems, the system of existing and proposed reservoirs or other alternatives, including nonstructural alternatives, that produces the maximum net benefits for flood control.

Reference 10 illustrates in considerable detail how HEC-5C can be used to analyze structural and nonstructural flood control measures.

A program for computing the discharge capacity of outlets for various openings of sluice gates is included as Appendix 2 of this volume and is entitled "Conduit Rating - Partial Gate Openings."

A program for computing the discharge capacity of a spillway for various openings of tainter gates is included as Appendix 3 of this volume and is entitled "Spillway Rating - Partial Tainter Gate Openings."

The program "Spillway Rating and Flood Routing," which is designed to facilitate the selection of spillway characteristics and to route floods through spillways, is described in Appendix 4.

Appendix 5 contains a description of a program entitled "Spillway Gate Regulation Curve," which performs most of the computations required for the development of emergency release diagrams discussed in Chapter 6.

The techniques employed in all of the above computer programs and the manner in which they are used are discussed in detail in the descriptions constituting each Appendix.

Selected Bibliography

SELECTED BIBLIOGRAPHY

1. Burnash, R. J. C., Ferral, R. L., and R. A. McGuire, "A Generalized Streamflow Simulation System-Conceptual Modeling for Digital Computers," Joint Federal-State River Forecast Center, Sacramento, California, March 1973.

2. Davis, C. V., ed., Handbook of Applied Hydraulics, 3rd ed., McGraw-Hill, 1969.

3. King, H. W. and Brater, E. F., Handbook of Hydraulics, 5th ed., McGraw-Hill, 1963.

4. U. S. Army Corps of Engineers, North Pacific Division, "Program Description and User Manual for Streamflow Synthesis and Reservoir Regulation SSARR," Portland, Oregon, September 1972.

5. U. S. Army Corps of Engineers, Office, Chief of Engineers, Hydraulic Design Criteria, prepared by the Waterways Experiment Station, Vicksburg, Mississippi.

6. U. S. Army Corps of Engineers, Office, Chief of Engineers, "Reservoir Regulation," EM 1110-2-3600, Washington D. C., 1959.

7. U. S. Army Corps of Engineers, Office, Chief of Engineers, "Routing of Floods Through River Channels," EM 1110-2-1408, Washington D. C., 1960.

8. U. S. Army Corps of Engineers, Office, Chief of Engineers, "Hydraulic Design of Reservoir Outlet Structures," EM 1110-2-1602, Washington D. C., 1963.

9. U. S. Army Corps of Engineers, Sacramento, California, "Reservoir Operation Criteria for Flood Control, Sacramento-San Joaquin Valley, California," October 1959.

10. U. S. Army Corps of Engineers, The Hydrologic Engineering Center, "Analysis of Structural and Nonstructural Flood Control Measures Using Computer Program HEC-5C," Training Document Number 7, April 1975.

11. U. S. Department of Commerce, National Weather Service, "National Weather Service River Forecast System Forecast Procedure," NOAA Technical Memorandum NWS-HYDRO-14, Washington D. C., 1972.

12. United Nations and World Meteorological Organization, "Methods of Hydrological Forecasting for the Utilization of Water Resources," Transactions of the Inter-Regional Seminar on Methods of Hydrological Forecasting for the Utilization of Water Resources, held at Bangkok, Thailand, 4-17 August 1964, Water Resources Series No. 27, United Nations Publication.

Appendix 1

HEC-5C
Simulation of Flood Control And Conservation Systems

COMPUTER PROGRAM 723-500
HEC-5C RESERVOIR SYSTEM OPERATION FOR FLOOD CONTROL AND CONSERVATION

JULY 1975

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEER, U.S. ARMY
609 SECOND STREET
DAVIS, CALIFORNIA 95616

FOREWORD

This is the fifth in a special series of comprehensive programs, each of which is intended to be a major computational aid for solving problems associated with a particular area of hydrologic engineering. The programs currently in this series are:

HEC-1, Flood Hydrograph Package

HEC-2, Water Surface Profiles

HEC-3, Reservoir System Analysis (for Conservation)

HEC-4, Monthly Streamflow Simulation

HEC-5C, Simulation of Flood Control and Conservation Systems

Up-to-date information and copies of source statement cards for the programs are available from the Center. While the Government is not responsible for the results obtained when using the programs, assistance in resolving malfunctions in the programs will be furnished to the extent that time and funds are available. It is desired that users notify the Center of inadequacies in, or desirable modifications to, the program.

SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS

USERS MANUAL

TABLE OF CONTENTS

Table of Contents (Continued)

HEC-5C

SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS

USERS MANUAL

INTRODUCTION

1. ORIGIN OF PROGRAM

This program was developed in The Hydrologic Engineering Center by Bill S. Eichert. The initial version was written for flood control operation of a single flood event and was released as HEC-5, "Reservoir System Operation for Flood Control," in May 1973. The source deck for the HEC-5 program is still available and data prepared for HEC-5 is compatible with the HEC-5C version as presented in this manual.

2. PURPOSE OF PROGRAM

This program was developed to assist in planning studies for evaluating proposed reservoirs in a system and to assist in sizing the flood control and conservation storage requirements for each project recommended for the system. The program can be used in studies made immediately after the occurrence of a flood to evaluate preproject conditions and to show the effects of existing and/or proposed reservoirs on flows and damages in the system. The program should also be useful in selecting the proper reservoir releases throughout the system during flood emergencies in order to minimize flooding as much as possible and yet empty the system as quickly as possible while maintaining a balance of flood control storage among the reservoirs.

The above purposes are accomplished by simulating the sequential operation of a system of reservoirs of any configuration for short interval historical or synthetic floods or for long duration nonflood periods or for combinations of the two. Specifically the program may be used to determine:

a. Flood control and conservation storage requirements for each reservoir in the system.

b. The influence of a system of reservoirs on the spatial and temporal distribution of runoff in a basin.

c. The evaluation of operational criteria for both flood control and conservation (including hydropower) for a system of reservoirs.

d. The expected annual flood damages, systems costs, and system net benefits for flood damage reduction.

e. The system of existing and proposed reservoirs or other alternatives including nonstructural alternatives that results in the maximum net flood control benefits for the system by making simulation runs for selected alternative systems.

3. HARDWARE AND SOFTWARE REQUIREMENTS

The program, written in FORTRAN IV, was developed on a CDC 7600 computer with 65K words of central memory and 500K words of extended memory. The UNIVAC 1108 version using 65K words of storage, can simulate the operation of 10 reservoirs, 15 control points, 11 diversions, and 9 power plants, using any number of time periods in each flood or nonflood event. The program may be used on a smaller computer system with 8 scratch units if arrays are appropriately dimensioned. Dimension limits for the CDC 7600 computer allows the simulation of 35 reservoirs, 55 control points, 20 diversions, and 9 power plants for any number of time periods for each runoff event.

4. GENERAL CAPABILITIES AND LIMITATIONS OF PROGRAM

a. Configuration of system

(1) Any reservoir system configuration may be used as long as dimension limits are not exceeded for number of reservoirs, number of control points, number of diversions, etc. (See para. 3 above.)

(2) The most upstream control point on each tributary must be a reservoir.

(3) Reservoirs which have flood control storage may be operated to minimize flooding at any number of downstream control points.

(4) Reservoirs without flood storage will be operated for their own requirements (power or low flow) and can be operated to provide low flow requirements for any number of downstream control points.

(5) Reservoirs may be deleted by specifying the applicable identification number on the J5 card (becomes a reservoir with no storage) or by removing the appropriate cards RL-PH (becomes only a control point).

(6) Upstream tandem reservoirs may not be operated directly for control points below a downstream tandem reservoir, however the downstream tandem reservoir considers the upstream system storage when making its release.

(7) Reservoirs in the system that operate for a common control point are kept in balance as much as possible.

(8) Reservoir and control point identification number may be any integer number up to six digits. The computer uses a series of internally generated numbers for storage of variable arrays.

(9) Dimension limits (shown for UNIVAC 1108) can be easily modified by changing these variables and the common statements:

KNCPT = 15 - Number of control points
KRES = 10 - Number of reservoirs
KCHSTG = 18 - Number of values of channel storage and discharge
KDIV = 11 - Number of diversions
KLEV = 8 - Number of reservoir target levels
KNCAPT = 18 - Number of values of reservoir storage, discharge, etc.
KFLCON = 9 - Number of ratios of a flood
KPWR = 9 - Number of power plants
KPER = 50 - Number of periods of system operation for one flood.

b. Reservoir Description

(1) Each reservoir must have a starting storage and storage values for each target level. Target levels can vary monthly or remain constant.

(2) Each reservoir operates for itself and as many downstream points as desired.

(3) Each reservoir must have a table of outlet capacities as a function of reservoir storages.

(4) Each reservoir is also considered a control point and requires control point data.

(5) Additional data on reservoir areas, elevations, and costs can be given as a function of reservoir storages.

c. Control Point Description.

(1) Each control point must have an operating channel capacity. The channel capacity can be constant or increase with channel flows.

(2) Each control point has an identifying name with up to 32 characters.

(3) Each control point is linked to the next downstream point by specifying the channel routing criteria.

(4) Additional data on elevation (or channel storage) vs discharge can be given for the channel.

d. Flow Data

(1) The program uses average incremental local flows (flows between adjacent control points) in the system routings.

(2) Incremental local flows can be calculated from observed discharges and reservoir releases.

(3) Incremental local flows can be calculated from natural flows.

(4) The system operation can be performed or omitted after flows are determined.

(5) Computed incremental local flows can be output on punched cards for subsequent system operations.

(6) If end of period flow data is given, the program will first average the flow data.

(7) Flow data at some of the control points can be a ratio of the flow at another system point. The flows can also be shifted by even time intervals.

(8) Cumulative local and natural (if requested) flows are calculated for printout purposes.

(9) Flow cards can be for more time periods than the dimension limit and the computer will automatically generate an equivalent series of floods so that entire flood is operated.

(10) Flow data is normally read in 10 field formats but can be read in 12 field format for monthly flows.

e. Stream Routing

(1) The following stream routing methods are available: Straddle-stagger, Tatum, Muskingum, Modified Puls, and Working R&D.

(2) Each routing reach may be subdivided into several steps.

(3) When reservoir releases are routed by nonlinear methods (Modified Puls or Working R&D), linear approximations are used to determine the reservoir releases. The actual release is then routed by the nonlinear method.

(4) Steady state is assumed for flows prior to the first period of routing.

f. Reservoir Routing

(1) Accounting method - the reservoir release is determined based on desired operation, storage is equal to inflow less outflow plus previous storage less evaporation (if specified).

(2) Surcharge routing - when the desired release is greater than the physical outlet capacity, an iterative method is used to find the outflow. This method provides the same results as the Modified Puls method.

(3) Emergency releases - when the desired release for the current period plus channel capacity releases for future periods (up to the limit of foresight specified) would cause a reservoir to exceed maximum flood storage in current or future periods, a release can be made for the current period (up to the outlet capacity) so that the reservoir does not exceed the top of flood pool in the near future.

g. Reservoir Operation

(1) Outflows can be specified for any number of reservoirs for any or all time periods (providing the outlet capacity is greater than the specified release) and the computer will adjust other reservoir releases as necessary; otherwise the computer will determine all reservoir releases.

(2) System operation can be made for a fewer number of time intervals than are used on the flow cards.

(3) Effects of forecast errors can be evaluated by specifying the number of forecast periods and a corresponding contingency allowance.

(4) Part of the system can be operated without removing the remaining system cards.

(5) For printout purposes, uncontrolled cumulative local flows (flow below all upstream reservoirs) do not include releases from upstream reservoirs if one acre-foot or more of flood control storage is used, otherwise uncontrolled local flows will include flows from upstream reservoir drainage areas.

(6) In addition to flood control operation, conservation operation may be specified to provide minimum flows at one or more downstream locations, for two levels of dependability (desired and required), based on reservoir storage.

(7) A reservoir can operate to meet at-site power requirements in kilowatt-hours.

h. Reservoir Releases	Case*
(1) Can be based on channel capacity at dam	.01
(2) Can be based on rate of change of release	.02
(3) Can be based on not exceeding the top of conservation pool	.03
(4) Can be based on emergency releases:	
(a) Surcharge routing (maximum outlet capacity)	.06
(b) Prerelease up to channel capacity using specified foresight	.04
(c) Prerelease which may be greater than the channel capacity using specified foresight	.04
(5) Can be based on keeping tandem reservoirs in balance using target levels	.05
(6) Can be based on maximum outlet capacity for given pool elevation	.06
(7) Can be based on not drawing reservoir empty (level 1)	.07
(8) Can be based on minimum <u>required</u> low flows read on CP card	.08
(9) Can be based on releases to draw to top of buffer pool	.09

***Shown on HEC-5C output**

		Case*
(10)	Can be based on primary energy demand for hydropower	.10
(11)	**Can be based on minimum release if all higher priority reservoirs in parallel with this project are not releasing**	.11
(12)	Can be based on release given on QA card	.99
(13)	Can be based on minimum desired low flows read from CP or MR or QM cards	.00
(14)	Can be based on filling downstream channel at location X and future time period Y for flood control or conservation operation	X.Y

i. Evaporation

(1) Evaporation data can be read for the entire basin or for individual reservoirs by monthly periods.

(2) Period by period evaporation data can be provided for any reservoir in the system.

j. Diversions

(1) Diversions can be made from any reservoir or control point up to the limit of dimension (KDIV=11). Only one diversion from each control point or reservoir is allowed.

(2) Diversions can be made to any downstream control point or reservoir, or they can also leave the system.

(3) Diversions may be routed using any linear method allowed and multiplied by a constant representing the percent of return flow.

(4) Types of diversions

(a) Diversions can be a function of inflows, e.g.,

QS (Channel Q)	0	10	20	50
QD (Diversion)	0	5	7	10

(b) Diversions can be functions of reservoir storages, e.g.,

RS (Reservoir storage)	0	10,000	20,000	30,000
RD (Reservoir diversion)	0	50	700	1,000

(c) Diversions can be constant (e.g., 50 cfs for control point #5).

(d) Diversions can be constant for certain periods such as 50 cfs for January, 40 cfs for February, etc.

(e) Diversions can be made for all excess water above the top of conservation pool up to the diversion capacity.

k. Hydropower

(1) Reservoirs can operate to meet **combinations of monthly, weekly, daily and multihourly** primary hydropower energy requirements.

(2) A tailwater rating curve can be defined as a reservoir outflow vs elevation table. Tailwater elevation can also be based on a downstream reservoir elevation **or on a block loading tailwater.**

(3) Power peaking capability can be a constant, a function of reservoir storage, or a function of reservoir releases.

(4) Power efficiency can be a constant, a function of reservoir storage, or a kw/cfs coefficient vs reservoir storage.

(5) A constant leakage through the dam can be specified. This water would not be available for power generation.

l. Multifloods

(1) The multiflood option may be used to operate the system for a continuous period of record with a mixture of computation intervals. A monthly operation could be used for a few years (assuming no routing is desired) and then operate for daily or hourly flows during a major flood (with detailed flood routing) and then back to a weekly or monthly routing interval, etc. An unlimited number of events can be simulated in this manner.

(2) Up to 9 ratios of any or all floods read can be run in a simulation operation.

(3) Each flood in a series of floods can **start at different** reservoir storages on RI card, or from the same storages, or can be continued using the storages from the previous flood.

(4) Long floods may be routed by dividing the flood into flow events which are each less than the dimension limit KPER. This may be done by manually setting up several sets of flow data (with each less

than KPER) or by allowing the computer to generate separate floods (when the data read exceeded KPER). A minimum of a 10 period overlap between floods is used to preserve continuity in channel routing.

m. Expected annual damages

(1) Expected annual damages can be computed for any or all control points (nonreservoirs) using one or more ratios for each of several historical or synthetic floods (minimum combination of six events recommended) as described in Exhibit 5.

(2) Damages for a single flood can be computed if only that flood is operated in a given computer run.

(3) Expected annual damage (or damages for a single flood) will be computed for the following three conditions:

(a) Natural or unregulated conditions

(b) Regulated conditions due to the reservoir system assumed

(c) Unlimited flood control storage at all reservoir sites (uncontrolled local flows)

(4) Damages calculated for natural flows using selected floods and ratios are adjusted to expected annual damages by integrating the natural damage-frequency curve. A predetermined expected annual damage may be input and the succeeding calculations will be adjusted by the ratio to the computed damages.

(5) The expected annual damages for modified conditions and for the uncontrolled local flows are based on flow values determined by a linear interpolation between each flood event, expressed as a ratio to the natural flow.

(6) Up to 9 different damage categories may be used.

(7) If the proposed system contains existing reservoirs, the damage reduction can be evaluated from a base condition which is for the existing system.

(8) Expected annual damages, costs and system net benefits for flood damage reduction can also be evaluated for nonreservoir alternatives such as levees, channel improvements and nonstructural alternatives (flood proofing, relocation, flood plain zoning, etc.).

n. Input data

(1) All data cards use the first two columns for identification.

(2) Most data cards are optional and can be omitted unless options are desired (e.g., J3-J8, etc.).

(3) Input is coded into 8 column fields for all input except for one optional flow data format of 6 column fields.

(4) A blank field is taken as a zero input.

(5) All cards used must be in correct order as shown on card summary and control points must be in order of treatment in routing and combining flows.

(6) Metric or English units can be used.

o. Output

(1) Input data card images and a rearranged labeled input summary are always provided. The following output will be provided if requested:

(2) Flow data

(3) Results of system operation arranged in downstream sequence for reservoirs and control points.

(4) Reservoir data by period.

(5) Reservoir releases and control point regulated flow by period.

(6) Summary of flooding in system for each flood.

(7) Summary of maximum and minimum values for all floods.

(8) Economic output.

(9) Summaries of expected annual damages for system, and of reservoir and control point costs and system net benefits for flood control.

(10) Frequency curve printer plot.

(11) Hydrologic efficiencies based on multiflood events.

(12) Computation of incremental local flows.

(13) Output error check.

(14) Printer plots for hydrographs at designated control points.

(15) Specified variables at selected control points can be printed for all time periods (user determined output).

(16) Trace features can be called to print out intermediate answers for certain control points (TC card) and certain time periods (TP cards). The level of trace is assumed as 15 unless shown on the J2 card.

5. RESERVOIR OPERATIONAL CRITERIA

a. Reservoirs are operated to satisfy constraints at individual reservoirs, to maintain specified flows at downstream control points, and to keep the system in balance. Constraints at individual reservoirs are as follows:

(1) When the level of a reservoir is between the top of conservation pool and the top of flood pool, releases are made to attempt to draw the reservoir to the top of conservation pool without exceeding the designated channel capacity at the reservoir or at downstream control points for which the reservoir is being operated.

(2) Releases are made equal to or greater than the minimum desired flows when the reservoir storage is greater than the top of buffer storage, and equal to the required flow if between level one and the top of buffer pool. No releases are made when the reservoir is below level one (top of inactive pool). Releases calculated for hydropower requirements will override minimum flows if they are greater than the controlling desired or required flows.

(3) Releases are made equal to or less than the designated channel capacity at the reservoir until the top of flood pool is exceeded, then all excess flood water is dumped if sufficient outlet capacity is available. If insufficient capacity exists, a surcharge routing is made. Input options permit channel capacity releases (or greater) to be made prior to the time that the reservoir level reaches the top of the flood pool if forecasted inflows are excessive.

(4) The reservoir release is never greater (or less) than the previous period release plus (or minus) a specified percentage of the channel capacity at the dam site, unless the reservoir is in surcharge operation.

b. Operational criteria for specified downstream control points are as follows:

(1) Releases are not made (as long as flood storage remains) which would contribute to flooding at one or more specified downstream

locations during a predetermined number of future periods. The number of future periods considered is the lesser of the number of reservoir release routing coefficients or the number of local flow forecast periods.

(2) Releases are made, where possible, to exactly maintain downstream flows at channel capacity (for flood operation) or for minimum desired or required flows (for conservation operation). In making a release determination, local (intervening area) flows can be multiplied by a contingency allowance (greater than 1 for flood control and less than 1 for conservation) to account for uncertainty in forecasting these flows.

c. Operational criteria for keeping a reservoir system in balance are as follows:

(1) Where two or more reservoirs are in parallel operation for a common control point, the reservoir that is at the highest index level (see paragraph 6), assuming no releases for the current time period, will be operated first to try to increase the flows in the downstream channel to the target flow. Then the remaining reservoirs will be operated in a priority established by index levels to attempt to fill any remaining space in the downstream channel without causing flooding during any of a specified number of future periods.

(2) If one of two parallel reservoirs has one or more reservoirs upstream whose storage should be considered in determining the priority of releases from the two parallel reservoirs, then an equivalent index level is determined for the tandem reservoirs based on the combined storage in the tandem reservoirs. (See paragraph 7.)

(3) If two reservoirs are in tandem, the upstream reservoir can be operated for control points between the two reservoirs. In addition, when the upstream reservoir is being operated for the downstream reservoir, an attempt is made to bring the upper reservoir to the same index level as the lower reservoir based on index levels at the end of the previous time period.

d. Reservoir operational priority for different purposes is shown in Table 1.

TABLE 1

RESERVOIR OPERATIONAL PRIORITY[1]

Reservoir Operating for:	Reservoir Storage Space: Flood Control	Main Conservation	Buffer
Flood Control[2]	Yes[3]	Yes[3]	Yes[3]
Hydropower (Primary)	No [3]	Yes	No [3]
Reservoir Diversion	Yes	Yes	No [3]
Channel Diversion[4]	Yes	Yes	Yes
Desired Minimum Flow	No [3]	Yes	No
Required Minimum Flow	No	Yes	Yes

(1) Table shows whether reservoir will be operated for a specific purpose based on the current reservoir pool elevation.

(2) No releases are normally made which would contribute to downstream flooding.

(3) Operation priorities can be changed by using input variable IPRIO(J3.9).

(4) Channel diversions are made as long as there is water in the channel.

6. INDEX LEVELS

As indicated in previous paragraphs, index levels assigned by the program user to each reservoir are used to determine priority of releases among reservoirs. The program operates to meet specified constraints throughout the system and then to keep all reservoirs in the system in balance if possible. A system is "in balance" when all reservoirs are at the same index level. In establishing the reservoir index level at a given point in time during a system operation, the program interpolates linearly on an input table of index level vs storage. In balancing levels among reservoirs, priority for releases is governed by index levels such that reservoirs at the highest levels at the end of the current time period (assuming no releases) are given first priority for the current time period. Exhibit 4 shows how the index levels can be used to specify operating rules for a system.

7. EQUIVALENT RESERVOIRS

In determining the priority of reservoir release among parallel reservoirs, or among subsystems of a reservoir system, the concept of an "equivalent" reservoir is used. The concept is based on weighting the level of each reservoir in a subsystem by the storage in the reservoir to determine a storage-weighted level for the subsystem. For example, consider a situation in which two parallel reservoirs are upstream from a third, as shown in figure 1.

Figure 1. Reservoir Configuration for Equivalent Reservoir Example

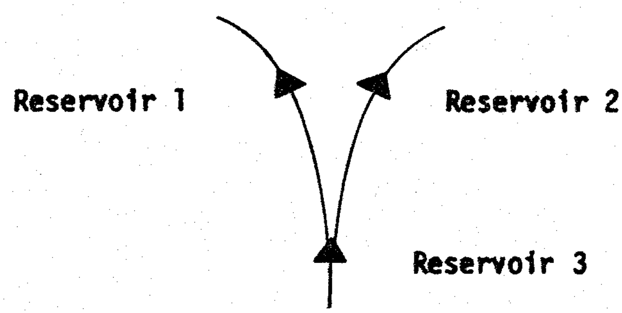


Table 2 shows the level-storage characteristics of the equivalent reservoir.

Cumulative Storage - Acre Feet				
Index Level	Reservoir 1	Reservoir 2	Reservoir 3	Equivalent Reservoir
5	40	20	8	68
4	30	15	6	51
3	20	10	4	34
2	10	5	2	17
1	0	0	0	0

Table 2. Equivalent Reservoir Level-Storage Characteristics

Suppose that it is desired to determine the amount of release to make from reservoirs 1 and 2 and that storages in reservoirs 1, 2 and 3 at the end of the previous time period are 35, 12.5 and 3, respectively. For these storages, the equivalent reservoir storage is 50.5 and the equivalent level is 3.97. The levels of reservoirs 1, 2, and 3 are 4.5, 3.5 and 2.5, respectively. The criteria used in the computer program is that releases will be made from an upstream reservoir if its level is above the greater of the level of reservoir 3 or the equivalent reservoir level. Therefore, a release would be made from reservoir 1 and not from reservoir 2 because the level of reservoir 1 is above the equivalent reservoir level and the level of reservoir 2 is below the equivalent reservoir level. However, the releases would also be governed by physical and other constraints that have been specified.

Figure 2 and table 3 illustrate the use of the equivalent reservoirs concept with both parallel and tandem reservoirs.

Figure 2. Example for Reservoirs in Parallel and Tandem

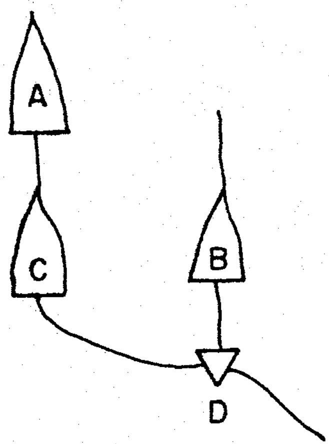


Table 3 shows 3 reservoirs with same flood control storage. Values are given in percent of storage used.

A	C	Equivalent A-C	B	Highest Priority B or C	Release from A
60	40	50*	30	C	Yes
60	20	40*	30	C	Yes
30	20	25*	30	B	Yes
15	35*	25	30	C	No

*highest of C or A-C

Table 3. Release Priority for Tandem and Parallel Reservoirs

8. RESERVOIR RELEASE DETERMINATION

The determination of a reservoir release required to bring the flow at a downstream control point to channel capacity is based on solving the following linear-routing equation:

$$O_n = C_1R_n + C_2R_{n-1} + C_3R_{n-2} + \ldots \qquad (1)$$

where:

O_n = Ordinate of discharge hydrograph at a downstream control point at time n.

R_n, R_{n-1}, etc. = Ordinates of a reservoir release hydrograph at times n, n-1, etc.

C_1, C_2, etc. = Reservoir release routing coefficients

The routing coefficients in equation (1) are determined from routing criteria input to the program. Theoretically, there can be an infinite number of coefficients; however, the sum of the coefficients will equal 1. An illustration of the application of equation (1) to determine reservoir releases (R_n) is given in exhibit 2.

9. STREAM ROUTING METHODS

Stream routing procedures incorporated in the program are the Modified Puls, Muskingum, progressive average-lag (straddle-stagger), and Working R and D methods. These methods are described in Engineering Manual 1110-2-1408, "Routing of Floods through River Channels," US Army Corps of Engineers, March 1960, and are briefly summarized in exhibit 1.

10. DIVERSIONS

Diversions may be specified from any control point or reservoir as long as there is only one diversion from that location. The diversions may be routed using linear routing criteria as specified on the DR card (card required for each point of diversion). Diversion cards (DR and RD or QD) are prepared for locations where the flow is diverted from the system and are not used at locations where the flow returns to the system. Four types of diversions may be specified:

a. Diversions can be a function of flows in the channel.

b. Diversions can be a function of reservoir storages.

c. Diversions can be constant.

d. Diversions can be constant for a given number of periods. The diversion data are specified on the QD card.

Where diversions are a function of reservoir storage, it can also be specified that any excess flow above the top of conservation pool is diverted up to the limit of the diversion shown as RD vs RS cards.

11. HYDROELECTRIC POWER

The operation for hydroelectric power currently consists of operation of individual projects (no power systems) based on a specified installed power plant nameplate capacity. The program determines the quantity of water required to produce a specified energy using the available head for the current period. The power requirements can be specified in thousands of kilowatt-hours for the twelve months of the year or they may be specified as a plant factor for each month. The requirements may also be specified for each time period (PV cards). Daily and hourly distributions can also be specified on PD and PH cards. An overload factor of 15% is normally allowed, but may be specified differently in the input. The block loading tailwater is normally used in determining the effective head for power, however, if a downstream reservoir influences this tailwater elevation this may be considered in the calculation. For run-of-river power plants, the tail-water elevation may be described as a function of the discharge at that control point. The power plant efficiency at the installation is normally assumed to be equal to .86 throughout the range of operating heads, however, the efficiency may be specified by input as some other constant or the power plant efficiency may be specified to vary with the reservoir storage. The power plant efficiency may also be specified as a function of reservoir storage using kw/cfs coefficients. Turbine-generator capability can be evaluated as a function of reservoir storage where head fluctuations are primarily due to headwater fluctuations <u>or</u> the capability can be evaluated as a function of reservoir release where head fluctuations are primarily due to changes in tailwater.

12. ALTERNATIVE RESERVOIR SYSTEMS

When studies are being performed to evaluate proposed reservoirs, the data set (T1-ED cards) should be assembled so that all proposed reservoirs are included even if some of them would serve as alternatives of others. Control points should be selected and coded for all damage centers, reservoir operational locations, and information points. Once the entire system is coded, a J5 card can be used to delete reservoirs from the system for each alternative system selected. The J5 card can be used to delete any reservoir in the system except for downstream tandem reservoirs (these reservoirs can be deleted by removing cards (RL-PE). Expected annual flood damages (or flood damages for a single flood) can be evaluated at any number of control points by using cards DA-DC. Reservoir costs can also be evaluated by using the R$ card to show how the costs vary with reservoir storage (RS cards). The reservoir cost is based on the top of flood control storage value. If costs and expected annual flood damages are calculated, the net system flood benefits will be printed out for each alternative system operated. By careful selection of alternative systems, the system that produces the maximum net flood benefits can be determined by a reasonable number of separate computer runs.

13. NONRESERVOIR ALTERNATIVES

Structural and nonstructural alternatives to certain reservoirs can also be evaluated in the system simulation with or without reservoirs in the system. The existence of a levee or channel improvement can be reflected in the reservoir system operation by changing the channel capacity (CP.2) and by changing the routing criteria (RT cards) if appropriate. The performance can be represented by a revised damage function. At the present time only one set of routing criteria can be read for each reach and thus the natural and modified routings use the same criteria. This limitation requires that when the routing criteria is different between natural and modified conditions, the natural flows must be calculated by a separate computer run and entered as NQ cards when evaluating modified conditions. Costs of nonreservoir alternatives can be shown on the C$ card as functions of the channel discharges (QS card). For a given design discharge (C$.1) an interpolation is made using the above cards to determine the capital cost applicable to the control point. The average annual flood damages can be evaluated in the same manner as reservoirs. However, the zero damage point on the DC cards will be automatically changed to the design discharge (C$.1) for modified conditions if the C$ card is read and the 1st field of the C$ card is positive. Two sets of DC cards can be read as an alternative to the above procedure, in representing natural and regulated conditions, so that the entire damage curve can be changed for regulated conditions.

Certain nonstructural alternatives such as flood proofing and flood plain regulation can be handled similarly to structural alternatives by using two sets of DC cards; however, the nonstructural alternative will require defining the upper limit of the flood proofing, zoning, etc., as a channel capacity (CP.2) or design discharge (C$.1).

14. MULTIFLOOD OPTIONS

Since all input data arrays involving time periods are stored in the computer core for the dimension limit of KPER periods (50 or 100 depending on computer) each complete system operation can be made for only KPER periods (or less) at one time. Thus if the dimension limit of KPER is 50 and the number of flow periods read (NPER) is 60, two sets of flow data must be stored in the computer and operated upon separately. These two flow sets are called floods 1 and 2 even though in some instances they may represent monthly data. The flow data described above can be read as two separate floods using NFLRD=2 (field 5 of J2 card) with each flood having NPER less than KPER or it can be read as one flood (NFLRD=0 or 1) with NPER greater than KPER (see Table 4).

If the 60 periods of flow data are read as one flood, the program will automatically store the data on tape as two floods, will operate the system for the first flood and store the results on tape. The program then will transfer (except for monthly data) the last 10 flows plus a forecast period (card J2.3) to the beginning of the next flood, will read the second flood flows from tape, will operate the system for the second flood and printout all the results as if it were one flood. If flow cards are read using station number, date and 8 flows on the first card and 10 flows on each card thereafter, the length of the first flood will be set equal to 48 periods (based on reading the maximum number of full cards without exceeding KPER values). If the forecast period is 4 periods, then the last 14 periods of the data from the first flood (periods 35-48) will be transferred automatically to the beginning of the second flood.

The second flood will use the flow data for periods 49 through 60 of the original data. This data will be read as period 15 through 26 of the second flood. Periods 1 through 14 of the second flood is the carryover of periods 35 to 48 from the first flood (10 periods of flow for continuity and 4 periods for the forecast period). The first flood operated 48 periods, but with 4 periods of forecast, the operation could not "see" the four periods of flow after period 44. Thus the system must be reoperated starting with the original 45th period of flow data and using the reservoir storages from the first flood period 44. The second flood operation starts with the 45th period flow data which in terms of flood two is period 11. Periods 1 through 10 in flood 2 are not operated (they were operated in the first flood); they are required for routing purposes to preserve continuity. All of the above manipulation of flow data is accomplished automatically by the program if the number of flows (NPER) read is larger than the dimension limit of KPER.

TABLE 4

EXAMPLE OF TIMING CHANGES FOR MULTIFLOOD OPTION

Internal time Period Used in HEC-5C	Flood No. 1 Original Flow Period		Flood No. 2 Original Flow Period	
1	1		35	
∫	∫		∫	***
10	10		44	**
11	11		45	
12	12		46	
13	13		47	
14	14		48	X
15	15	X	49	
∫	∫	Y	∫	Y
26	26		60	
∫	∫			
35	35			
∫	∫			
43	43	***		
44	44*			
45	45	**		
46	46			
47	47			
48	48			

Y New flows

X Final system operation is made

* Reservoir Storages are transferred to second flood

** 14 flows which are transferred from flood 1 to flood 2

*** 10 flows transferred because of routing effects

If the number of floods read, NFLRD (J2.5) is specified as 2, and the first NPER is 48 (BF.2 or J1.1), and NPSTO (BF.6) is 44, and NPER of the second flood (BF.2) is 12, the same results will be obtained as if only one flood was read as described above.

If NPER is greater than KPER and it is desired to use only one flood the variable EPER (J1.6 or BF.6) can be set equal to 49 (one less than KPER) and the operation will be terminated after 49 periods of the first flood.

If it is desired to operate the system using two different ratios of the 60 period flow data and 4 periods of forecast in the above example, this can be accomplished by reading NFLRD = 0 (J2.5), NPER = 60 (J1.1 or BF.2), and by reading the two coefficients on the FC card (following the BF card). The results are translated into 4 floods as follows:

Flood	Period of Operation	Ratio
1	1 - 48	1
2	45 - 60	1
3	1 - 48	2
4	45 - 60	2

Combinations can be accommodated for several floods read, several ratios of each flood read, and automatic division of flood into several parts (because of number of ordinates exceeding dimension limits of KPER). The following table demonstrates how these options are noted where two floods are read (NFLRD = 2), three ratios are used (NFLCON = 3), and two floods are automatically generated to cover the length of the flood:

TABLE 5

EXAMPLE OF FLOOD SEQUENCING

Flood Read (IFLRD)	Flood Ratio (IFLCON)	Flood Half (INIF)	Flood No.
1	1	1	1
1	1	2	2
1	2	1	3
1	2	2	4
1	3	1	5
1	3	2	6
2	1	1	7
2	1	2	8
2	2	1	9
2	2	2	10
2	3	1	11
2	3	2	12

Flood 1 used the first half of the flood (INIF = 1), for the first flood ratio (IFLCON = 1) for the first flood read (IFLRD = 1), while flood 2 was for the second half of that flood. Flood 3 was for the first half of the first flood read using the second ratio, etc. Since the output is merged as one flood where the computation period is the same, the flood half (INIF) is only shown in trace output.

INPUT STRUCTURE

15. ORGANIZATION OF INPUT

The input structure is designed to be flexible with respect to specifying characteristics of the reservoir system and other inputs to the system. Each input card is described in detail in exhibit 7. The last two pages of the exhibit are a "Summary of Input Cards." The summary shows the order in which the cards should be placed.

16. TYPES OF INPUT CARDS

The various types of cards used are identified by two characters in card columns 1 and 2. These characters are read by the computer to identify the card. Types of cards are as follows:

a. Title Cards T1, T2, T3. Three title cards are required for each job. The titles specified on the cards are read in alpha format and printed at the beginning of each job.

b. Job Cards J1-J8. These cards are used to specify general information for the entire job such as the number of periods of routing, the routing time interval (Δt), etc. Cards J3-J8 are optional and are used only when one or more of the options or variables on the card apply. The J5 card is for reservoirs to be deleted, the J6 card represents basin evaporation, the J7 card is presently not used, and the J8 card allows the program user to specify output tables.

c. Trace Cards, TP, TC. These cards are also optional and are used to indicate the control points (TC) and time periods (TP) for which detailed output (trace information) is required.

d. Reservoir Cards, RL, RO, RS, RQ, RA, RE, RD, R$, R1, R2, and R3. These cards are used to describe characteristics of each reservoir. The first four cards are required and are used to specify the reservoir index levels (RL card), the downstream control points that the reservoir is operated for (RO card), and the reservoir storage-outflow characteristics (RS and RQ cards). Optional cards are used to describe the reservoir areas (RA), elevations (RE), reservoir diversions (RD), and costs (R$), and the R1 card is used to describe the initial storages for multiple floods or for multiple ratios of the same flood. The optional R2 card is to store rate of change variables and the optional R3 card stores evaporation data for this reservoir.

e. Power Reservoir Cards P1, PR, PD, PH, PQ, PT, PP, PS, PE and PV. The P1 and PR cards are required for a reservoir which has a power plant, but are omitted for all other reservoirs and nonreservoirs. The P1 card is a general card describing the general power characteristics. The PR card specifies the monthly power requirements. The PD and PH cards are used to specify the daily and multihourly power demands. The optional PQ and PT cards describe a tailwater rating curve, and the optional PP, PS and PE cards describe the peaking capabilities, power storage and power efficiencies, respectively. The optional PV cards can be used to specify power demand for each time period.

f. Control Point Cards, CP, ID, RT, DR, QS, SQ, QD, EL, C$, CC, and QM. The first three cards, which are required for each control point, are used to identify the control point and to specify channel capacity and routing criteria. The optional DR card describes the diversion routing criteria and the QS and SQ cards are used to input a storage-outflow table for routing to the next downstream control point and are required only if a nonlinear routing method is called for. In addition to control points at damage centers, each reservoir is considered to be a control point. Hence, control point cards and reservoir cards (paragraph d) are required for reservoirs.

The diversion data for the control point is described by the optional QD card. The optional EL card contains stage or elevation data corresponding to discharge data in a similar field of the QS card. The optional C$ card is used for control point costs (such as levees, etc.) and the optional CC card allows channel capacities to be a function of the inflows. The optional QM card is used to describe the minimum flows.

g. Damage Data Cards, DA, DB, DF, DQ, and DC. These optional cards are also control point cards and are, for a given control poing, used in computing damages for a single flood or expected annual damages. If damages are to be calculated for a given control point all of these cards except DB are required. The DA card is for predetermined expected annual damages for natural conditions while the DB card is for base conditions (existing reservoir system). The DF, DQ, and DC cards are for corresponding damage frequencies (DF), damage discharges (DQ), and damages (DC).

h. End of Data Card, ED. The ED card follows the data cards (CP-DC) for the most downstream control point in the system.

i. Beginning of Flood Cards, BF and FC. Optional card, BF, describes the conditions for the subsequent flow cards, IN-PV, such as the card format, the number of flows, the computational interval, etc. The optional FC card specifies up to 9 ratios of the flows which will be used in up to 9 system operations.

j. Period Cards IN, QA, NQ, MR, EV, and PV. These cards are used to describe the sequential data for each control point. For convenience only, all of the IN cards for the system should be read before the QA cards, all of the QA cards before the NQ cards, etc. The local flow cards (IN cards) are required. The QA cards are optional and are used to specify reservoir releases. The optional NQ cards can be used to describe base conditions for computing expected annual damages. When NQ data is provided, it is printed as natural flows instead of the computed natural flows. Other optional cards are MR cards to specify minimum flows, EV cards to provide evaporation data, and PV cards for power demands. The optional period cards can be selectively used for individual control points on any flow sequence.

k. End of Job Card, EJ. The EJ card is read following the last flow-data cards.

l. Multiple Floods. NFLRD sets of flow-data cards (i.e., BF through EJ cards) specified by variable NFLRD on the J2 card will follow the first ED card for a job.

m. Multiple Jobs. An unlimited number of sets of T1-EJ cards can follow the first EJ card. Four blank cards follow the EJ card of the last job.

OUTPUT

17. OUTPUT OPTIONS

The amount of program output can be controlled by the program user. A list of available output tables is shown in the input description (Exhibit 7) for the J2 card, field 6. Exhibit 6 provides a detailed description of the variables shown in the output and examples of output can be seen in the Test Problems of Exhibit 3. There is also provision for user designed output using the J8 card. Presently 24 variables can be displayed by time period for any control point in the system. The input description for the J8 card provides a description of the options available.

18. TRACES

In addition to ordinary output, trace information showing intermediate computations can be printed out. Such information may be required as a basis for verifying the performance of, or modifying, the program. There are several levels of trace (specified on the 10th field of the J2 card), as indicated in Exhibit 7. The choice of trace level depends on the extent and detail of intermediate printout required. The user requests the trace at specific control points with a TC card and for specific time periods with a TP card. The user is cautioned to use traces sparingly because very large volumes of output can be generated.

STREAM ROUTING METHODS

Routing options available in the program are the Muskingum method, the progressive average lag (straddle-stagger), the modified Puls method, and the Working R and D method. Equations used for each of these methods are given below.

a. Muskingum Method

In this method, outflow from a routing reach is a linear function of the sum of prism and wedge storage in the reach. The basic routing equation is:

$$O_n = C_1 I_n + C_2 I_{n-1} + C_3 I_{n-2} \ldots \quad (1)$$

where:

O_n = Ordinate of outflow hydrograph at time n

I_n, I_{n-1}, etc. = Ordinates of inflow hydrograph at times n, n-1, etc.

C_1, C_2, etc. = Routing coefficients, as coefficients of inflow

Equations used to determine the coefficients C_1, C_2, etc., are as follows:

$$C_1 = (\Delta t - 2XK) / (2\ K(1-X) + \Delta t) \quad (2)$$

$$CC = ((2K(1-X) + \Delta t) - 2\Delta t)/(2K(1-X) + \Delta t) \quad (3)$$

$$C_2 = C_1 \cdot CC + (\Delta t + 2KX) / (2K(1-X) + \Delta t) \quad (4)$$

$$C_i = C_{i-1} \cdot CC \text{ for } i > 2$$

where:

Δt = Routing time increment

K = Muskingum routing parameter having units of time

X = Muskingum dimensionless routing parameter between 0 and .5

To avoid negative coefficients in equation (1), the Muskingum K should be greater than or equal to $(\Delta t)/[2\cdot(1-X)]$ and less than or equal to $(\Delta t)/2X$.

b. Progressive Average-Lag Method

This method uses equation (1) for the routing with the routing coefficients determined as follows:

$$NCOEF = STAG + (STRAD + 1)/2 \quad (6)$$

$$M = NCOEF - STRAD \quad (7)$$

$$C_i = 0 \text{ for } 1 \leq i \leq m \quad (8)$$

$$C_i = 1/STRAD \text{ for } (M + 1) \leq i \leq NCOEF \quad (9)$$

where:

NCOEF = Number of routing coefficients in equation (1)

STRAD = Number of inflow ordinates to be averaged (straddled)

STAG = Number of ordinates the average value is to be lagged (staggered) from the mid-ordinate of the averaged ordinates

c. Modified Puls Method

In this method, outflow from a routing reach is a unique function of storage and therefore of storage indication, $(S/\Delta t + O/2)$. The following equations are used:

$$STRI(2) = STRI(1) + QH - O(1) \quad (10)$$

$$O(2) = f(STRI(2)) \text{ from storage indication - outflow function} \quad (11)$$

where:

S = Volume of storage in routing reach

STRI(1), STRI(2)= Storage indication at beginning and end of time interval, respectively

QH = Average inflow during time interval

O(1), O(2) = Outflow at start and end of interval, respectively

d. Working R and D Method

The working R and D permits use of a nonlinear storage-outflow relation, as does the modified Puls method; and it permits use of wedge storage, as does the Muskingum method. Indeed for a linear storage-outflow relation, the working R and D method produces results identical to the Muskingum method. For routing with no wedge storage (Muskingum X =0), the working R and D method produces results identical to the modified Puls method. The working R and D method uses a "working" storage as indicated in the following equations:

$$R(2)/\Delta t = R(1)/\Delta t + QH - D(1) \quad (12)$$

$$D(2) = f(R(2)/\Delta t) \quad (13)$$

where:

R(2) = "Working" storage at end of a routing interval

R(1) = "Working" storage at the beginning of a routing interval

QH = Average inflow during routing interval

D(1), D(2) = "Working" discharges at beginning and end of routing interval, respectively

The functional relationship described by equation (13) is analogous to the storage indication-outflow relation used in the modified Puls method. Outflow is a function of "working" discharge and is determined from the following equation:

$$O(2) = D(2) - X/(1-X) \cdot (I(2) - D(2)) \quad (14)$$

where

X = Muskingum X (dimensionless)

O(2) = Outflow at end of routing interval

I(2) = Inflow at end of routing interval

EXHIBIT 2

EXAMPLE PROBLEMS ILLUSTRATING RESERVOIR RELEASE DETERMINATION

The two examples in this exhibit are intended to illustrate the considerations that are made in determining reservoir releases. In HEC-5C, the routing equation used in release determination is:

$$O_n = C_1R_n + C_2R_{n-1} + C_3R_{n-2} \ldots \qquad (1)$$

where:

O_n = Ordinate of discharge hydrograph at downstream control point at time n due to upstream reservoirs

R_n, R_{n-1}, etc. = Ordinates of reservoir release hydrograph at times n, n-1, etc.

C_1, C_2, etc. = Routing coefficients

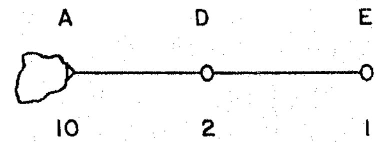
Example 1 illustrates a flood control routing operation for a single flood control reservoir being operated to minimize flooding at two downstream control points. The progressive average lag method is used for routing with coefficients of 3/2 between the reservoir and control point D (see tabular computation, example 1) and coefficients of 3/1 between D and E. The corresponding coefficients for equation (1) are shown in Table 1.

Coefficients For Progressive Average Lag	Coefficients in Equation (1)			
	C_1	C_2	C_3	C_4
3/2	0	.333	.333	.333
3/1	.333	.333	.333	0

Table 1. **Routing Coefficients**

EXAMPLE I

SINGLE RESERVOIR FLOOD CONTROL ROUTING OPERATION FOR TWO DOWNSTREAM CONTROL POINTS ROUTING RESERVOIR RELEASES BY STRADDLE-STAGGER



DATE YEAR = 1950	TIME (HOURS) END OF PERIOD	PERIOD NUMBER	RESERVOIR A (CP #10)						CONTROL POINT D (#2)			CONTROL POINT E (#1)		
			INFLOW AVG *cfs*	RELEASE AVG *cfs*	Δ S AVG *6 hr-cfs*	FLOOD STORAGE *6 hr-cfs*	CASE	LEVEL	RELEASES ROUTED A-D 3/2 SS	LOCAL FLOW *cfs*	ACTUAL FLOW *cfs*	RELEASES ROUTED D-E 3/1 SS	CUM. LOCAL FLOW *cfs*	ACTUAL FLOW *cfs*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
JAN 23	0000	1	0	0		0	10.03	2.000	0	0	0	0	0	0
JAN 23	0600	2	8,000	6,030	+ 2,030	1,970	1.07	2.020	0	2,000	2,000	0	5,000	5,000
	1200	3	18,000	0	+18,000	19,970	2.06	2.198	2,010	7,340	9,350	670	11,120	11,790
	1800	4	30,000	0	+30,000	49,970	2.06	2.496	2,010	11,340	13,350	1,340	16,220	17,560
	2400	5	20,000	0	+20,000	69,970	2.06	2.694	2,010	16,340	18,350	2,010	20,010	22,020
JAN 24	0600	6	12,000	0	+12,000	81,970	1.07	2.813	0	27,330	27,330	1,340	38,330	39,670
	1200	7	6,000	21,000	-15,000	66,970	10.01	2.664	0	24,330	24,330	670	39,330	40,000
	1800	8	2,000	3,990	- 1,990	64,980	2.10	2.644	7,000	12,330	19,330	2,333	31,830	34,163
	2400	9	1,000	0	+ 1,000	65,980	2.10	2.654	8,330	15,340	23,670	5,110	21,600	26,710
JAN 25	0600	10	0	0	0	65,980	2.10	2.654	8,330	16,670	25,000	7,887	22,450	30,337
	1200	11	0	0	0	65,980								
TOTALS			97,000	31,020	+65,980				29,690	133,020	162,710	21,360	205,890	227,250

In determining the release from the reservoir for time period 2, it is necessary to determine the maximum release that can be made without causing flooding at location D at times 2, 3, 4 and 5 since a release from A will have an effect as many as four time periods into the future. The routing coefficients for equation (1) of 0, .333, .333, and .333 are such that none of the release has an effect at time 2 at D, and 1/3 of the release passes D at times 3, 4 and 5. It is also necessary to consider control point E when determining the reservoir release. The release at time 2 will be distributed over 5 time periods at E. The maximum release that can be made at time 2 is governed by the flow conditions at E at time 7. The release may be calculated from the following equation:

$$O_7 = C_1R_7 + C_2R_6 + C_3R_5 + C_4R_4 + C_5R_3 + C_6R_2 \qquad (2)$$

The coefficients C_1 through C_6 are obtained by combining routing coefficients for the two reaches and are 0, .111, .222, .333, .222, and .111, respectively. The desired additional flow at E is the channel capacity of 40,000 minus the local flow of 39,330. Assuming that future reservoir releases are zero, substitution of values into equation (2) results in:

$$40{,}000 - 39{,}330 = 0 \cdot 0 + .111 \cdot 0 + .222 \cdot 0 + .333 \cdot 0 + .222 \cdot 0 + .111 \cdot R_2$$

therefore:

$$R_2 = 670/.111 = 6030$$

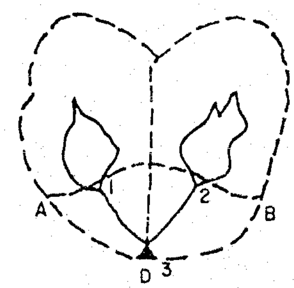
The procedure in the computer program for determining reservoir release is similar to the above except that future releases are not assumed to be zero but are assumed to be the minimum releases that can be made taking into consideration the specified maximum rate-of-change of release, the minimum flow requirements, and releases that must be made when the reservoir level exceeds the top of flood pool. In determining releases for the second and subsequent periods, the previous releases must be considered when applying equation (1).

When a nonlinear channel routing procedure is used, the program determines a Muskingum K based on the slope of the storage-outflow function and the outflow at the end of the previous time period. The K is used to determine coefficients for the linear routing equation (equation (1)) and this equation is used to determine the reservoir release. The final routing of reservoir releases is accomplished by the nonlinear routing method.

Example 1 has been coded for solution by HEC-5 and is included as test problem 1 in Exhibit 3.

Example 2 (see tabular computation) illustrates a flood control routing operation for two flood control reservoirs operated in parallel to minimize flooding at a single downstream control point. Footnotes at the bottom of the example indicate the controlling factors that govern reservoir releases during each time period. Example 2 has been coded for solution by HEC-5C and is included as test problem 2 in Exhibit 3.

Example 3 (see tabular computations) illustrates a flood control routing operation for three reservoirs with Reservoirs A and B in parallel and Reservoirs C and B in tandem. Reservoirs A and B are operated to minimize flooding at D and to evacuate the two reservoirs as quickly as possible while keeping the two reservoirs in "balance." In determining which reservoir, A or B, should be given priority in making releases, the level for Reservoir A is compared with the higher of the level for Reservoir B or the equivalent Reservoir B-C. The actual releases from A and B are then determined in a manner similar to example 2. No releases are made from Reservoir C unless Reservoir C is at a higher level than Reservoir B. When releases are made from C, they are made to attempt to bring Reservoir C to the equivalent level of Reservoirs B and C for the previous computation period. Example 3 has also been coded for solution by HEC-5C and is included as test problem 3 in Exhibit 3.

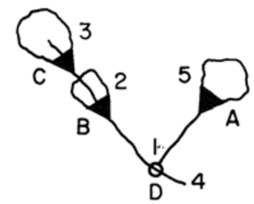


EXAMPLE 2

TWO PARALLEL RESERVOIRS - FLOOD CONTROL ROUTING OPERATION FOR ONE DOWNSTREAM CONTROL POINT BY ROUTING RESERVOIR RELEASES AND COMBINING WITH LOCAL FLOW USING 100% FORECASTING ABILITY

			RESERVOIR A (CP #1)						RESERVOIR B (CP #2)						CONTROL POINT D (CP #3) cc = 25,000 c.f.s.				
Date Month/Day Year = 1950	Time Hours (End of Period)	Period No.	Inflow Avg cfs	Release Avg cfs Max = 6,000	△Stg Avg cfs Col 4 minus Col 5	Case	F.C. Stg End of Period 6 hr-cfs Max = 200,000	Percent F.C. Storage Used (Col 8/ 200,000)	Inflow Avg cfs	Release Avg cfs Max = 12,000	△ Stg Avg cfs Col 10 minus Col 11	Case	F.C. Stg End of Period 6 hr-cfs Max = 500,000	Percent F.C. Storage Used (Col 14/ 500,000)	Res A Release Routed to D SS-3/2	Res B Release Routed to D SS-3/1	Local Flow at D cfs	Modified Flow at D	Natural Flow at D
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
JUNE 6	0600	2	10,000	0(1)	+10,000	3.04	10,000	5.0	0	0(1)	0	3.04	0	0	0	0	5,000	5,000	5,000
	1200	3	30,000	0(1)	+30,000	3.04	40,000	19.8	20,000	0(1)	+20,000	3.04	20,000	4.0	0	0	15,000	15,000	25,000
	1800	4	50,000	6,000(2)	+44,000	1.60	84,000	41.7	40,000	0(1)	+40,000	3.04	60,000	11.9	0	0	25,000	25,000	58.300
	2400	5	30,000	6,000(2)	+24,000	1.01	108,000	53.6	60,000	12,000(2)	+48,000	2.60	108,000	21.4	2,000	4,000	15,000	21,000	85,000
JUNE 7	0600	6	20,000	6,000(2)	+14,000	1.60	122,000	60.5	80,000	12,000(2)	+68,000	2.01	176,000	34.9	4,000	8,000	2,000	14,000	98,700
	1200	7	10,000	0(4)	+10,000	3.10	132,000	65.5	100,000	9,000(3)	+91,000	3.09	267,000	53.0	6,000	11,000	5,000	22,000	118,300
	1800	8	5,000	0(4)	+ 5,000	3.10	137,000	67.9	90,000	0(4)	+90,000	3.10	357,000	70.8	4,000	7,000	10,000	21,000	120.000
	2400	9	1,000	0(4)	+ 1,000	3.10	138,000	68.4	70,000	0(4)	+70,000	3.10	427,000	84.7	2,000	3,000	20,000	25,000	118.400
JUNE 8	0600	10	0	6,000(5)	- 6,000	1.01	132,000	65.5	50,000	0(4)	+50,000	3.10	477,000	94.6	0	0	30,000	30,000	105,300
	1200	11	0	6,000(6)	- 6,000	1.60	126,000	62.5	30,000	9,000(5)	+21,000	3.11	498,000	98.8	2,000	3,000	20,000	25,000	72,000
	1800	12	1,000	6,000(6)	- 5,000	1.60	121,000	60.0	10,000	12,000(6)	- 2,000	2.61	496,000	98.4	4,000	7,000	10,000	21,000	40,300
	2400	13	5,000	6,000(6)	- 1,000	1.01	120,000	59.5	1,000	12,000(6)	-11,000	2.60	485,000	98.0	5,000	12,000	1,000	13,000	14,700
JUNE 9	0600	14	10,000	6,000(6)	+ 4,000	1.01	124,000	61.5	0	12,000(6)	-12,000	2.60	473,000	95.6	6,000	12,000	0	18,000	3,700

NOTES:
(1) Minimum releases made to limit flow at D for June 6, 1800 hours.
(2) Maximum releases made to increase flow at D from June 6, 2400 hours, to June 7, 1800 hours.
(3) Releases made to provide channel capacity at D for June 7, 2400 hours. The maximum was released from A because it was fuller than B.
(4) Minimum releases made to limit flow at D for June 8, 0600 hours.
(5) Releases made to provide channel capacity at D for June 8, 1200 hours. The maximum was released from B because it was fuller than A.
(6) Maximum releases were made to fill channel as much as possible from June 8, 1800 hours on.



EXAMPLE 3

THREE RESERVOIR SYSTEM FLOOD CONTROL OPERATION FOR ONE CONTROL POINT (D)
RESERVOIRS "A" AND "B" PARALLEL; RESERVOIRS "B" AND "C" TANDEM
USING 100% FORECASTING ABILITY AND NO CONTINGENCY FACTOR

			RESERVOIR C (CONTROL POINT 3)						RESERVOIR B (CONTROL POINT 2)						
Date Month/Day Year = 1950	Time Hours (End of Period)	Period No.	Inflow Avg cfs	Release Avg cfs	Δ Stg. Avg Col 4-Col 5	Case[1]	F.C. Stg. Used (End of period) 6 hr - cfs P. col 8 + col 6	Percent F.C. Storage Used Col 8/100,832	Local Flow Avg cfs	Inflow Avg cfs	Release Avg cfs	Δ Stg. Avg Col 11-Col 12	Case	F.C. Stg. Used (End of period) 6 hr - cfs P. col 15 + col 13	Percent F.C. Storage Used Col 15/554,576
Maximum Value				6,000			100,832	100.			21,000			554,576	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
June 5	2400	1	0	0	0	3.05	0	0	0	0	0	0	2.02	0	0
June 6	0600	2	0	0	0	3.05	0	0	0	0	0	0	2.02	0	0
	1200	3	3,000	2,999	+1	3.05	1	0	0	2,999	2,999	0	2.02	0	0
	1800	4	18,000	6,000	+12,000	3.01	12,001	11.9	6,000	12,000	12,000	0	1.04	0	0
	2400	5	37,000	6,000	+31,000	3.01	43,001	42.6	20,000	26,000	1	+25,999	1.05	25,999	4.7
June 7	0600	6	42,000	6,000	+36,000	3.01	79,001	78.4	57,000	63,000	5,999	+57,001	1.06	83,000	15.0
	1200	7	50,000	28,169	+21,831	3.04	100,832	100	100,000	128,169	21,000	+107,169	2.60	190,169	34.3
	1800	8	27,000	27,000	0	3.04	100,832	100	90,000	117,000	9,001	+107,999	1.08	298,168	53.8
	2400	9	20,000	20,000	0	3.04	100,832	100	70,000	90,000	5,999	+84,001	1.09	382,169	68.9
June 8	0600	10	13,000	13,000	0	3.04	100,832	100	50,000	63,000	0	+63,000	1.12	445,169	80.3
	1200	11	5,000	6,000	-1,000	3.01	99,832	99.0	37,000	43,000	0	+43,000	1.12	488,169	88.0
	1800	12	0	6,000	-6,000	3.01	93,832	93.1	24,000	30,000	0	+30,000	1.12	518,169	93.4
	2400	13	0	0	0	3.05	93,832	93.1	24,000	24,000	21,000	+3,000	2.60	521,169	94.0
June 9	0600	14	0	0	0	3.05	93,832	93.1	15,000	15,000	9,000	+6,000	1.14	527,169	95.1
	1200	15	0	0	0	3.05	93,832	93.1	9,000	9,000	0	+9,000	1.15	536,169	96.7
	1800	16	0	0	0	3.05	93,832	93.1	3,000	3,000	21,000	-18,000	2.01	518,169	93.4
	2400	17	0	0	0	3.05	93,832	93.1	0	0	21,000	-21,000	2.60	497,169	89.6

		EQUIVALENT RESERVOIRS B+C					RESERVOIR A (CONTROL POINT 5)						CONTROL POINT D				
													Outflow				
Date Month/Day Year = 1950	Time Hours (End of Period)	Inflow Avg cfs col 11 + col 10	Release Avg cfs (same as col 12)	Δ Stg. Avg Col 17-Col 18	F.C. Stg. Used (End of period) 6 hr - cfs P. col 20 + col 19	Percent F.C. Storage Used Col 20/655,408	Inflow Avg cfs	Release Avg cfs	Δ Stg. Avg Col 22-Col 23	Case	F.C. Stg. Used (End of period) 6 hr - cfs P. col 26 + col 24	Percent F.C. Storage Used Col 26/403,328	Res A Routed 3/2	Res B Routed 3/1	Local Flow Avg cfs	Modified Flow Avg cfs	Natural Flow Avg cfs
Maximum Value			21,000		655,408	100.		12,000			403,328					25,000	
1	*2*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*
June 5	2400	0	0	0	0	0	0	0	0	5.02	0	0	0	0	0	0	0
June 6	0600	0	0	0	0	0	6,000	6,000	0	5.02	0	0	0	0	4,000	4,000	4,000
	1200	3,000	2,999	1	1	0	27,000	12,000	+15,000	5.60	15,000	3.7	2,000	1,000	19,000	22,000	22,000
	1800	24,000	12,000	+12,000	12,001	1.8	60,000	12,000	+48,000	5.01	63,000	15.6	6,000	5,000	13,000	24,000	33,000
	2400	57,000	1	56,999	69,000	10.5	105,000	12,000	+93,000	5.01	156,000	38.7	10,000	5,000	10,000	25,000	69,000
June 7	0600	99,000	5,999	+93,001	162,001	24.7	78,000	12,000	+66,000	5.01	222,000	55.0	12,000	6,000	7,000	25,000	131,000
	1200	150,000	21,000	+129,000	291,000	44.4	60,000	12,000	+48,000	5.01	270,000	66.9	12,000	9,000	4,000	25,000	187,000
	1800	117,000	9,001	+107,999	398,999	60.9	45,000	12,000	+33,000	5.60	303,000	75.1	12,000	12,000	1,000	25,000	204,000
	2400	90,000	5,999	+84,001	483,000	73.7	33,000	0	+33,000	1.12	336,000	83.3	12,000	12,000	1,000	25,000	181,000
June 8	0600	63,000	0	+63,000	546,000	83.3	24,000	0	+24,000	1.12	360,000	89.3	8,000	5,000	4,000	17,000	140,000
	1200	42,000	0	+42,000	588,000	89.7	18,000	0	+18,000	1.12	378,000	93.7	4,000	2,000	10,000	16,000	109,000
	1800	24,000	0	+24,000	612,000	93.4	12,000	12,000	0	5.01	378,000	93.7	0	0	25,000	25,000	93,000
	2400	24,000	21,000	+3,000	615,000	93.8	12,000	12,000	0	5.01	378,000	93.7	4,000	7,000	13,000	24,000	61,000
June 9	0600	15,000	9,000	+6,000	621,000	94.8	9,000	9,000	0	1.15	378,000	93.7	8,000	10,000	7,000	25,000	42,000
	1200	9,000	0	+9,000	630,000	96.1	6,000	12,000	-6,000	5.01	372,000	92.2	11,000	10,000	4,000	25,000	31,000
	1800	3,000	21,000	-18,000	612,000	93.4	3,000	12,000	-9,000	5.60	363,000	90.0	11,000	10,000	1,000	22,000	19,000
	2400	0	21,000	-21,000	591,000	90.2	0	12,000	-12,000	5.60	351,000	87.0	11,000	14,000	0	25,000	10,000

1. CASE = X.Y, WHERE X = CONTROLLING LOCATION AND Y = CONTROLLING TIME PERIOD EXCEPT WHEN RESERVOIR NO = CONTROLLING LOCATION NO THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF, Y =

Y = 0 MINIMUM FLOW WAS RELEASED
Y = 1 MAXIMUM RESERVOIR RELEASE
Y = 2 BASED ON MAXIMUM RATE OF CHANGE
Y = 3 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
Y = 4 BASED ON NOT EXCEEDING TOP FLOOD POOL
Y = 5 BASED ON EQUAL LEVELS - TANDEM RESERVOIRS
Y = 6 BASED ON MAXIMUM RELEASE DUE TO OUTLET CAPACITY
Y = 7 BASED ON NOT DRAWING RESERVOIR STAGE BELOW 0
Y = 99 RELEASE GIVEN ON QA CARD

EXHIBIT 3

TEST PROBLEMS

1. INTRODUCTION

Input and output for several test problems are shown in this exhibit along with a general description of each. Manual solutions of the first three test problems are shown in Exhibit 2. The following table shows some of the options used in each example problem.

TABLE 1

SUMMARY OF EXAMPLE OPTIONS

		Test Number						
		1	2	3	4	5	6	10
1.	Routing Interval-hours	6	6	6	2	720 & 6	720	6
2.	Number of Floods Read	1	1	1	2	2	1	1
3.	Number of Floods by Constants	-	-	-	-	-	-	6
4.	Local Flows: N = Natural I = Incremental Local	I	I	N	I	I	I	I
5.	Output: C = Complete P = Partial	P	P	C	C	P	C	P
6.	Channel Routing N = None L = Linear NL = Nonlinear	L	L	L	NL	N&L	N	L
7.	Average Annual Damage	-	-	-	-	-	-	X
8.	Hydrograph Plots	-	-	-	X	-	-	-

2. TEST PROBLEM 1

a. The first test problem involves a single flood control reservoir operating to minimize flooding at two downstream control points. The problem is the same as that shown in Example 1 of Exhibit 2. Input and output for the problem is shown on the following pages. Output was limited to the sequential output for each control point (J2.6=8).

b. The output indicates that the regulated flow at the downstream control point, labeled 1, did not exceed the channel capacity of 40,000 cfs. The flow of 40,000 cfs on the seventh period resulted from a local flow of 39,330 cfs and a flow from the reservoir of 670 cfs. The flow from the reservoir is derived from the release of 6,029 cfs made in period 2. Reservoir releases did not cause flooding at either of the downstream control points, as indicated by the "FLOOD BY RES" lines for those two points.

c. No additional reservoir releases could have been made on periods 2 through 6 without causing flooding on period 7 at control point 1 or period 6 at control point 2. This is indicated by the values of "CASE=LOC.TYP" for LOC 10. The full channel capacity release was made on periods 7 and 10. The release of 3,989 cfs on period 8 was made to exactly fill the space on period 9 because flooding would have resulted at control point 2 on period 10.

d. If the allowable rate-of-change for reservoir release had been specified as 50 percent of channel capacity rather than 100 percent, the release on period 7 and 8 would have been 10,500 cfs and 12,495 cfs, respectively. The use of such a constraint on rate-of-change of release generally provides a more realistic operation.

```
      HEC-5C SIMULATION OF FLOOD CONTROL
             AND CONSERVATION SYSTEMS
             UPDATED  OCT. 3 , 1975
      RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1        SINGLE RESERVOIR OPERATING FOR 2 CONTROL PTS           TEST 1
T2        STRADDLE STAGGER ROUTING
T3        EXAMPLE NO 1 FROM EXHIBIT 2
J1         10.00        6.00        3.00        2.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00
J2         -0.00       -0.00        7.00        1.00       -0.00        8.00       -1.00       -0.00       -0.00       -0.00
J3         -0.00       -0.00 60012300.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00


RL         10.00        0.00        0.00        0.00        0.00    50000.00       -0.00       -0.00       -0.00       -0.00
RO          2.00        2.00        1.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS          2.00        0.00    50000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RQ          2.00    21000.00    21000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         10.00    21000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID     RESERVOIR A CP-10                                   -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         10.00        2.00        1.10        3.20        0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP          2.00    25000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID     CONTROL POINT D-CP-2                                -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT          2.00        1.00        1.10        3.10        0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP          1.00    40000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID     CONTROL POINT E  CP 1                               -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT          1.00        0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ED         -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

       NRES=     1  NCPT=     3  NCPTR=    -0
```

```
J1     NPER     IPER       NL      NL1      NLM     EPER    NLRUF  ILOCAL   INFLOW    IOPMP
         10        6        3        2        3       10        1      -0       -0       -0
J2    CNSTI    CFLOD   IFCAST   RATCHG    NFLRD   IPRINT   FLONAT  NORDUT    NCPTR    TRACE
       1.00     1.00        7     1.00        1        8      -1.       0       -0      -0.
J3   METRIC    ECFCT     DATE   BCRFAC   COSFAC   IPRECN   IANDAM  ISCHED    IPRIO   IPLOTJ
         -0   1.0060012300.     -0.00     1.00       -0       -0      -0       -0       -0
USER ID COMP ID     QMAX     RTFR     RTTO     RTMD      X        K      LAG    LQCP   RTLQ   QLAG  QMIND  QMINR

     10       1   21000.      10.       2.     1.10    3.20    0.000     -0     -0  -0.000    -0.    -0.    -0.  RESERVOIR A CP-10
      2       2   25000.       2.       1.     1.10    3.10    0.000     -0     -0  -0.000    -0.    -0.    -0.  CONTROL POINT D-CP-2
      1       3   40000.       1.       0.    -0.00   -0.00   -0.000     -0     -0  -0.000    -0.    -0.    -0.  CONTROL POINT E  CP 1

USER ID COMP ID     STOR1    STORL-1       -2       -3       -4       -5      ISERV(M,K)-

     10       1       0.        0.        0.    50000.       0.       0.      1      2      3

RESERVOIR DATA

USER ID=      10   COMP ID=      1

RS   STORAGES=            0.     50000.
RQ   Q CAPACITIES=    21000.     21000.
RA   AREAS=               0.        0.
RE   ELEVATIONS=          0.        0.
R1   START-STORAGE        0.        0.       0.       0.       0.       0.       0.       0.       0.

ROUTING COEFFICIENTS FROM RES     10 TO MY
      MY=       2   0.0000    .3333    .3333    .3333
      MY=       1   0.0000    .1111    .2222    .3333    .2222    .1111
```

```
SINGLE RESERVOIR OPERATING FOR 2 CONTROL PTS            TEST 1
STRADDLE STAGGER ROUTING
EXAMPLE NO 1 FROM EXHIBIT 2

COMPUTATION INTERVAL IN HOURS=    6

               ***** FLOOD NUMBER   1 *****                                  UNITS OF OUTPUT

                                                              ALL FLOWS IN CFS OR CMS
          NFLRD=          1  NFLCON=        0                 EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
          IFLRD =         1  IFLCON=        1                 ELEVATIONS IN FEET OR METERS
             FLOWS MULTIPLIED BY        1.000                 POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

******************************************************************************************************************************
**** LOC     10    RESERVOIR A CP=10                SERVED BY     10

                                                                                   STARTING TIME=        1
                          SERVING       10      2      1                           HOUR= 6,DAY=23,MON= 1,YEAR=1960,
PER        CUM LOCAL Q

   1      0.   8000.  18000.  30000.  20000.  12000.   6000.   2000.   1000.      0.

                                                                                   AVG=   9700.000  MAX=  30000.000
PER        NATURAL FLOW                                                                             MIN=      0.000

   1      0.   8000.  18000.  30000.  20000.  12000.   6000.   2000.   1000.      0.

                                                                                   AVG=   9700.000  MAX=  30000.000
PER        INFLOW                                                                                   MIN=      0.000

   1      0.   8000.  18000.  30000.  20000.  12000.   6000.   2000.   1000.      0.

                                                                                   AVG=   9700.000  MAX=  30000.000
PER        OUTFLOW                                                                                  MIN=      0.000

   1      0.   6029.      0.      0.      0.      0.  21000.   3989.      0.  21000.

                                                                                   AVG=   5201.896  MAX=  21000.000
PER        CASE=LOC.TYP                                                                             MIN=      0.000

   1     .03   1.05    2.03    2.02    2.01    1.01     .01    2.02    2.01     .01

                                                                                   AVG=      1.220  MAX=      2.030
PER        LEVEL                                                                                    MIN=       .010

   1   2.000  2.020   2.198   2.496   2.694   2.813   2.664   2.644   2.654   2.446

                                                                                   AVG=      2.463  MAX=      2.813
PER        EOP STORAGE                                                                              MIN=      2.000

   1      0.   977.   9903.  24779.  34697.  40647.  33209.  32222.  32718.  22305.

                                                                                   AVG=  23145.777  MAX=  40647.141
                                                                                                    MIN=      0.000
```

```
************************************************************************************************************
**** LOC     2   CONTROL POINT D-CP-2          SERVED BY    10
PER        CUM LOCAL Q
   1      0.   2000.   7340.  11340.  16340.  27330.  24330.  12330.  15340.  16670.
                                                                                      AVG=  13302.000  MAX=  27330.000
PER        NATURAL FLOW                                                                                MIN=      0.000
   1      0.   2000.  10007.  20007.  35007.  49997.  44997.  24997.  22007.  19670.
                                                                                      AVG=  22868.667  MAX=  49996.667
PER        REGULATED FLOW                                                                              MIN=      0.000
   1      0.   2000.   9350.  13350.  18350.  27330.  24330.  19330.  23670.  25000.
                                                                                      AVG=  16270.913  MAX=  27330.000
PER        Q SPACE AVAIL.                                                                              MIN=      0.000
   1  25000.  23000.  15650.  11650.   6650.  -2330.    670.   5670.   1330.      0.
                                                                                      AVG=   8729.087  MAX=  25000.000
PER        Q BY US RES,DIVS                                                                            MIN=  -2330.000
   1      0.      0.   2010.   2010.   2010.      0.      0.   7000.   8330.   8330.
                                                                                      AVG=   2968.913  MAX=   8329.833
PER        FLOOD BY RES                                                                                MIN=      0.000
   1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
                                                                                      AVG=      0.000  MAX=      0.000
************************************************************************************************************ MIN=      0.000
**** LOC     1   CONTROL POINT C  CP 1         SERVED BY    10
PER        CUM LOCAL Q
   1      0.   5000.  11120.  16220.  20009.  38330.  39330.  31830.  21599.  22449.
                                                                                      AVG=  20588.733  MAX=  39329.667
PER        NATURAL FLOW                                                                                MIN=      0.000
   1      0.   5000.  12009.  19998.  30009.  54996.  59996.  50497.  34933.  29893.
                                                                                      AVG=  29733.178  MAX=  59996.333
PER        REGULATED FLOW                                                                              MIN=      0.000
   1      0.   5000.  11790.  17560.  22019.  39670.  40000.  34163.  26709.  30336.
                                                                                      AVG=  22724.663  MAX=  39999.607
PER        Q SPACE AVAIL.                                                                              MIN=      0.000
   1  40000.  35000.  28210.  22440.  17981.    330.      0.   5837.  13291.   9664.
```

```
                                                                                 AVG=  17275.337  MAX=  40000.000
PER       Q BY US RES,DIVS                                                                        MIN=       .393

  1    0.     0.    670.   1340.   2010.   1340.    670.   2333.   5110.   7887.

                                                                                 AVG=   2135.929  MAX=   7886.556
PER       FLOOD BY RES                                                                            MIN=      0.000

  1    0.     0.     0.     0.     0.     0.     0.     0.     0.     0.

                                                                                 AVG=      0.000  MAX=      0.000
                                                                                                  MIN=      0.000
******************************************************************************************************************

******************************************************************************************************************

** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
    Y=00 MINIMUM DESIRED FLOW WAS RELEASED
    Y=01 MAXIMUM RESERVOIR RELEASE
    Y=02 BASED ON MAX RATE OF CHANGE
    Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
    Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
    Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
    Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
    Y=07 BASED ON RELEASE FOR LEVEL 1
    Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
    Y=09 BASED ON RELEASES FOR BUFFER LEVEL
    Y=10 BASED ON POWER DEMAND
    Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
    Y=99 RELEASE GIVEN ON QA CARD
```

3. TEST PROBLEM 2

a. This test problem illustrates the flood control operation of two parallel reservoirs being operated for a common downstream control point. The problem is the same as that shown in Example 2 of Exhibit 2. Program input and output for this problem are shown on the following pages. The output was limited to the sequential output by control points (J2.6=8).

b. The output for Reservoir A shows the maximum index level was 2.684, indicating that 68 percent of the flood control storage was utilized. A release from Reservoir A was not permitted for periods 2 or 3 because flooding would be caused on period 4 at location 3; this is indicated by CASE. The maximum channel capacity release of 6,000 cfs was made for periods 4 through 6 and 10 through 14. Releases were not made on periods 7 through 9 because they would contribute to the flooding that occurs on period 10.

c. Releases were not made from Reservoir B for period 3 and 4 to prevent flooding on period 4 at location 3. Maximum releases were made to exactly fill the remaining channel space at location 3 on period 9. Releases were not made on periods 8 through 10 to avoid making a contribution to the flooding that occurs on period 10. The flood space in Reservoir B was virtually filled because the maximum index level was 2.988.

d. Output for location 3, the downstream control point, indicates that reservoir releases do not contribute to flooding (FLOOD BY RES=0). It also shows that there is flooding on period 10 because the uncontrolled local flow (CUM LOCAL) of 30,000 cfs exceeds the channel capacity of 25,000 cfs.

e. In this operation the permitted rate-of-change for reservoir release from one period to the next was 100 percent of channel capacity.' If this percentage were reduced, more flood control storage would be utilized. Also, more storage would be required if a contingency allowance for local flows wasused or if the number of "forecast" periods was less than the 4 periods used in this run. While it is easier to analyze the operation with the contingency factor equal to 1.0, it is strongly recommended that a 1.2 or larger factor be used on any practical problem.

```
      HEC-5C SIMULATION OF FLOOD CONTROL
             AND CONSERVATION SYSTEMS
             UPDATED  OCT. 3 , 1975
      RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1       TWO RESERVOIRS IN PARALLEL                                 TEST 2
T2       ONE DOWNSTREAM CONTROL POINT
T3       EXAMPLE NO 2 FROM EXHIBIT 2
J1        14.00        6.00        3.00        2.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00
J2        -0.00       -0.00       -0.00        1.00        1.00        8.00       -1.00       -0.00       -0.00       -0.00

RL         1.00        0.00        0.00        0.00        0.00   100000.00       -0.00       -0.00       -0.00       -0.00
RO         1.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         2.00        0.00   100000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RQ         2.00     6000.00     6000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         1.00     6000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID RESERVOIR A                                            -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         1.00        3.00        1.00        3.20       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

RL         2.00        0.00        0.00        0.00        0.00   250000.00       -0.00       -0.00       -0.00       -0.00
RO         1.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         2.00        0.00   250000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RQ         2.00    12000.00    12000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         2.00    12000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID RESERVOIR B                                            -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         2.00        3.00        1.00        3.10       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         3.00    25000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID CONFLUENCE BELOW A AND B                               -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         3.00        0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ED         1.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

    NRES=      2  NCPT=      3  NCPTR=     -0

BF         0.00        0.00        0.00        0.00 57060600.00       -0.00       -0.00       -0.00       -0.00       -0.00
```

```
J1    NPER     IPER       NL      NL1     NLM    EPER   NLBUF  ILOCAL  INFLOW   IOPMP
        14        6        3        2       3      14       1      -0      -0      -0
J2   CNSTI    CFLOD   IFCAST   RATCHG   NFLRD  IPRINT  FLONAT  NOROUT   NCPTR   TRACE
      1.00     1.00        4     1.00       1       8     -1.       0      -0     -0.
J3  METRIC    ECFCT     DATE   BCRFAC  COSFAC  IPRECN  IANDAM  ISCHED   IPRIO  IPLOTJ
         0   1.0057060600.      1.00    1.00       0       0       0       0       0

USER ID COMP ID     QMAX    RTFR    RTTO    RTMD      X       K     LAG   LQCP    RTLQ   QLAG  QMIND  QMINR

      1       1    6000.     1.      3.    1.00    3.20  -0.000     -0     -0  -0.000    -0.    -0.    -0. RESERVOIR A
      2       2   12000.     2.      3.    1.00    3.10  -0.000     -0     -0  -0.000    -0.    -0.    -0. RESERVOIR B
      3       3   25000.     3.      0.   -0.00   -0.00  -0.000     -0     -0  -0.000    -0.    -0.    -0. CONFLUENCE BELOW A AND

USER ID COMP ID    STOR1   STORL-1     -2        -3       -4      -5     ISERV(M,K)-

      1       1      0.      0.        0.   100000.       0.      0.      1      3
      2       2      0.      0.        0.   250000.       0.      0.      2      3

RESERVOIR DATA

USER ID=      1   COMP ID=      1

RS   STORAGES=              0.   100000.
RQ   Q CAPACITIES=       6000.     6000.
RA   AREAS=                 0.        0.
RE   ELEVATIONS=            0.        0.
R1   START-STORAGE          0.        0.       0.       0.       0.       0.       0.       0.       0.
USER ID=      2   COMP ID=      2

RS   STORAGES=              0.   250000.
RQ   Q CAPACITIES=      12000.    12000.
RA   AREAS=                 0.        0.
RE   ELEVATIONS=            0.        0.
R1   START-STORAGE          0.        0.       0.       0.       0.       0.       0.       0.       0.

ROUTING COEFFICIENTS FROM RES      1 TO MY
       MY=       3   0.0000    .3333    .3333    .3333
ROUTING COEFFICIENTS FROM RES      2 TO MY
       MY=       3    .3333    .3333    .3333
```

```
     TWO RESERVOIRS IN PARALLEL                            TEST 2
     ONE DOWNSTREAM CONTROL POINT
     EXAMPLE NO 2 FROM EXHIBIT 2

COMPUTATION INTERVAL IN HOURS=   6

               ***** FLOOD NUMBER  1 *****                                   UNITS OF OUTPUT

                   NFLRD=        1  NFLCON=      0              ALL FLOWS IN CFS OR CMS
                   IFLRD =       1  IFLCON=      1              EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
                      FLOWS MULTIPLIED BY     1.000             ELEVATIONS IN FEET OR METERS
                                                                POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

****************************************************************************************************************************
**** LOC     1  RESERVOIR A                        SERVED BY     1

                                                                                  STARTING TIME=       1
                                   SERVING      1     3                           HOUR= 6,DAY= 6,MON= 6,YEAR=1957,
PER        CUM LOCAL Q

   1       0.  10000.  30000.  50000.  30000.  20000.  10000.   5000.   1000.      0.
  11       0.   1000.   5000.  10000.

                                                                                  AVG=  12285.714  MAX=  50000.000
PER        NATURAL FLOW                                                                            MIN=      0.000

   1       0.  10000.  30000.  50000.  30000.  20000.  10000.   5000.   1000.      0.
  11       0.   1000.   5000.  10000.

                                                                                  AVG=  12285.714  MAX=  50000.000
PER        INFLOW                                                                                  MIN=      0.000

   1       0.  10000.  30000.  50000.  30000.  20000.  10000.   5000.   1000.      0.
  11       0.   1000.   5000.  10000.

                                                                                  AVG=  12285.714  MAX=  50000.000
PER        OUTFLOW                                                                                 MIN=      0.000

   1       0.      0.      0.   6000.   6000.   6000.      0.      0.      0.   6000.
  11    6000.   6000.   6000.   6000.

                                                                                  AVG=   3428.571  MAX=   6000.000
PER        CASE=LOC.TYP                                                                            MIN=      0.000

   1      .03    3.02    3.01     .01     .01     .01    3.03    3.02    3.01     .01
  11      .01     .01     .01     .01

                                                                                  AVG=      1.086  MAX=      3.030
PER        LEVEL                                                                                   MIN=       .010

   1    2.000   2.050   2.198   2.417   2.536   2.605   2.655   2.679   2.684   2.655
  11    2.625   2.600   2.595   2.615

                                                                                  AVG=      2.494  MAX=      2.684
                                                                                                   MIN=      2.000
```

```
PER        EOP STORAGE

  1      0.   4959.  19835.  41654.  53555.  60497.  65455.  67935.  68431.  65455.
 11  62480.  60001.  59505.  61488.

                                                                                        AVG=  49374.982  MAX=  68430.750
                                                                                                         MIN=      0.000
****************************************************************************************************************************
**** LOC     2  RESERVOIR B                        SERVED BY     2

                                                                                        STARTING TIME=       1
                                          SERVING       2     3                         HOUR= 6,DAY= 6,MON= 6,YEAR=1957.
PER        CUM LOCAL Q

  1      0.      0.  20000.  40000.  60000.  80000. 100000.  90000.  70000.  50000.
 11  30000.  10000.  10000.      0.

                                                                                        AVG=  40000.000  MAX= 100000.000
PER        NATURAL FLOW                                                                                  MIN=      0.000

  1      0.      0.  20000.  40000.  60000.  80000. 100000.  90000.  70000.  50000.
 11  30000.  10000.  10000.      0.

                                                                                        AVG=  40000.000  MAX= 100000.000
PER        INFLOW                                                                                        MIN=      0.000

  1      0.      0.  20000.  40000.  60000.  80000. 100000.  90000.  70000.  50000.
 11  30000.  10000.  10000.      0.

                                                                                        AVG=  40000.000  MAX= 100000.000
PER        OUTFLOW                                                                                       MIN=      0.000

  1      0.      0.      0.      0.  12000.  12000.   8999.      0.      0.      0.
 11   8999.  12000.  12000.  12000.

                                                                                        AVG=   5571.343  MAX=  12000.000
PER        CASE=LOC.TYP                                                                                  MIN=      0.000

  1    .03     .03    3.01    3.00     .01     .01    3.02    3.02    3.01    3.00
 11   3.00     .01     .01     .01

                                                                                        AVG=      1.512  MAX=      3.020
PER        LEVEL                                                                                         MIN=       .010

  1  2.000   2.000   2.040   2.119   2.214   2.349   2.530   2.708   2.847   2.946
 11  2.988   2.984   2.980   2.956

                                                                                        AVG=      2.547  MAX=      2.988
PER        EOP STORAGE                                                                                   MIN=      2.000

  1      0.      0.   9917.  29753.  53555.  87274. 132399. 177028. 211739. 236533.
 11 246946. 245955. 244963. 239012.

                                                                                        AVG= 136790.916  MAX= 246946.345
                                                                                                         MIN=      0.000
****************************************************************************************************************************
```

```
**** LOC     3  CONFLUENCE BELOW A AND B        SERVED BY     1     2

PER        CUM LOCAL Q

   1     -0.    5000.  15000.  25000.  15000.    2000.    5000.  10000.  20000.  30000.
  11  20000.  10000.    1000.      0.

                                                                                          AVG=  11285.714  MAX=  30000.000
                                                                                                           MIN=     -0.000
PER        NATURAL FLOW

   1      0.    5000.  25000.  58333.  85000.  98667. 118333. 120000. 118333. 105333.
  11  72000.  40333.  18000.   8667.

                                                                                          AVG=  62357.143  MAX= 120000.000
                                                                                                           MIN=      0.000
PER        REGULATED FLOW

   1      0.    5000.  15000.  25000.  21000.  14000.  22000.  21000.  25000.  30000.
  11  25000.  21000.  18000.  18000.

                                                                                          AVG=  18571.343  MAX=  30000.000
                                                                                                           MIN=      0.000
PER        Q SPACE AVAIL.

   1  25000.  20000.  10000.      0.    4000.  11000.   3000.   4000.      0.  -5000.
  11      0.   4000.   7000.   7000.

                                                                                          AVG=   6428.657  MAX=  25000.000
                                                                                                           MIN=  -5000.000
PER        Q BY US RES,DIVS

   1      0.      0.      0.      0.    6000.  12000.  17000.  11000.   5000.      0.
  11   5000.  11000.  17000.  18000.

                                                                                          AVG=   7285.629  MAX=  18000.000
                                                                                                           MIN=      0.000
PER        FLOOD BY RES

   1      0.      0.      0.     -0.      0.      0.      0.      0.      0.      0.
  11      0.      0.      0.      0.

                                                                                          AVG=      0.000  MAX=      0.000
                                                                                                           MIN=      0.000
**************************************************************************************************************************

**************************************************************************************************************************

** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON QA CARD
```

4. TEST PROBLEM 3

a. This test problem is the same three reservoir system shown in the third sample problem of Exhibit 2. Reservoir C is upstream from Reservoir B (tandem) and the two reservoirs operate in parallel with Reservoir A for downstream Control Point D. The output for this problem shows the complete default output (J2.6=0).

b. The flows provided as IN cards in the model represent full natural flows and variable ILOCAL (J1.8) was set equal to 20 telling the program to compute local flows and then operate the system. Following the summary of input data, the computation of incremental local flows is shown. The table labeled INC LOCAL FLOWS COMPUTED provides the resulting local flows.

c. A review of the sequential output shows the upstream tandem Reservoir C operating up to channel capacity until period 7 when its flood control storage space is filled. Inflow equals outflow after period 7 until period 11 when the reservoir can start releasing water from storage. No releases were made from period 13 to 17 because the downstream reservoir was at a higher level.

The downstream tandem Reservoir B does not fill flood control space (Max level = 2.967) and is able to operate for downstream Control Point 1. The Reservoir B level and the equivalent (B+C) level are both shown for this reservoir.

The third reservoir (A) released channel capacity whenever possible. Reservoir releases were reduced on periods 9-11 and 14 to avoid flooding Control Point 1. Reservoir A operates at a level that is equal to or higher than the level of Reservoir B (and the equivalent Reservoir B-C) until period 8. After that, Reservoir B has a higher priority than Reservoir A for making flood control releases. However, Reservoir B releases were reduced during periods 14 and 15 to prevent flooding at the downstream control point 1. The routing criteria for Reservoir A allowed the channel capacity release on period 15, while the release from Reservoir B had to be zero for the same period.

Output for location 1 indicates that reservoir releases do not contribute to flooding (FLOOD BY RES = 0), and that there is no flooding at this location (no negative values for Q SPACE AVAIL.).

d. Following the sequential output by control point, the reservoir system operation by period is printed. This output should be reviewed in analyzing the operation of Reservoir C. Reservoir C is operated primarily for constraints at the reservoir but also to keep in balance with the downstream Reservoir B. During the first three periods, both reservoirs are at the top of conservation pool. Starting with period 4, Reservoir C remains above the level of the equivalent Reservoir B-C and maximum releases are made for periods 4-6. On periods 7-10, releases are made to prevent the storage in C from exceeding the top of the flood control pool (level 3.00). On periods 11 and 12, the full channel capacity is released since Reservoir C was higher than the equivalent reservoir on periods 10 and 11. No releases were made from Reservoir C for periods 13-17 since the equivalent reservoir levels were higher than Reservoir C for periods 12-16.

e. The remaining output shows all of the standard output options available in the program. Options are printed based on the total value of the PRINT variable (J2.6).

```
HEC-5C SIMULATION OF FLOOD CONTROL
       AND CONSERVATION SYSTEMS
       UPDATED  OCT. 3 , 1975
RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1     THREE RESERVOIR OPERATION FOR FLOOD CONTROL              TEST 3
T2     COMPUTE LOCAL FLOWS FROM NATURAL FLOWS
T3     EXAMPLE NO 3 FROM EXHIBIT 2
J1     17.00      6.00      3.00      2.00      3.00     -0.00     -0.00     20.00     -0.00     -0.00
J2     -0.00     -0.00     -0.00      1.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

RL      3.00      0.00      0.00      0.00      0.00  50000.00     -0.00     -0.00     -0.00     -0.00
RO      1.00      2.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS      2.00      0.00  50000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RQ      2.00   6000.00 100000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP      3.00   6000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID RESERVOIR C                                 -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT      3.00      2.00      1.00      1.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

RL      2.00      0.00      0.00      0.00      0.00 275000.00     -0.00     -0.00     -0.00     -0.00
RO      1.00      1.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS      2.00      0.00 275000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RQ      2.00  21000.00  21000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP      2.00  21000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID RESERVOIR B                                 -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT      2.00      1.00      1.00      3.10     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

RL      5.00      0.00      0.00      0.00      0.00 200000.00     -0.00     -0.00     -0.00     -0.00
RO      1.00      1.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS      2.00      0.00 200000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RQ      2.00  12000.00  12000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP      5.00  12000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID RESERVOIR A                                 -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT      5.00      1.00      1.00      3.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP      1.00  25000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID CONTROL POINT D                             -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT      5.00      0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ED     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
    NRES=     3  NCPT=     4  NCPTR=     -0

IN     3 6JUNE        0.0       0.0    3000.0   18000.0   37000.0   42000.0   50000.0   27000.0   20000.0   13000.0
                   5000.0       0.0      -0.0      -0.0      -0.0      -0.0      -0.0
                                                                                                         SUM=    215000.
IN     2   JUNE      -0.0      -0.0    3000.0   24000.0   57000.0   99000.0  150000.0  117000.0   90000.0   63000.0
                  42000.0   24000.0   24000.0   15000.0    9000.0    3000.0      -0.0
                                                                                                         SUM=    720000.
IN     5 6JUNE        0.0    6000.0   27000.0   60000.0  105000.0   78000.0   60000.0   45000.0   33000.0   24000.0
                  18000.0   12000.0   12000.0    9000.0    6000.0    3000.0       0.0
                                                                                                         SUM=    496000.
IN     1   JUNE      -0.0    4000.0   22000.0   33000.0   69000.0  131000.0  187000.0  204000.0  181000.0  140000.0
                 109000.0   93000.0   61000.0   42000.0   31000.0   19000.0   10000.0
                                                                                                         SUM=   1336000.
EJ    -0             -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0
```

```
J1    NPER    IPER      NL      NL1      NLM     EPER    NLBUF   ILOCAL   INFLOW    IOPMP
        17       6       3        2        3       17        1       20       -0       -0
J2   CNSTI   CFLOD  IFCAST   RATCHG    NFLRD   IPRINT   FLONAT   NORDUT    NCPTR    TRACE
      1.00    1.00       4     1.00        1      511      -0.        0       -0      -0.
J3  METRIC   ECFCT    DATE   BCRFAC   COSFAC   IPRECN   IANDAM   ISCHED    IPRIO   IPLOTJ
         0    1.00      0.     1.00     1.00        0        0        0        0        0

USER ID COMP ID      QMAX     RTFR     RTTO     RTMD        X        K    LAG   LQCP    RTLQ   QLAG  QMIND  QMINR

      3      1      6000.       3.       2.     1.00     1.00   -0.000     -0     -0  -0.000    -0.    -0.    -0. RESERVOIR C
      2      2     21000.       2.       1.     1.00     3.10   -0.000     -0     -0  -0.000    -0.    -0.    -0. RESERVOIR B
      5      3     12000.       5.       1.     1.00     3.20   -0.000     -0     -0  -0.000    -0.    -0.    -0. RESERVOIR A
      1      4     25000.       1.       0.    -0.00    -0.00   -0.000     -0     -0  -0.000    -0.    -0.    -0. CONTROL POINT D

USER ID COMP ID     STOR1   STORL-1       -2        -3        -4        -5       ISERV(M,K)=

     3       1        0.        0.       0.    50000.        0.        0.       1       2
     2       2        0.        0.       0.   275000.        0.        0.       2       4
     5       3        0.        0.       0.   200000.        0.        0.       3       4

RESERVOIR DATA

USER ID=       3   COMP ID=        1

RS   STORAGES=             0.     50000.
RQ   Q CAPACITIES=      6000.    100000.
RA   AREAS=                0.         0.
RE   ELEVATIONS=           0.         0.
R1   START-STORAGE         0.         0.        0.        0.        0.        0.        0.        0.        0.
USER ID=       2   COMP ID=        2

RS   STORAGES=             0.    275000.
RQ   Q CAPACITIES=     21000.     21000.
RA   AREAS=                0.         0.
RE   ELEVATIONS=           0.         0.
R1   START-STORAGE         0.         0.        0.        0.        0.        0.        0.        0.        0.
USER ID=       5   COMP ID=        3

RS   STORAGES=             0.    200000.
RQ   Q CAPACITIES=     12000.     12000.
RA   AREAS=                0.         0.
RE   ELEVATIONS=           0.         0.
R1   START-STORAGE         0.         0.        0.        0.        0.        0.        0.        0.        0.
ROUTING COEFFICIENTS FROM RES        3 TO MY
       MY=        2     1.0000
ROUTING COEFFICIENTS FROM RES        2 TO MY
       MY=        1      .3333      .3333      .3333
ROUTING COEFFICIENTS FROM RES        5 TO MY
       MY=        1     0.0000      .3333      .3333      .3333

OBS Q AT     3
```

```
      MY=        1      .3333      .3333      .3333
ROUTING COEFFICIENTS FROM RES        5 TO MY
      MY=        1     0.0000      .3333      .3333      .3333

OBS Q AT    3

M=   3                   0.         0.      3000.     18000.     37000.     42000.     50000.     27000.     20000.     13000.
                      5000.         0.        -0.        -0.        -0.        -0.        -0.
SUM=   215000.

ROUTED Q FROM MX=   3 TO    2
RTMD=      1.00 RTCOF=      1.00 K=     -0.00

            COEF=   1.00000

M=   2                   0.         0.      3000.     18000.     37000.     42000.     50000.     27000.     20000.     13000.
                      5000.         0.         0.         0.         0.         0.         0.
SUM=   215000.

OBS Q AT    2

M=   2                  -0.        -0.      3000.     24000.     57000.     99000.    150000.    117000.     90000.     63000.
                     42000.     24000.     24000.     15000.      9000.      3000.        -0.
SUM=   720000.

ROUTED Q FROM MX=   2 TO    1
RTMD=      1.00 RTCOF=      3.10 K=     -0.00

            COEF=    .33333     .33333     .33333

M=   1                   0.         0.      1000.      9000.     28000.     60000.    102000.    122000.    119000.     90000.
                     65000.     43000.     30000.     21000.     16000.      9000.      4000.
SUM=   719000.

OBS Q AT    5

M=   5                   0.      6000.     27000.     60000.    105000.     78000.     60000.     45000.     33000.     24000.
                     18000.     12000.     12000.      9000.      6000.      3000.         0.
SUM=   498000.

ROUTED Q FROM MX=   5 TO    1
RTMD=      1.00 RTCOF=      3.20 K=     -0.00

            COEF=   0.00000     .33333     .33333     .33333

M=   1                   0.         0.      2000.     11000.     31000.     64000.     81000.     81000.     61000.     46000.
                     34000.     25000.     18000.     14000.     11000.      9000.      6000.
SUM=   494000.
```

SUM OF ROUTED FLOWS TO C.P. 1

M= 1	0.	0.	3000.	20000.	59000.	124000.	183000.	203000.	180000.	136000.
	99000.	68000.	48000.	35000.	27000.	18000.	10000.			

```
INC LOCAL FLOWS COMPUTED

RES INFLOW,OUTFLOW=   215000.        0. ALL RES I=0=        0.

M=   3                    0.        0.      3000.    18000.    37000.    42000.    50000.    27000.    20000.    13000.
                       5000.        0.       -0.       -0.       -0.       -0.       -0.

M=   3                    0.        0.      3000.    18000.    37000.    42000.    50000.    27000.    20000.    13000.
                       5000.        0.        0.        0.        0.        0.        0.
SUM=   215000. -SUM=       0. -MAX=        0.

RES INFLOW,OUTFLOW=   720000.        0. ALL RES I=0=        0.

M=   2                   -0.       -0.        0.      6000.    20000.    57000.   100000.    90000.    70000.    50000.
                      37000.    24000.    24000.    15000.     9000.     3000.       -0.

M=   2                    0.        0.        0.      6000.    20000.    57000.   100000.    90000.    70000.    50000.
                      37000.    24000.    24000.    15000.     9000.     3000.        0.
SUM=   505000. -SUM=       0. -MAX=        0.

RES INFLOW,OUTFLOW=   498000.        0. ALL RES I=0=        0.

M=   5                    0.     6000.     27000.    60000.   105000.    78000.    60000.    45000.    33000.    24000.
                      18000.    12000.     12000.     9000.     6000.     3000.        0.

M=   5                    0.     6000.     27000.    60000.   105000.    78000.    60000.    45000.    33000.    24000.
                      18000.    12000.     12000.     9000.     6000.     3000.        0.
SUM=   498000. -SUM=       0. -MAX=        0.

RES INFLOW,OUTFLOW=  1336000.        0. ALL RES I=0=        0.

M=   1                   -0.     4000.     19000.    13000.    10000.     7000.     4000.     1000.     1000.     4000.
                      10000.    25000.     13000.     7000.     4000.     1000.        0.

M=   1                    0.     4000.     19000.    13000.    10000.     7000.     4000.     1000.     1000.     4000.
                      10000.    25000.     13000.     7000.     4000.     1000.        0.
SUM=   123000. -SUM=       0. -MAX=        0.
SUM ALL INC FLOWS(CFS-PER)=          1341000. AVG=     78882. SUM LAST MX=        1336000. D.S.VOL(RES.I=0,+MX)=  1
```

```
THREE RESERVOIR OPERATION FOR FLOOD CONTROL          TEST 3
COMPUTE LOCAL FLOWS FROM NATURAL FLOWS
EXAMPLE NO 3 FROM EXHIBIT 2

COMPUTATION INTERVAL IN HOURS=   6

          ***** FLOOD NUMBER  1 *****                          UNITS OF OUTPUT

     NFLRD=         1  NFLCON=      0       ALL FLOWS IN CFS OR CMS
     IFLRD =        1  IFLCON=      1       EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
        FLOWS MULTIPLIED BY     1.000       ELEVATIONS IN FEET OR METERS
                                            POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

**********************************************************************************************************

**** LOC    3  RESERVOIR C                SERVED BY    3

                                                                          STARTING TIME=      1
PER      CUM LOCAL Q            SERVING      3    2                       HOUR= 6,DAY= 1,MON= 0,YEAR=19 0.

  1       0.      0.   3000.  18000.  37000.  42000.  50000.  27000.  20000.  13000.
 11    5000.      0.      0.      0.      0.      0.      0.

                                                                          AVG=  12647.059   MAX=  50000.000
PER      NATURAL FLOW                                                                       MIN=      0.000

  1       0.      0.   3000.  18000.  37000.  42000.  50000.  27000.  20000.  13000.
 11    5000.      0.     -0.     -0.     -0.     -0.     -0.

                                                                          AVG=  12647.059   MAX=  50000.000
PER      INFLOW                                                                             MIN=      0.000

  1       0.      0.   3000.  18000.  37000.  42000.  50000.  27000.  20000.  13000.
 11    5000.      0.      0.      0.      0.      0.      0.

                                                                          AVG=  12647.059   MAX=  50000.000
PER      OUTFLOW                                                                            MIN=      0.000

  1       0.      0.   3000.   6000.   6000.   6000.  28168.  27000.  20000.  13000.
 11    6000.   6000.      0.      0.      0.      0.      0.

                                                                          AVG=   7127.537   MAX=  28168.137
PER      CASE=LOC.TYP                                                                       MIN=      0.000

  1     .03     .03     .03     .01     .01     .01     .04     .04     .04     .04
 11     .01     .01     .05     .05     .05     .05     .05

                                                                          AVG=       .032   MAX=       .050
PER      LEVEL                                                                              MIN=       .010

  1   2.000   2.000   2.000   2.119   2.426   2.783   3.000   3.000   3.000   3.000
 11   2.990   2.931   2.931   2.931   2.931   2.931   2.931

                                                                          AVG=      2.700   MAX=      3.000
                                                                                            MIN=      2.000
```

```
PER        EOP STORAGE

  1      0.        0.        0.     5951.   21323.   39174.   50000.   50000.   50000.   50000.
 11  49504.    46529.    46529.    46529.   46529.   46529.   46529.

                                                                              AVG=  35007.331  MAX=  50000.000
                                                                                               MIN=      0.000
**************************************************************************************************************
**** LOC     2  RESERVOIR B                         SERVED BY      3     2

                                                                              STARTING TIME=       1
                                        SERVING        2     1                HOUR= 6,DAY= 1,MIN= 0,YEAR=19 0,
PER        CUM LOCAL Q

  1      0.        0.        0.     6000.   20000.   57000.  100000.   90000.   70000.   50000.
 11  37000.    24000.    24000.    15000.    9000.    3000.       0.

                                                                              AVG=  29705.882  MAX= 100000.000
PER        NATURAL FLOW                                                                        MIN=      0.000

  1     -0.       -0.     3000.    24000.   57000.   99000.  150000.  117000.   90000.   63000.
 11  42000.    24000.    24000.    15000.    9000.    3000.      -0.

                                                                              AVG=  42352.941  MAX= 150000.000
PER        INFLOW                                                                              MIN=     -0.000

  1      0.        0.     3000.    12000.   26000.   63000.  128168.  117000.   90000.   63000.
 11  43000.    30000.    24000.    15000.    9000.    3000.       0.

                                                                              AVG=  36833.420  MAX= 128168.137
PER        OUTFLOW                                                                             MIN=      0.000

  1      0.        0.     3000.    12000.       0.    6000.   21000.    9000.    6000.       0.
 11      0.        0.    21000.     9000.       0.   21000.   21000.

                                                                              AVG=   7588.204  MAX=  21000.000
PER        CASE=LOC.TYP                                                                        MIN=      0.000

  1     .03       .03       .03      1.01     1.00     1.00     1.00     1.00     1.00     1.02
 11    1.01      1.00       .01      1.00     1.00      .01     1.00

                                                                              AVG=       .715  MAX=      1.020
PER        LEVEL                                                                               MIN=       .010

  1   2.000     2.000     2.000     2.000    2.047    2.150    2.343    2.538    2.689    2.803
 11   2.880     2.934     2.940     2.951    2.967    2.934    2.896

                                                                              AVG=      2.534  MAX=      2.967
PER        EQUIVALENT LEVEL                                                                    MIN=      2.000

  1   2.000     2.000     2.000     2.018    2.105    2.247    2.444    2.609    2.737    2.833
 11   2.897     2.934     2.938     2.948    2.961    2.934    2.902

                                                                              AVG=      2.559  MAX=      2.961
                                                                                               MIN=      2.000
```

```
PER       EOP STORAGE

  1       0.       0.       0.       0.  12893.  41158.  94300. 147854. 189508. 220748.
 11  242070. 256947. 258434. 261410. 265873. 256947. 246534.

                                                                              AVG= 146745.577  MAX= 265872.598
                                                                                               MIN=      0.000
*****************************************************************************************************************
**** LOC     5  RESERVOIR A                          SERVED BY     5

                                                                              STARTING TIME=      1
                                       SERVING      5     1                   HOUR= 6,DAY= 1,MON= 0,YEAR=19 0.
PER       CUM LOCAL Q

  1       0.   6000.  27000.  60000. 105000.  78000.  60000.  45000.  33000.  24000.
 11   18000.  12000.  12000.   9000.   6000.   3000.      0.

                                                                              AVG=  29294.118  MAX= 105000.000
PER       NATURAL FLOW                                                                         MIN=      0.000

  1       0.   6000.  27000.  60000. 105000.  78000.  60000.  45000.  33000.  24000.
 11   18000.  12000.  12000.   9000.   6000.   3000.      0.

                                                                              AVG=  29294.118  MAX= 105000.000
PER       INFLOW                                                                               MIN=      0.000

  1       0.   6000.  27000.  60000. 105000.  78000.  60000.  45000.  33000.  24000.
 11   18000.  12000.  12000.   9000.   6000.   3000.      0.

                                                                              AVG=  29294.118  MAX= 105000.000
PER       OUTFLOW                                                                              MIN=      0.000

  1       0.   6000.  12000.  12000.  12000.  12000.  12000.  12000.      0.      0.
 11       0.  12000.  12000.   9000.  12000.  12000.  12000.

                                                                              AVG=   8647.064  MAX=  12000.000
PER       CASE=LOC.TYP                                                                         MIN=      0.000

  1      .03     .03     .01     .01     .01     .01     .01     .01    1.03    1.02
 11     1.01     .01     .01    1.01     .01     .01     .01

                                                                              AVG=       .249  MAX=      1.030
PER       LEVEL                                                                                MIN=       .010

  1    2.000   2.000   2.037   2.156   2.387   2.550   2.669   2.751   2.833   2.893
 11    2.937   2.937   2.937   2.937   2.922   2.900   2.870

                                                                              AVG=      2.630  MAX=      2.937
PER       EOP STORAGE                                                                          MIN=      2.000

  1       0.      0.   7438.  31240.  77357. 110084. 133886. 150250. 166614. 178515.
 11  187441. 187441. 187441. 187441. 184465. 180003. 174052.

                                                                              AVG= 126098.085  MAX= 187440.750
                                                                                               MIN=      0.000
*****************************************************************************************************************
```

```
*****************************************************************************************************************************
**** LOC     1  CONTROL POINT D                  SERVED BY    -3     2     5

PER        CUM LOCAL Q

   1      0.    4000.  19000.  13000.  10000.   7000.   4000.   1000.   1000.   4000.
  11  10000.  25000.  13000.   7000.   4000.   1000.      0.

                                                                                          AVG=   7235.294   MAX=  25000.000
                                                                                                            MIN=      0.000
PER        NATURAL FLOW

   1     -0.    4000.  22000.  33000.  69000. 131000. 187000. 204000. 181000. 140000.
  11 109000.  93000.  61000.  42000.  31000.  19000.  10000.

                                                                                          AVG=  78588.235   MAX= 204000.000
                                                                                                            MIN=     -0.000
PER        REGULATED FLOW

   1      0.    4000.  22000.  24000.  25000.  25000.  25000.  25000.  25000.  17000.
  11  16000.  25000.  24000.  25000.  25000.  22000.  25000.

                                                                                          AVG=  20823.506   MAX=  25000.000
                                                                                                            MIN=      0.000
PER        Q SPACE AVAIL.

   1  25000.  21000.   3000.   1000.      0.      0.      0.      0.      0.   8000.
  11   9000.      0.   1000.      0.      0.   3000.      0.

                                                                                          AVG=   4176.494   MAX=  25000.000
                                                                                                            MIN=      0.000
PER        Q BY US RES,DIVS

   1      0.      0.   3000.  11000.  15000.  18000.  21000.  24000.  24000.  13000.
  11   6000.      0.  11000.  18000.  21000.  21000.  25000.

                                                                                          AVG=  13588.212   MAX=  25000.000
                                                                                                            MIN=      0.000
PER        FLOOD BY RES

   1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  11      0.     -0.      0.      0.      0.      0.     -0.

                                                                                          AVG=      0.000   MAX=      0.000
                                                                                                            MIN=      0.000
*****************************************************************************************************************************

RESERVOIR OPERATION BY PERIOD


            CUM TIME=      1


RES NO=        3       2       5
INFLOW        0.      0.      0.
OUTFLOW       0.      0.      0.
EOP STOR      0.      0.      0.
CASE=        .03     .03     .03
LEVEL      2.000   2.000   2.000
EQ LEVEL   2.000   2.000   2.000

            CUM TIME=      2
```

RES NO=	3	2	5
INFLOW	0.	0.	6000.
OUTFLOW	0.	0.	6000.
EOP STOR	0.	0.	0.
CASE=	.03	.03	.03
LEVEL	2.000	2.000	2.000
EQ LEVEL	2.000	2.000	2.000

CUM TIME= 3

RES NO=	3	2	5
INFLOW	3000.	3000.	27000.
OUTFLOW	3000.	3000.	12000.
EOP STOR	0.	0.	7438.
CASE=	.03	.03	.01
LEVEL	2.000	2.000	2.037
EQ LEVEL	2.000	2.000	2.037

CUM TIME= 4

RES NO=	3	2	5
INFLOW	18000.	12000.	60000.
OUTFLOW	6000.	12000.	12000.
EOP STOR	5951.	0.	31240.
CASE=	.01	1.01	.01
LEVEL	2.119	2.000	2.156
EQ LEVEL	2.119	2.018	2.156

CUM TIME= 5

RES NO=	3	2	5
INFLOW	37000.	26000.	105000.
OUTFLOW	6000.	0.	12000.
EOP STOR	21323.	12893.	77357.
CASE=	.01	1.00	.01
LEVEL	2.426	2.047	2.387
EQ LEVEL	2.426	2.105	2.387

CUM TIME= 6

RES NO=	3	2	5
INFLOW	42000.	63000.	78000.
OUTFLOW	6000.	6000.	12000.
EOP STOR	39174.	41158.	110084.
CASE=	.01	1.00	.01
LEVEL	2.783	2.150	2.550
EQ LEVEL	2.783	2.247	2.550

CUM TIME= 7

RES NO=	3	2	5
INFLOW	50000.	128168.	60000.
OUTFLOW	28168.	21000.	12000.
EOP STOR	50000.	94300.	133886.
CASE=	.04	1.00	.01
LEVEL	3.000	2.343	2.669
EQ LEVEL	3.000	2.444	2.669

CUM TIME= 8

RES NO=	3	2	5
INFLOW	27000.	117000.	45000.
OUTFLOW	27000.	9000.	12000.
EOP STOR	50000.	147854.	150250.
CASE=	.04	1.00	.01
LEVEL	3.000	2.538	2.751
EQ LEVEL	3.000	2.609	2.751

CUM TIME= 9

RES NO=	3	2	5
INFLOW	20000.	90000.	33000.
OUTFLOW	20000.	6000.	0.
EOP STOR	50000.	189508.	166614.
CASE=	.04	1.00	1.03
LEVEL	3.000	2.689	2.833
EQ LEVEL	3.000	2.737	2.833

CUM TIME= 10

RES NO=	3	2	5
INFLOW	13000.	63000.	24000.
OUTFLOW	13000.	0.	0.
EOP STOR	50000.	220748.	178515.
CASE=	.04	1.02	1.02
LEVEL	3.000	2.803	2.893
EQ LEVEL	3.000	2.833	2.893

CUM TIME= 11

RES NO=	3	2	5
INFLOW	5000.	43000.	18000.
OUTFLOW	6000.	0.	0.
EOP STOR	49504.	242070.	187441.
CASE=	.01	1.01	1.01
LEVEL	2.990	2.880	2.937
EQ LEVEL	2.990	2.897	2.937

CUM TIME= 12

RES NO=	3	2	5
INFLOW	0.	30000.	12000.
OUTFLOW	6000.	0.	12000.
EOP STOR	46529.	256947.	187441.
CASE=	.01	1.00	.01
LEVEL	2.931	2.934	2.937
EQ LEVEL	2.931	2.934	2.937

CUM TIME= 13

RES NO=	3	2	5
INFLOW	0.	24000.	12000.
OUTFLOW	0.	21000.	12000.
EOP STOR	46529.	258434.	187441.
CASE=	.05	.01	.01
LEVEL	2.931	2.940	2.937
EQ LEVEL	2.931	2.938	2.937

CUM TIME= 14

RES NO=	3	2	5
INFLOW	0.	15000.	9000.
OUTFLOW	0.	9000.	9000.
EOP STOR	46529.	261410.	187441.
CASE=	.05	1.00	1.01
LEVEL	2.931	2.951	2.937
EQ LEVEL	2.931	2.948	2.937

CUM TIME= 15

RES NO=	3	2	5
INFLOW	0.	9000.	6000.
OUTFLOW	0.	0.	12000.
EOP STOR	46529.	265873.	184465.
CASE=	.05	1.00	.01
LEVEL	2.931	2.967	2.922
EQ LEVEL	2.931	2.961	2.922

CUM TIME= 16

RES NO=	3	2	5
INFLOW	0.	3000.	3000.
OUTFLOW	0.	21000.	12000.
EOP STOR	46529.	256947.	180003.
CASE=	.05	.01	.01
LEVEL	2.931	2.934	2.900
EQ LEVEL	2.931	2.934	2.900

CUM TIME= 17

RES NO=	3	2	5
INFLOW	0.	0.	0.
OUTFLOW	0.	21000.	12000.
EOP STOR	46529.	246534.	174052.
CASE=	.05	1.00	.01
LEVEL	2.931	2.896	2.870
EQ LEVEL	2.931	2.902	2.870

RESERVOIR RELEASES BY PERIOD

RES NO	3	2	5
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	0.	0.	0.
2	0.	0.	6000.
3	3000.	3000.	12000.
4	6000.	12000.	12000.
5	6000.	0.	12000.
6	6000.	6000.	12000.
7	28168.	21000.	12000.
8	27000.	9000.	12000.
9	20000.	6000.	0.
10	13000.	0.	0.
11	6000.	0.	0.
12	6000.	0.	12000.
13	0.	21000.	12000.
14	0.	9000.	9000.
15	0.	0.	12000.
16	0.	21000.	12000.
17	0.	21000.	12000.
SUM =	121168.	128999.	147000.
MAX =	28168.	21000.	12000.
MIN =	0.	0.	0.
MPER=	7.	13.	3.
AVG =	7128.	7588.	8647.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	1
CHAN CAP	25000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	0.
2	4000.
3	22000.
4	24000.
5	25000.
6	25000.
7	25000.
8	25000.
9	25000.
10	17000.

```
11        16000.
12        25000.
13        24000.
14        25000.
15        25000.
16        22000.
17        25000.

  SUM = 354000.

  MAX =  25000.

  MIN =      0.

  MPER=     12.

  AVG =  20824.
```

SINGLE FLOOD SUMMARY COPY= 1
COMPUTATION INTERVAL IN HOURS= 6

THREE RESERVOIR OPERATION FOR FLOOD CONTROL TEST 3
COMPUTE LOCAL FLOWS FROM NATURAL FLOWS
EXAMPLE NO 3 FROM EXHIBIT 2

***** FLOOD NUMBER 1 *****

LOC=	NONRESERVOIRS	MAX REG Q	MAX NAT	MAX UNC	Q BY RES	NO FLOODS TOTAL	VOL FLOODS TOTAL	NO FLOODS FROM RES	VOL FLOODS FROM RES	PER FLOODS FROM RES	CH CAP
1	CONTROL POINT D	25000.	204000.	25000.	0.	0.	0.	0.	0.	0.- 0.	25000.

LOC=	RESERVOIRS	STOR1	MAX STG	MAX LEVEL	EXCEEDED TOP F.C. 1ST PER.	EXCEEDED TOP F.C. LAST PER.	MAX INFLOW	MAX REL	CHAN CAP
3	RESERVOIR C	0	50000	3,000	7	10	50000	28168	6000
2	RESERVOIR B	0	265872	2,967	0	0	128168	20999	21000
5	RESERVOIR A	0	187440	2,937	0	0	105000	12000	12000

MAX SYSTEM STORAGE= 503312

SUMMARY OF AVERAGES FOR RESERVOIRS

LOC=	CUM LOCA	NATURAL	INFLOW	OUTFLOW	CASE=LOC	LEVEL	EOP STOR
3	12647.06	12647.06	12647.06	7127.54	.03	2,70	35007.33
2	29705.88	42352.94	36833.42	7588.20	.71	2,53	146745.58
5	29294.12	29294.12	29294.12	8647.06	.25	2,63	126098.09

SUMMARY OF AVERAGES FOR NON RESERVOIRS

LOC=	CUM LOCA	NATURAL	REGULATE	Q SPACE	Q BY US	FLOOD BY
1	7235.29	78588.24	20823.51	4176.49	13588.21	0,00

FLOOD SUMMARY-EACH FLOOD COPY= 1

THREE RESERVOIR OPERATION FOR FLOOD CONTROL   TEST 3
COMPUTE LOCAL FLOWS FROM NATURAL FLOWS
EXAMPLE NO 3 FROM EXHIBIT 2

***** FLOOD NUMBER 1 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	1 CONTROL POINT D	1.012	25000. *	1.008	204000. *	1.012	25000. *	0. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	3 RESERVOIR C	1.003	0.	2.000 *	1.008	50000	3.000 *	1.007	28168	6000	0
LOC	2 RESERVOIR B	1.003	0.	2.000 *	1.015	265872	2.967 *	1.013	20999	21000	0
LOC	5 RESERVOIR A	1.002	0.	2.000 *	1.011	187440	2.937 *	1.003	12000	12000	0

MIN SYSTEM STG= 0   MAX SYSTEM STG= 503312

HYDROLOGIC EFFICIENCIES

**** LOC 1 CONTROL POINT D SERVED BY -3 2 5

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	204000.	25000.	179000.0	87.75	.00	.00	0.00	0.00

```
****************************************************************************************************************************************
        COMPUTER CHECK FOR POSSIBLE ERRORS

                       ***** FLOOD NUMBER  1 *****

POSSIBLE ERRORS FOUND=       0 ALLOWABLE ERROR CHECK=      50
****************************************************************************************************************************************


** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON GA CARD
```

5. TEST PROBLEM 4

a. This test problem is for a single reservoir operating for two downstream locations. The channel routing criteria is Modified Puls with a nonlinear storage-discharge relationship (QS and SQ Cards). The flow data is defined using two sets of flow cards (J2.5) with data transferred from period 18 of the first flow set (BF.3=18) to the first period of the second flow set.

b. The release routing in the program uses a set of linear routing coefficients in determining the proper reservoir releases as explained in Exhibit 2. This set of coefficients is shown on the computer output between the input summary and the sequential output by control point under the heading "ROUTING COEFFICIENTS FROM RES ___ TO MY ___". The coefficients of .0364, .1461, etc., under reservoir 1 operating for control point 2, show that 3.64 and 14.6 percent of the current period's release will be at location 2 during the current period and the next future period, respectively. These coefficients remain the same for all time periods when linear routing methods (coefficient methods like Muskingum) are used. When nonlinear routing is used the final flows are routed with the actual non-linear method, but all reservoir releases are determined by a linear approximation of the channel storage-discharge curve. The linear approx-imation (equivalent to Muskingum K) changes with the flow in the river. The coefficients that are printed are for period 1 only. The linear routing assumption for release determination causes little flooding if a sufficiently large contingency allowance (CFLOD-J2.2) is used. In our example a 1.2 value (or 20% forecast error) was used. The note "4110 SUM COMB COEFF = ___" results from the FORTRAN statement 4100 and indicates that for time periods 18 to 23, the sum of the routing coefficients were less than 1.00. This occurred after the ending period of flood one because the number of coefficients exceeded the number of operating periods.

c. This particular test was developed to test the computer program for automatically dividing a long flood into two or more parts. By coding this problem for one flood, instead of two, and by setting a dimension limit for 28 time periods (temporary change to program) the output is identical to this example. Thus, this example shows how a user can code a long flood into two or more parts and make assumptions on the transition between floods that are different than the automatic routine. In this example the first half of the flood (flood 1) was coded (on IN cards) for 28 flow periods and the second flood for 18 additional flows. The BF card was required (prior to the IN cards for each flood) to cause the reservoir storages to be transferred from the first flood, at period 18, to the second flood (NPSTO-18 on BF.3 of first flood) and to read in only 18 flow values for the second flood (NPER=18 on BF.2 of second Flood). The results of the first flood were transferred at period

18 and the flows from the previous 10 periods were also transferred to maintain continuity. Thus the second flood operates with flows starting with period 9 of flood 1 and displays results starting with period 19 of flood 1. The last 10 flows from the first flood (periods 19-28) are shown under flood 2.

d. The project operation is quite simple in that no releases were made until the flood control storage was exceeded and then all excess flood water was released, since sufficient outlet capacity existed. An operation with a smaller contingency allowance (less than 1.2) did allow releases which slightly increased the downstream flooding.

e. The plot option was also requested on this job, for control point 3 only, by inputting a 4 on the 9th field of the ID card. Although 4 hydrographs were requested only the natural and regulated hydrographs are shown. The local flow was so clase to the regulated that only the regulated was plotted. The inflow is not shown because it is the same as regulated for a control point. The two plots (flood 1 and flood 2) clearly show how the flood was divided into two parts. Also, the different plot scale selected by the program for the two parts of the plot point out the desirability of the user preselecting the scale to be used so that the hydrographs will be displayed at the same scale. (See field ID.9 and J3.10.)

```
HEC-5C SIMULATION OF FLOOD CONTROL
     AND CONSERVATION SYSTEMS
     UPDATED  OCT. 3 , 1975
RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1      TWO FLOOD SERIES WITH AN OVERLAP                              TEST4
T2      USING MODIFIED PULS ROUTING
T3      STORAGE IS TRANSFERRED AT PERIOD 18 OF FLOOD 1  (BF.3=18)
J1        28.00        2.00        3.00        1.00        2.00        0.00        0.00        1.00        0.00        1.00
J2         0.00        1.20        6.00        0.00        2.00       -0.00       -1.00        0.00       -0.00       -0.00

RL         1.00    86600.00        0.00    86600.00   146500.00   188100.00       -0.00       -0.00       -0.00       -0.00
RO         2.00        2.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         3.00    86600.00   146500.00   188100.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RQ         3.00     5000.00    10000.00    60000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         1.00     5000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID TEST RES                                               -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         1.00        2.00        2.30        0.00        0.00       -0.00       -0.00       -0.00       -0.00       -0.00
QS         9.00        0.00     1000.00     5000.00     9000.00    17000.00    27000.00    35000.00    40000.00    50000.00
SQ         9.00        0.00      500.00     2500.00     5000.00    10000.00    20000.00    30000.00    40000.00    70000.00

CP         2.00    10000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID FIRST CONTROL POINT                                    -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         2.00        3.00        2.30        0.00        0.00       -0.00       -0.00       -0.00       -0.00       -0.00
QS         8.00        0.00     1000.00     5000.00     9000.00    17000.00    35000.00    50000.00    60000.00       -0.00
SQ         8.00        0.00     1500.00     7500.00    15000.00    30000.00    90000.00   210000.00   330000.00       -0.00

CP         3.00    20000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID SECOND AND LAST CP                                     -0.00       -0.00       -0.00       -0.00        4.00       -0.00
RT         3.00        0.00        0.00        0.00        0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ED         1.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

   NRES=     1  NCPT=     3  NCPTR=     -0

BF        -0.00       28.00       18.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
IN     1     TEST    2000.0    3300.0    4650.0    5900.0    9700.0   16600.0   24500.0   31900.0   37800.0   41300.0
                    41400.0   38500.0   33000.0   25200.0   17000.0   10800.0    6600.0    4000.0    2000.0    1900.0
                     1700.0    1600.0    1500.0    1390.0    1300.0    1200.0    1150.0    1100.0
                                                                                                   SUM=     368990.
IN     2     TEST    3600.0    4330.0    3700.0    3600.0    5100.0    7400.0    9170.0    9860.0   10000.0    9900.0
                    10800.0   15900.0   24300.0   25600.0   27500.0   28900.0   36600.0   46200.0   52300.0   53000.0
                    48300.0   40500.0   31800.0   23600.0   16900.0   12000.0    8600.0    6400.0
                                                                                                   SUM=     575860.
EJ    -0             -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0
```

```
J1    NPER   IPER     NL     NL1     NLM    EPER   NLBUF  ILOCAL  INFLOW   IOPMP
        28      2      3       1       2      28       1       1       0       1
J2   CNSTI  CFLOD  IFCAST  RATCHG   NFLPD  IPRINT  FLUNAT  NOROUT   NCPTR   TRACE
      1.00   1.20      6     .50       2     511     -1.       0      -0      -0.
J3  METRIC  ECFCT   DATE  BCRFAC  COSFAC  IPRECN  IANDAM  ISCHED   IPRIO  IPLOTJ
         0   1.00     0.    1.00    1.00       0       0       0       0       0

USER ID COMP ID     QMAX    RTFR    RTTU    RTMD      X       K    LAG   LQCP    RTLQ   QLAG  QMIND  QMINR

     1      1      5000.      1.      2.    2.30    0.00   0.000    -0    -0   -0.000   -0.    -0.    -0. TEST RES
     2      2     10000.      2.      3.    2.30    0.00   0.000    -0    -0   -0.000   -0.    -0.    -0. FIRST CONTROL POINT
     3      3     20000.      3.      0.    0.00    0.00   0.000    -0    -0   -0.000   -0.    -0.    -0. SECOND AND LAST CP

USER ID COMP ID    STUR1   STORL-1      -2       -3        -4       -5      ISERV(M,K)-

     1      1     86600.   86600.   146500.  188100.       0.       0.      1       2       3

RESERVOIR DATA

USER ID=      1   COMP ID=      1

RS   STORAGES=         86600.   146500.   188100.
RQ   Q CAPACITIES=      5000.    10000.    60000.
RA   AREAS=                0.        0.        0.
RE   ELEVATIONS=           0.        0.        0.
R1   START-STORAGE         0.        0.        0.       0.       0.       0.       0.       0.       0.

ROUTING COEFFICIENTS FROM RES      1 TO MY
       MY=      2      .0364    .1461    .2446    .2353    .1602    .0911    .0466    .0219    .0094    .0036
                       .0013    .0004
       MY=      3      .0000    .0000    .0002    .0011    .0038    .0104    .0229    .0419    .0655    .0892
                       .1075    .1165    .1151    .1046    .0883    .0698    .0520    .0367    .0246    .0158
                       .0097    .0057    .0032    .0016
                                                                                        COMCUF   4100.00
4110 SUM COMB COEF=        .36 MXX,MYY,MX,MY,IP=      2       3       1       3      18
                                                                                        COMCUF   4100.00
4110 SUM COMB COEF=        .40 MXX,MYY,MX,MY,IP=      2       3       1       3      19
                                                                                        COMCUF   4100.00
4110 SUM COMB COEF=        .00 MXX,MYY,MX,MY,IP=      2       3       1       3      20
                                                                                        COMCOF   4100.00
4110 SUM COMB COEF=        .00 MXX,MYY,MX,MY,IP=      2       3       1       3      21
                                                                                        COMCOF   4100.00
4110 SUM COMB COEF=        .40 MXX,MYY,MX,MY,IP=      2       3       1       3      22
                                                                                        COMCOF   4100.00
4110 SUM COMB COEF=        .40 MXX,MYY,MX,MY,IP=      2       3       1       3      23

BF       -0.00      18.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
IN    1   TEST    1000.0     900.0     850.0     800.0     750.0     700.0     650.0     600.0     570.0     550.0
                   500.0     500.0     500.0     500.0     500.0     500.0     500.0     500.0
                                                                                              SUM=      11370.
IN    2   TEST    5100.0    4200.0    3600.0    3200.0    2900.0    2700.0    2500.0    2300.0    2100.0    2000.0
                  1870.0    1740.0    1600.0    1500.0    1400.0    1300.0    1230.0    1150.0
                                                                                              SUM=      42390.
EJ   -0             -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0
```

```
        TWO FLOOD SERIES WITH AN OVERLAP                        TEST4
        USING MODIFIED PULS ROUTING
        STORAGE IS TRANSFERRED AT PERIOD 18 OF FLOOD 1  (BF,3=18)

COMPUTATION INTERVAL IN HOURS=   2

                    ***** FLOOD NUMBER  1 *****                                    UNITS OF OUTPUT

                                                                   ALL FLOWS IN CFS OR CMS
                NFLRD=       2  NFLCUN=       0                    EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
                IFLRD =      1  IFLCON=       1                    ELEVATIONS IN FEET OR METERS
                   FLOWS MULTIPLIED BY     1.000                   POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

*****************************************************************************************************************************

**** LOC     1  TEST RES                          SERVED BY     1

                                                                                          STARTING TIME=       1
                                  SERVING        1      2      3                          HOUR= 2,DAY= 1,MON= 0,YEAR=19 0,
PER        CUM LOCAL Q

   1   2000.    3300.    4650.    5900.    9700.   16600.   24500.   31900.   37800.   41300.
  11  41400.   38500.   33000.   25200.   17000.   10800.    6600.    4000.

                                                                                          AVG=  19675.000  MAX=  41400.000
PER        NATURAL FLOW                                                                                    MIN=   2000.000

   1   2000.    3300.    4650.    5900.    9700.   16600.   24500.   31900.   37800.   41300.
  11  41400.   38500.   33000.   25200.   17000.   10800.    6600.    4000.

                                                                                          AVG=  19675.000  MAX=  41400.000
PER        INFLOW                                                                                          MIN=   2000.000

   1   2000.    3300.    4650.    5900.    9700.   16600.   24500.   31900.   37800.   41300.
  11  41400.   38500.   33000.   25200.   17000.   10800.    6600.    4000.

                                                                                          AVG=  19675.000  MAX=  41400.000
PER        OUTFLOW                                                                                         MIN=   2000.000

   1      0.       0.       0.       0.       0.       0.       0.       0.       0.       0.
  11      0.       0.       0.       0.       0.       0.       0.       0.

                                                                                          AVG=      0.000  MAX=      0.000
PER        CASE=LOC.TYP                                                                                    MIN=      0.000

   1     2.06     2.05     2.04     2.03     2.02     2.01     2.00     2.00     2.00     2.00
  11     2.00     2.00     2.00     2.01     3.06     3.06     3.06     3.06

                                                                                          AVG=      2.248  MAX=      3.060
PER        LEVEL                                                                                           MIN=      2.000

   1    1.006    1.015    1.027    1.044    1.071    1.116    1.184    1.272    1.376    1.490
  11    1.604    1.711    1.802    1.871    1.918    1.948    1.966    1.977

                                                                                          AVG=      1.467  MAX=      1.977
                                                                                                           MIN=      1.006
```

```
PER        EOP STORAGE

  1  86931.  87476.  88245.  89220.  90823.  93567.  97617. 102889. 109138. 115964.
 11 122807. 129171. 134625. 138791. 141601. 143386. 144477. 145138.

                                                                    AVG= 114548.066  MAX= 145138.044
                                                                                     MIN=  86930.583
****************************************************************************************************
**** LOC    2  FIRST CONTROL POINT              SERVED BY     1

PER        CUM LOCAL Q

  1   3600.   4330.   3700.   3600.   5100.   7400.   9170.   9860.  10000.   9900.
 11  10800.  15900.  24300.  25600.  27500.  28900.  36600.  46200.

                                                                    AVG=  15692.222  MAX=  46200.000
PER        NATURAL FLOW                                                              MIN=   3600.000

  1   5600.   6410.   6105.   6635.   9116.  12939.  17166.  21333.  25419.  28780.
 11  32657.  40651.  51395.  54193.  56724.  57819.  64237.  71439.

                                                                    AVG=  31589.930  MAX=  71439.228
PER        REGULATED FLOW                                                            MIN=   5600.000

  1   3600.   4330.   3700.   3600.   5100.   7400.   9170.   9860.  10000.   9900.
 11  10800.  15900.  24300.  25600.  27500.  28900.  36600.  46200.

                                                                    AVG=  15692.222  MAX=  46200.000
PER        Q SPACE AVAIL.                                                            MIN=   3600.000

  1   6400.   5670.   6300.   6400.   4900.   2600.    830.    140.      0.    100.
 11   -800.  -5900. -14300. -15600. -17500. -18900. -26600. -36200.

                                                                    AVG=  -5692.222  MAX=   6400.000
PER        Q BY US RES,DIVS                                                          MIN= -36200.000

  1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 11      0.      0.      0.      0.      0.      0.      0.      0.

                                                                    AVG=      0.000  MAX=      0.000
PER        FLOOD BY RES                                                              MIN=      0.000

  1      0.      0.      0.      0.      0.      0.      0.      0.     -0.      0.
 11      0.      0.      0.      0.      0.      0.      0.      0.

                                                                    AVG=      0.000  MAX=      0.000
                                                                                     MIN=      0.000
****************************************************************************************************
**** LOC    3  SECOND AND LAST CP               SERVED BY     1

PER        CUM LOCAL Q

  1   3600.   3607.   3627.   3648.   3675.   3756.   3942.   4239.   4617.   5018.
 11   5406.   5834.   6420.   7254.   8326.   9559.  10882.  12303.

                                                                    AVG=   5872.936  MAX=  12303.156
PER        NATURAL FLOW                                                              MIN=   3600.000

  1   5600.   5605.   5623.   5653.   5713.   5854.   6141.   6631.   7361.   8343.
 11   9546.  10908.  12426.  14145.  16048.  17661.  18988.  20439.
```

```
                                                                                          AVG=  10149.179  MAX=  20439.235
                                                                                                           MIN=   5600.000
PER        REGULATED FLOW

  1   3600.   3607.   3627.   3648.   3675.   3756.   3942.   4239.   4617.   5018.
 11   5406.   5834.   6420.   7254.   8326.   9559.  10882.  12303.

                                                                                          AVG=   5872.936  MAX=  12303.156
                                                                                                           MIN=   3600.000
PER        Q SPACE AVAIL.

  1  16400.  16393.  16373.  16352.  16325.  16244.  16058.  15761.  15383.  14982.
 11  14594.  14166.  13580.  12746.  11674.  10441.   9118.   7697.

                                                                                          AVG=  14127.064  MAX=  16400.000
                                                                                                           MIN=   7696.844
PER        Q BY US RES,DIVS

  1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 11      0.      0.      0.      0.      0.      0.      0.      0.

                                                                                          AVG=      0.000  MAX=      0.000
                                                                                                           MIN=      0.000
PER        FLOOD BY RES

  1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 11      0.      0.      0.      0.      0.      0.      0.      0.

                                                                                          AVG=      0.000  MAX=      0.000
                                                                                                           MIN=      0.000
*******************************************************************************************************************************

RESERVOIR OPERATION BY PERIOD


           CUM TIME=      1


RES NO=         1
INFLOW       2000.
OUTFLOW         0.
EOP STOR    86931.
CASE=        2.06
LEVEL        1.006
EQ LEVEL     1.006

           CUM TIME=      2


RES NO=         1
INFLOW       3300.
OUTFLOW         0.
EOP STOR    87476.
CASE=        2.05
LEVEL        1.015
EQ LEVEL     1.015
```

PERIODS 3 to 18 OMITTED

RESERVOIR RELEASES BY PERIOD

RES NO	1
CHAN CAP	5000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	0.
2	0.
3	0.
4	0.
5	0.
6	0.
7	0.
8	0.
9	0.
10	0.
11	0.
12	0.
13	0.
14	0.
15	0.
16	0.
17	0.
18	0.
SUM =	0.
MAX =	0.
MIN =	0.
MPER=	1.
AVG =	0.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

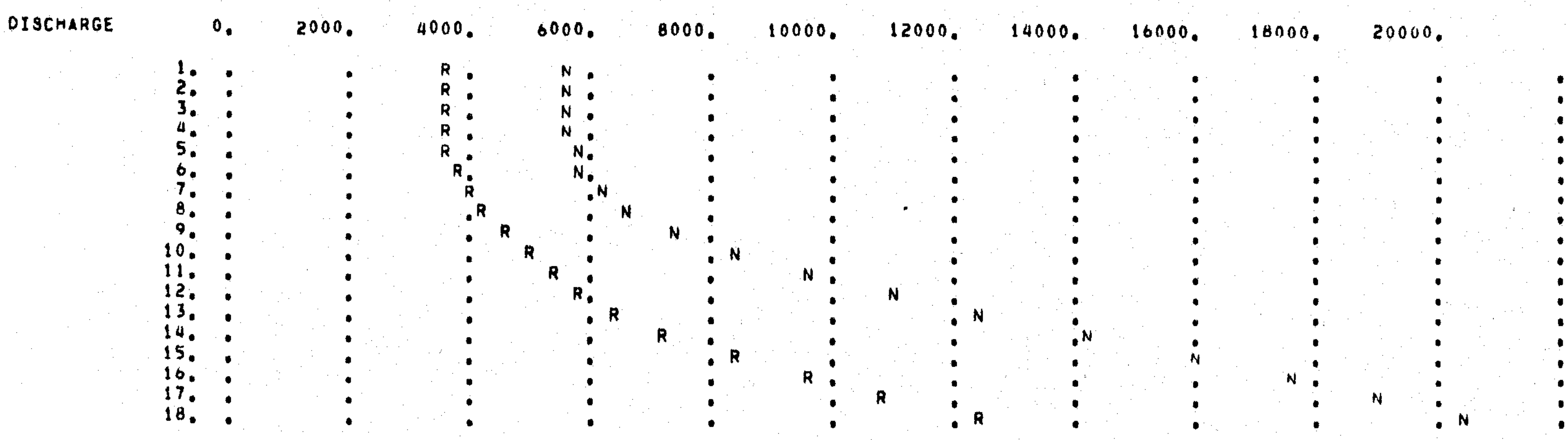
C.P. NO.	2	3
CHAN CAP	10000.	20000.
MIN DES Q	-1.	-1.
MIN REQ Q	-1.	-1.
PERIOD		
1	3600.	3600.
2	4330.	3607.
3	3700.	3627.
4	3600.	3648.
5	5100.	3675.
6	7400.	3756.
7	9170.	3942.
8	9860.	4239.
9	10000.	4617.
10	9900.	5018.

11	10800.	5406.
12	15900.	5834.
13	24300.	6420.
14	25600.	7254.
15	27500.	8326.
16	28900.	9559.
17	36600.	10882.
18	46200.	12303.
SUM =	282460.	105713.
MAX =	46200.	12303.
MIN =	3600.	3600.
MPER=	18.	18.
AVG =	15692.	5873.

PLOTTED POINTS (BY PRIORITY)=R=REGULATED,N=NATURAL,L=LOCAL(CUM),I=INFLOW

MAX= 12303. 20439. 12303. 12303.

SECOND AND LAST CP HX= 3 CH CAP= 20000. HOUR= 0,DAY= 0,MON= 0,YEAR=19 0.



```
SINGLE FLOOD SUMMARY  COPY=   1
COMPUTATION INTERVAL IN HOURS=   2

      TWO FLOOD SERIES WITH AN OVERLAP                          TEST4
      USING MODIFIED PULS ROUTING
      STORAGE IS TRANSFERRED AT PERIOD 18 OF FLOOD 1  (BF,3=18)

                  ***** FLOOD NUMBER  1 *****

LOC=     NONRESERVOIRS      MAX REG Q   MAX NAT   MAX UNC    Q BY RES  NO FLOODS VOL FLOODS  NO FLOODS VOL FLOODS PEN FLOODS
                                                                           TOTAL      TOTAL    FROM RES   FROM RES    FROM RES CH CAP

  2 FIRST CONTROL POINT     46200.     71439.    46200.         0.        8.    135800.        0.         0.      0.= 0.  10000.
  3 SECOND AND LAST CP      12303.     20439.    12303.         0.        0.         0.        0.         0.      0.= 0.  20000.

                                                          EXCEEDED TOP F.C.
LOC=     RESERVOIRS              STOR1     MAX STG   MAX LEVEL  1ST PER.  LAST PER.  MAX INFLOW    MAX REL   CHAN CAP

  1 TEST RES                     86600     145138      1.977        0          0       41400          0       5000

         MAX SYSTEM STORAGE=   145138


SUMMARY OF AVERAGES FOR RESERVOIRS

LOC=      CUM LOCA    NATURAL     INFLOW      OUTFLOW     CASE=LOC    LEVEL      EOP STOR

  1       19675.00    19675.00    19675.00       0.00        2.25       1.47  114548.07

SUMMARY OF AVERAGES FOR NON RESERVOIRS

LOC=      CUM LOCA    NATURAL     REGULATE    Q SPACE     Q BY US     FLOOD BY

  2       15692.22    31589.93    15692.22       0.00        0.00        0.00
  3        5872.94    10149.18     5872.94   14127.06        0.00        0.00


COMPUTATION INTERVAL IN HOURS=   2

                  ***** FLOOD NUMBER  2 *****                               UNITS OF OUTPUT

               NFLRD=        2  NFLCON=       0                  ALL FLOWS IN CFS OR CMS
               IFLRD =       2  IFLCON=       1                  EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
                 FLOWS MULTIPLIED BY      1.000                  ELEVATIONS IN FEET OR METERS
                                                                 POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS=IN KWH

*****************************************************************************************************************************

**** LOC     1  TEST RES                        SERVED BY      1

                                                                                      STARTING TIME=        1
                                                                                      HOUR= 2,DAY= 1,MON= 0,YEAR=19 0.
```

```
                                        SERVING        1      2      3
PER        CUM LOCAL Q

  1    2000.    1900.    1700.    1600.    1500.    1390.    1300.    1200.    1150.    1100.
 11    1000.     900.     850.     800.     750.     700.     650.     600.     570.     550.
 21     500.     500.     500.     500.     500.     500.     500.     500.

                                                                                                   AVG=     936.071   MAX=   2000.000
                                                                                                                      MIN=    500.000
PER        NATURAL FLOW

  1    2000.    1900.    1700.    1600.    1500.    1390.    1300.    1200.    1150.    1100.
 11    1000.     900.     850.     800.     750.     700.     650.     600.     570.     550.
 21     500.     500.     500.     500.     500.     500.     500.     500.

                                                                                                   AVG=     936.071   MAX=   2000.000
                                                                                                                      MIN=    500.000
PER        INFLOW

  1    2000.    1900.    1700.    1600.    1500.    1390.    1300.    1200.    1150.    1100.
 11    1000.     900.     850.     800.     750.     700.     650.     600.     570.     550.
 21     500.     500.     500.     500.     500.     500.     500.     500.

                                                                                                   AVG=     936.071   MAX=   2000.000
                                                                                                                      MIN=    500.000
PER        OUTFLOW

  1       0.       0.       0.       0.     460.    1390.    1300.    1200.    1150.    1100.
 11    1000.     900.     850.     800.     750.     700.     650.     600.     570.     550.
 21     500.    3000.    5000.    5000.    5000.    5000.    5000.    5000.

                                                                                                   AVG=    1695.367   MAX=   5000.000
                                                                                                                      MIN=      0.000
PER        CASE=LOC.TYP

  1    3.06     2.03     3.00     3.06      .04      .04      .04      .04      .04      .04
 11     .04      .04      .04      .04      .04      .04      .04      .04      .04      .04
 21     .04      .02      .01      .01      .01      .01      .01      .01

                                                                                                   AVG=        .425   MAX=      3.060
                                                                                                                      MIN=       .010
PER        LEVEL

  1    1.983    1.988    1.993    1.997    2.000    2.000    2.000    2.000    2.000    2.000
 11    2.000    2.000    2.000    2.000    2.000    2.000    2.000    2.000    2.000    2.000
 21    2.000    1.993    1.981    1.968    1.956    1.943    1.931    1.919

                                                                                                   AVG=       1.988   MAX=      2.000
                                                                                                                      MIN=      1.919
PER        EOP STORAGE

  1 145469. 145783. 146064. 146328. 146500. 146500. 146500. 146500. 146500. 146500.
 11 146500. 146500. 146500. 146500. 146500. 146500. 146500. 146500. 146500. 146500.
 21 146500. 146087. 145343. 144599. 143855. 143112. 142368. 141624.

                                                                                                   AVG= 145754.659   MAX= 146500.000
                                                                                                                     MIN= 141623.896
*************************************************************************************************************************************
**** LOC      2  FIRST CONTROL POINT              SERVED BY      1

PER        CUM LOCAL Q

  1   52300.   53000.   48300.   40500.   31800.   23600.   16900.   12000.    8600.    6400.
 11    5100.    4200.    3600.    3200.    2900.    2700.    2500.    2300.    2100.    2000.
 21    1870.    1740.    1600.    1500.    1400.    1300.    1230.    1150.
```

```
                                                                          AVG=  11992.500  MAX=  53000.000
                                                                                           MIN=   1150.000
PER        NATURAL FLOW

  1  74222.  71163.  62135.  50267.  38695.  28452.  20304.  14483.  10537.   8004.
 11   6492.   5442.   4722.   4225.   3845.   3576.   3315.   3059.   2807.   2660.
 21   2490.   2323.   2153.   2032.   1919.   1811.   1736.   1654.
                                                                          AVG=  15518.728  MAX=  74222.023
                                                                                           MIN=   1653.545
PER        REGULATED FLOW

  1  52300.  53000.  48300.  40500.  31828.  23771.  17345.  12725.   9516.   7422.
 11   6165.   5260.   4622.   4170.   3815.   3560.   3307.   3055.   2804.   2659.
 21   2489.   2477.   2895.   3727.   4548.   5138.   5530.   5740.
                                                                          AVG=  13166.771  MAX=  53000.000
                                                                                           MIN=   2476.755
PER        Q SPACE AVAIL.

  1 -42300. -43000. -38300. -30500. -21828. -13771.  -7345.  -2725.    484.   2578.
 11   3835.   4740.   5378.   5830.   6185.   6440.   6693.   6945.   7196.   7341.
 21   7511.   7523.   7105.   6273.   5452.   4862.   4470.   4260.
                                                                          AVG=  -3166.771  MAX=   7523.245
                                                                                           MIN= -43000.000
PER        Q BY US RES,DIVS

  1      0.      0.      0.      0.     28.    171.    445.    725.    916.   1022.
 11   1065.   1060.   1022.    970.    915.    860.    807.    755.    704.    659.
 21    619.    737.   1295.   2227.   3148.   3838.   4300.   4590.
                                                                          AVG=   1174.271  MAX=   4589.510
                                                                                           MIN=      0.000
PER        FLOOD BY RES

  1      0.      0.      0.      0.     28.    171.    445.    725.      0.      0.
 11      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 21      0.      0.      0.      0.      0.      0.      0.      0.
                                                                          AVG=     48.932  MAX=    725.128
                                                                                           MIN=      0.000
************************************************************************************************************
**** LOC     3  SECOND AND LAST CP                  SERVED BY     1

PER        CUM LOCAL Q

  1  13887.  15656.  17234.  18456.  19574.  20601.  21474.  22152.  22621.  22883.
 11  22953.  22852.  22603.  22229.  21734.  21100.  20340.  19490.  18582.  17641.
 21  16406.  14881.  13416.  12073.  10839.   9708.   8678.   7747.
                                                                          AVG=  17778.881  MAX=  22952.938
                                                                                           MIN=   7747.124
PER        NATURAL FLOW

  1  21941.  23443.  24926.  26354.  27686.  28887.  29931.  30803.  31500.  32027.
 11  32385.  32544.  32461.  32146.  31639.  30975.  30186.  29299.  28338.  27308.
 21  26193.  24994.  23736.  22452.  21165.  19894.  18653.  17403.
                                                                          AVG=  27116.776  MAX=  32543.729
                                                                                           MIN=  17402.796
PER        REGULATED FLOW
```

```
  1  13887.  15656.  17234.  18456.  19574.  20602.  21476.  22161.  22641.  22920.
 11  23012.  22938.  22720.  22380.  21929.  21356.  20661.  19868.  19008.  18109.
 21  17092.  15759.  14283.  12950.  11771.  10753.   9889.   9166.

                                                                    AVG=  18151.687  MAX=  23011.909
PER      Q SPACE AVAIL.                                                              MIN=   9166.483

  1   6113.   4344.   2766.   1544.    426.   -602.  -1476.  -2161.  -2641.  -2920.
 11  -3012.  -2938.  -2720.  -2380.  -1929.  -1356.   -661.    132.    992.   1891.
 21   2908.   4241.   5717.   7050.   8224.   9247.  10111.  10834.

                                                                    AVG=   1848.313  MAX=  10833.517
PER      Q BY US RES,DIVS                                                            MIN=  -3011.909

  1      0.      0.      0.      0.      0.      1.      3.      9.     20.     37.
 11     59.     86.    117.    151.    195.    256.    321.    377.    426.    467.
 21    686.    878.    867.    877.    932.   1045.   1210.   1419.

                                                                    AVG=    372.806  MAX=   1419.359
PER      FLOOD BY RES                                                                MIN=       .000

  1      0.      0.      0.      0.      0.      1.      3.      9.     20.     37.
 11     59.     86.    117.    151.    195.    256.    321.      0.      0.      0.
 21      0.      0.      0.      0.      0.      0.      0.      0.

                                                                    AVG=     44.770  MAX=    320.807
****************************************************************************************  MIN=      0.000

RESERVOIR OPERATION BY PERIOD


             CUM TIME=       1

RES NO=          1
INFLOW       2000.
OUTFLOW         0.
EOP STOR   145469.
CASE=         3.06
LEVEL        1.983
EQ LEVEL     1.983

             CUM TIME=       2

RES NO=          1
INFLOW       1900.
OUTFLOW         0.
EOP STOR   145783.
CASE=         2.03
LEVEL        1.988
EQ LEVEL     1.988
```

PERIODS 3-28 OMITTED

RESERVOIR RELEASES BY PERIOD

RES NO	1
CHAN CAP	5000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	0.
2	0.
3	0.
4	0.
5	460.
6	1390.
7	1300.
8	1200.
9	1150.
10	1100.
11	1000.
12	900.
13	850.
14	800.
15	750.
16	700.
17	650.
18	600.
19	570.
20	550.
21	500.
22	3000.
23	5000.
24	5000.
25	5000.
26	5000.
27	5000.
28	5000.
SUM =	47470.
MAX =	5000.
MIN =	0.
HPER=	23.
AVG =	1695.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

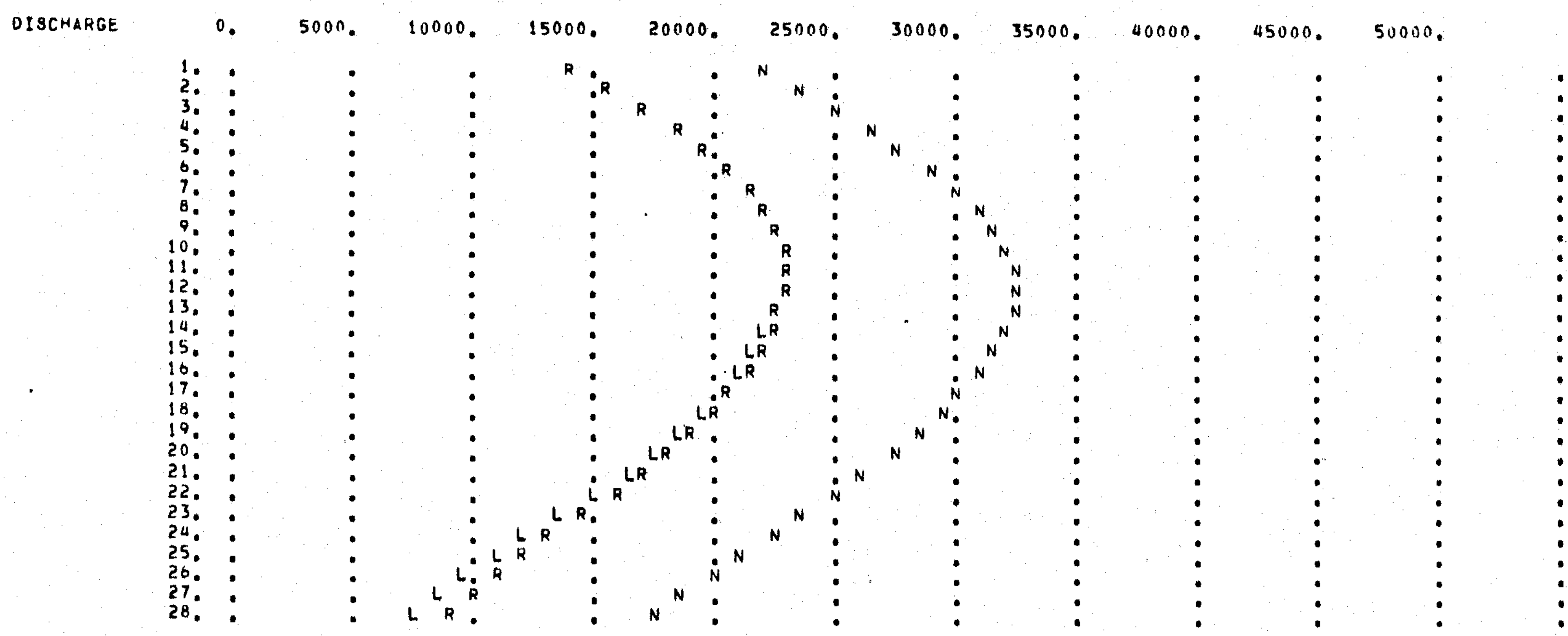
C.P. NO.	2	3
CHAN CAP	10000.	20000.
MIN DES Q	-1.	-1.
MIN REQ Q	-1.	-1.

PERIOD		
1	52300.	13887.
2	53000.	15656.
3	48300.	17234.
4	40500.	18456.
5	31828.	19574.
6	23771.	20602.
7	17345.	21476.
8	12725.	22161.
9	9516.	22641.
10	7422.	22920.
11	6165.	23012.
12	5260.	22938.
13	4622.	22720.
14	4170.	22380.
15	3815.	21929.
16	3560.	21356.
17	3307.	20661.
18	3055.	19868.
19	2804.	19008.
20	2659.	18109.
21	2489.	17092.
22	2477.	15759.
23	2895.	14283.
24	3727.	12950.
25	4548.	11771.
26	5138.	10753.
27	5530.	9889.
28	5740.	9166.
SUM =	368670.	508247.
MAX =	53000.	23012.
MIN =	2477.	9166.
MPER=	2.	11.
AVG =	13167.	18152.

PLOTTED POINTS (BY PRIORITY)=R=REGULATED,N=NATURAL,L=LOCAL(CUM),I=INFLOW

MAX= 23012. 32544. 22953. 23012.

SECOND AND LAST CP MX= 3 CH CAP= 20000. HOUR= 0,DAY= 0,MON= 0,YEAR=19 0.



SINGLE FLOOD SUMMARY COPY= 1
COMPUTATION INTERVAL IN HOURS= 2

TWO FLOOD SERIES WITH AN OVERLAP TEST4
USING MODIFIED PULS ROUTING
STORAGE IS TRANSFERRED AT PERIOD 18 OF FLOOD 1 (BF,3=18)

***** FLOOD NUMBER 2 *****

LOC=	NONRESERVOIRS	MAX REG Q	MAX NAT	MAX UNC	Q BY RES	NO FLOODS TOTAL	VOL FLOODS TOTAL	NO FLOODS FROM RES	VOL FLOODS FROM RES	PER FLOODS FROM RES	CH CAP
2	FIRST CONTROL POINT	53000.	74222.	53000.	0.	8.	199770.	4.	1370.	5.- 8.	10000.
3	SECOND AND LAST CP	23012.	32544.	22953.	59.	12.	24795.	12.	1254.	7.-17.	20000.

LOC=	RESERVOIRS	STOR1	MAX STG	MAX LEVEL	EXCEEDED TOP F.C. 1ST PER.	LAST PER.	MAX INFLOW	MAX REL	CHAN CAP
1	TEST RES	145138	146500	2,000	5	21	2000	5000	5000

MAX SYSTEM STORAGE= 146500

SUMMARY OF AVERAGES FOR RESERVOIRS

LOC=	CUM LOCA	NATURAL	INFLOW	OUTFLOW	CASE=LOC	LEVEL	EOP STOR
1	936.07	936.07	936.07	1695.37	.43	1.99	145754.66

SUMMARY OF AVERAGES FOR NON RESERVOIRS

LOC=	CUM LOCA	NATURAL	REGULATE	Q SPACE	Q BY US	FLOOD BY
2	11992.50	15518.73	13166.77	0.00	1174.27	48.93
3	17778.88	27116.78	18151.69	1848.31	372.81	44.77

FLOOD SUMMARY=EACH FLOOD COPY= 1

TWO FLOOD SERIES WITH AN OVERLAP TEST4
USING MODIFIED PULS ROUTING
STORAGE IS TRANSFERRED AT PERIOD 18 OF FLOOD 1 (BF,3=18)

***** FLOOD NUMBER 1 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	2 FIRST CONTROL POINT	1.018	46200. *	1.018	71439. *	1.018	46200. *	0. *	0.00	0.00
LOC	3 SECOND AND LAST CP	1.018	12303. *	1.018	20439. *	1.018	12303. *	0. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1 TEST RES	1.001	86931.	1.006 *	1.018	145138	1.977 *	1.001	0	5000	66600

MIN SYSTEM STG= 86930 MAX SYSTEM STG= 145138

***** FLOOD NUMBER 2 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	2 FIRST CONTROL POINT	2.002	53000. *	2.001	74222. *	2.002	53000. *	0. *	0.00	0.00
LOC	3 SECOND AND LAST CP	2.011	23012. *	2.012	32544. *	2.011	22953. *	59. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1 TEST RES	2.028	141624.	1.919 *	2.006	146500	2.000 *	2.023	5000	5000	145138

MIN SYSTEM STG= 141623 MAX SYSTEM STG= 146500

COPY= 1

***** MAX VALUES FOR MULTY FLOODS *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	WEIGHTED SHORTAGE DES	INDEX REQ
LOC	2 FIRST CONTROL POINT	2.002	53000. *	2.001	74222. *	2.002	53000. *	0. *		
LOC	3 SECOND AND LAST CP	2.011	23012. *	2.012	32544. *	2.011	22953. *	59. *		

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP
LOC	1 TEST RES	1.001	86931.	1.006 *	2.006	146500	2.000 *	2.023	5000	5000

HYDROLOGIC EFFICIENCIES

**** LOC 2 FIRST CONTROL POINT SERVED BY 1

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	71439.	46200.	25239.2	35.33	.00	.00	0.00	0.00
2	74222.	53000.	21222.0	28.59	.00	.00	0.00	0.00

**** LOC 3 SECOND AND LAST CP SERVED BY 1

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	20439.	12303.	8136.1	39.81	.00	.00	0.00	0.00
2	32544.	23012.	9531.8	29.29	.00	.00	0.00	0.00

```
****************************************************************************************************************************************
         COMPUTER CHECK FOR POSSIBLE ERRORS

                        ***** FLOOD NUMBER  1 *****

POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=        50

                        ***** FLOOD NUMBER  2 *****

POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=        50
****************************************************************************************************************************************

** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON QA CARD
```

6. TEST PROBLEM 5

This test problem illustrates the input and output associated with a reservoir with hydropower. The operation is for a single reservoir using monthly flow data from October 1964 through November 1971 (identified as flood 1). The time interval is then changed to a 6-hour interval to operate for flood control for the month of December (identified as flood 2). The operation stops at the end of December; however, the operation could have been continued using monthly flows again. Both the conservation and flood control sequences exceed the number of periods possible for a single operation; therefore they were automatically divided into several floods by the program. The results are presented as if the flow sequences were not subdivided.

The powerplant physical characteristics are described on the P1 card. The power requirements for the project are provided on a monthly basis on the PR card. The daily distribution of power requirements are defined for a week on the PD card and the distribution of the daily requirement is provided for 6-hour intervals on the PH card. The monthly data was sequentially coded starting with October, the starting month for the flow sequence. Had a different starting date been used, the J4 card (field 1) could be used to show the starting month for monthly data in the model.

The second flood sequence begins December 1, 1971 (BF.5). The variable DAYWK on the second BF card (field 8) was used to tell the program the starting day was Wednesday so that the daily distribution from the PD card can start with the correct day. If the day of week is not provided, the program will assume Sunday is the first day.

The conservation operation is for 86 periods of monthly flow. The program must subdivide those periods so that the operation can be made within the 50 period dimension limit. The program operates the first 48 periods and then the remaining 38. The subdivision of flow data is transparent to the program user. To start the flood operation of December 1971, the reservoir storage from the conservation operation must be transferred. The variable NPSTO (BF.3) is set equal to 86 on the BF card for the conservation sequence.

The flood operation is for 124 6-hour periods, which equals the 31 days of December. The program operation could have continued by changing back to a monthly operation until the next flood sequence. The variable NFLRD (J2.5) would have to be changed from 2 floods to a new value for the number of floods to be read.

The output for the operation was limited to the sequential output by control points. Added output for power shows the POWER REQUIRED, POWER GENERATED, and POWER SHORTAGE. The CASE values of .10 show periods where releases were based for power requirements. The first flood shows the monthly variation of power requirements and the second flood shows the variation of power requirements for days of the week and each 6-hour period. The power generated during the second flood shows the added power generated during the flood release periods.

EXHIBIT 3

```
          HEC-5C SIMULATION OF FLOOD CONTROL
               AND CONSERVATION SYSTEMS
               UPDATED  OCT. 3 , 1975
          RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1      HYDROPOWER RESERVOIR WITH MIN FLOW, AND DIVERSION          TEST 5
T2      MIXED MONTHLY AND 6 HOUR TIME INTERVALS
T3      BROKEN BOW DAM  OCT 1,1964 - DEC 31,1971
J1         86.00      720.00        4.00        2.00        3.00        0.00        0.00        1.00       -0.00       -0.00
J2         -0.00        1.20       -0.00         .25        2.00        8.00       -1.00       -0.00       -0.00       -0.00

RL         25.00   918800.00       -0.00   448700.00   918800.00  1368800.00  1602000.00       -0.00       -0.00       -0.00
RO          2.00       44.00       45.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         16.00   294400.00   457900.00   556500.00   667000.00   764400.00   790000.00   870000.00   918800.00   954700.00
RS     984100.00  1075500.00  1368800.00  1377700.00  1414200.00  1602000.00  1608200.00       -0.00       -0.00       -0.00
RQ         16.00     5000.00     5000.00     5000.00     5000.00     5000.00     5000.00     5000.00     7000.00     7000.00
RQ       8000.00     9000.00    10000.00    20000.00   130000.00   443000.00   500000.00       -0.00       -0.00       -0.00
RA         16.00     7100.00     9280.00    10430.00    11650.00    12670.00    12920.00    13720.00    14180.00    14550.00
RA      14820.00    15650.00    17930.00    18000.00    18370.00    20490.00    20570.00       -0.00       -0.00       -0.00
RE         16.00      540.00      560.00      570.00      580.00      588.00      590.00      596.00      599.50      602.00
RE        604.00      610.00      627.50      628.00      630.00      639.70      640.00       -0.00       -0.00       -0.00
R3         12.00       30.00         .15       -1.63       -2.41       -2.42       -1.57       -1.10        -.64       -1.53
R3          1.87        3.10        3.15        1.41       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
P1          1.20   100000.00        0.00        0.00        1.00         .86       10.00       -0.00       -0.00       -0.00
PR          -.05        -.05        -.09        -.09        -.05        -.05        -.05        -.09        -.09        -.17
PR          -.17        -.09       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
PD           .10         .16         .16         .16         .16         .16         .10       -0.00       -0.00       -0.00
PH          4.00        0.00         .20         .60         .20       -0.00       -0.00       -0.00       -0.00       -0.00
PQ          0.00     7500.00     8650.00    10000.00    20000.00    40000.00    80000.00   160000.00   240000.00   440000.00
PT        406.90      406.90      407.50      409.30      413.00      418.50      426.50      437.00      446.50      460.00
PP          0.00    77000.00    97500.00   119200.00   120000.00   120000.00       -0.00       -0.00       -0.00       -0.00
PS     294000.00   350800.00   525900.00   751000.00   752200.00  1602000.00       -0.00       -0.00       -0.00       -0.00

CP         25.00     8000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID     BROKEN BOW DAM                                    -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         25.00       44.00        1.20        0.00        3.00        0.00       -0.00       -0.00       -0.00       -0.00
DR         25.00       -0.00        1.1         1.00       -0.00       -0.00        1.00       -0.00       -0.00       -0.00
QD         12.00       68.00       52.00       50.00       50.00       56.00       54.00       74.00      110.00      190.00
QD        187.00      187.00      136.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
QM         12.00       30.00      118.00       90.00       86.00       86.00       88.00       90.00      120.00      173.00
QM        314.00      320.00      320.00      235.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         44.00    10000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID     EAGLETOWN                                         -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         44.00       45.00        1.20        0.00       32.00        1.00       -0.00       -0.00       -0.00       -0.00
ED          1.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
MX=        25    IF MUSK ROUT K LESS THAN     360.00                                                **** ERROR ****
MX=        44    IF MUSK ROUT K LESS THAN     360.00                                                **** ERROR ****

       NRES=     1  NCPT=     2  NCPTR=     -0

BF          1.00       86.00       86.00       -0.00 64100100.00       -0.00      720.00       -0.00       -0.00       -0.00
```

```
J1    NPER    IPER     NL     NL1     NLM    EPER   NLBUF  ILOCAL  INFLOW   IOPMP
        48     720      4       2       3      49       1       1      -0      -0
J2    CNSTI   CFLOD  IFCAST  RATCHG   NFLWD  IPRINT  FLONAT  NORDUT   NCPTR   TRACE
      1.00    1.20     -1     1.00       2       8     -1.      24      -0     -0.
J3    METRIC  ECFCT    DATE   BCRFAC  COSFAC  IPRECN  IANDAM  ISCHED   IPRIO  IPLOTJ
         0   1.0064100100.    1.00    1.00       0       0       0       0       0
J4    ISTMO
        10

USER ID COMP ID     QMAX    RTFR    RTTO    RTMD      X       K    LAG   LOCP   RTLQ   QLAG   GMIND  QMINR

     25      1     8000.     25.     44.    1.20    0.00   3.000    0     -0  -0.000    -0.     0.     -0.  BROKEN BOW DAM

     44      2    10000.     44.********    1.20    0.00  32.000    1     -0  -0.000    -0.     0.     -0.  EAGLETOWN

USER ID COMP ID    STOR1   STORL=1      =2        =3        =4        =5       ISERV(M,K)=

     25      1   918800.   448700.   918800.  1368800.  1602000.        0.       1      2

RESERVOIR DATA

USER ID=     25   COMP ID=      1

RS   STORAGES=          294400.   457900.   556500.   667000.   764400.   790000.   870000.   918800.   954700.
RS   STORAGES=          984100.  1075500.  1368800.  1377700.  1414200.  1602000.  1608200.
RQ   Q CAPACITIES=        5000.     5000.     5000.     5000.     5000.     5000.     5000.     7000.     7000.
RQ   Q CAPACITIES=        8000.     9000.    10000.    20000.   130000.   443000.   500000.
RA   AREAS=               7100.     9280.    10430.    11650.    12670.    12920.    13720.    14180.    14550.
RA   AREAS=              14820.    15650.    17930.    18000.    18370.    20490.    20570.
RE   ELEVATIONS=           540.      560.      570.      580.      588.      590.      596.      600.      602.
RE   ELEVATIONS=           604.      610.      628.      628.      630.      640.      640.
RD   DIVERSION Q =           0.        0.        0.        0.        0.        0.        0.        0.        0.
RD   DIVERSION Q =           0.        0.        0.        0.        0.        0.        0.
R1   START=STORAGE           0.        0.        0.        0.        0.        0.        0.        0.        0.
DIVERSION DATA

   DIV NO      TYPE     DIV Q    RET RAT      FROM        TO     METHOD         X          K

      1          1      -0.00     -0.00      25.00       0.00     1.10       1.00      -0.00

ROUTING COEFFICIENTS FROM RES       25 TO MY
      MY=       44     1.0000
MX=      25    IF MUSK ROUT K LESS THAN      360.00                                        **** ERROR ****
MX=      44    IF MUSK ROUT K LESS THAN      360.00                                        **** ERROR ****

2340 NEGATIVE LOCAL FLOW ON IN CARD LOC=       25 NUMBER= FLOWS=,       2 NEG VOL=        -45.

DIVERSION DATA

   DIV NO      TYPE     DIV Q    RET RAT      FROM        TO     METHOD         X          K

      1          1      -0.00     -0.00      25.00       0.00     1.10       1.00      -0.00

ROUTING COEFFICIENTS FROM RES       25 TO MY
      MY=       44     1.0000
MX=      25    IF MUSK ROUT K LESS THAN      360.00                                        **** ERROR ****
MX=      44    IF MUSK ROUT K LESS THAN      360.00                                        **** ERROR ****
```

BF	0.00	124.00	-0.00	-0.00	71120100.00	-0.00	6.00	4.00	-0.00	-0.00

DIVERSION DATA

DIV NO	TYPE	DIV Q	RET RAT	FROM	TO	METHOD	X	K
1	120	-0.00	-0.00	25.00	0.00	1.10	1.00	-0.00

ROUTING COEFFICIENTS FROM RES 25 TO MY
MY= 44 .5000 .5000

DIVERSION DATA

DIV NO	TYPE	DIV Q	RET RAT	FROM	TO	METHOD	X	K
1	120	-0.00	-0.00	25.00	0.00	1.10	1.00	-0.00

ROUTING COEFFICIENTS FROM RES 25 TO MY
MY= 44 .5000 .5000

DIVERSION DATA

DIV NO	TYPE	DIV Q	RET RAT	FROM	TO	METHOD	X	K
1	120	-0.00	-0.00	25.00	0.00	1.10	1.00	-0.00

ROUTING COEFFICIENTS FROM RES 25 TO MY
MY= 44 .5000 .5000

HYDROPOWER RESERVOIR WITH MIN FLOW, AND DIVERSION   TEST 5
MIXED MONTHLY AND 6 HOUR TIME INTERVALS
BROKEN BOW DAM OCT 1,1964 - DEC 31,1971

COMPUTATION INTERVAL IN HOURS= 720

***** FLOOD NUMBER 1 *****

NFLRD= 2 NFLCON= 0
IFLRD = 1 IFLCON= 1
FLOWS MULTIPLIED BY 1.000

UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

****

**** LOC 25 BROKEN BOW DAM   SERVED BY 25

STARTING TIME= 1
HOUR= 0,DAY= 1,MON=10,YEAR=1964,

SERVING 25 44

CUM LOCAL Q

PER	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
1	316.	1225.	589.	1200.	3579.	1208.	774.	2567.	1775.	139.	13.	394.	65
13	189.	102.	195.	504.	2701.	499.	1930.	2021.	41.	7.	568.	144.	66
25	16.	18.	107.	174.	225.	909.	2521.	3018.	1258.	746.	26.	239.	67
37	844.	851.	2885.	2620.	1975.	5304.	6285.	6298.	410.	112.	74.	72.	68
49	71.	1618.	2877.	3433.	2978.	1518.	1408.	1899.	1730.	338.	95.	30.	69
61	202.	898.	1551.	1083.	1629.	3494.	3609.	536.	167.	0.	83.	334.	70
73	2280.	572.	642.	1382.	1400.	1248.	1145.	783.	116.	229.	154.	0.	71
85	965.	281.	0.										

AVG= 1191.202 MAX= 6298.200
MIN= 0.000

NATURAL FLOW

PER	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	316.	1225.	589.	1200.	3579.	1208.	774.	2567.	1775.	139.	13.	394.
13	189.	102.	195.	504.	2701.	499.	1930.	2021.	41.	7.	568.	144.
25	16.	18.	107.	174.	225.	909.	2521.	3018.	1258.	746.	26.	239.
37	844.	851.	2885.	2620.	1975.	5304.	6285.	6298.	410.	112.	74.	72.
49	71.	1618.	2877.	3433.	2978.	1518.	1408.	1899.	1730.	338.	95.	30.
61	202.	898.	1551.	1083.	1629.	3494.	3609.	536.	167.	0.	83.	334.
73	2280.	572.	642.	1382.	1400.	1248.	1145.	783.	116.	229.	154.	0.
85	965.	281.										

AVG= 1191.202 MAX= 6298.200
MIN= 0.000

POWER REQUIRED

PER	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
13	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
25	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
37	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
49	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
61	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
73	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
85	3744.	3744.										

AVG= 6146.791 MAX= 12384.000
MIN= 3744.000

1	3744.	10755.	6192.	12212.	33386.	12157.	7094.	25841.	15524.	12384.	12384.	6192.
13	3744.	3744.	6192.	6192.	3744.	3744.	3744.	9476.	6192.	12384.	12384.	6192.
25	3744.	3744.	6192.	6192.	3744.	3744.	3744.	6192.	6192.	12384.	12384.	6192.
37	3744.	3744.	6192.	17304.	18933.	54880.	62717.	64758.	6192.	12384.	12384.	6192.
49	3744.	3744.	6192.	24778.	27728.	15390.	13494.	18870.	15070.	12384.	12384.	6192.
61	3744.	3744.	6192.	6192.	3744.	28350.	35710.	6192.	6192.	12384.	12384.	6192.
73	3744.	3744.	6192.	6192.	3744.	5258.	10834.	7229.	6192.	12384.	12384.	6192.
85	3744.	3744.										

AVG= 11186.481 MAX= 64758.358
MIN= 3744.000

PER POW.SHORTAGE

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
85	0.	0.										

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER MIN DESIRED FLOW

1	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
13	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
25	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
37	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
49	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
61	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
73	118.	90.	86.	86.	88.	90.	120.	173.	314.	320.	320.	235.
85	118.	90.										

AVG= 168.465 MAX= 320.000
MIN= 86.000

PER SHORTAGE

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
49	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
85	0.	0.										

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER DIVERSION Q

1	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
13	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
25	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
37	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
49	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
61	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
73	68.	52.	50.	50.	56.	54.	74.	110.	190.	187.	187.	136.
85	68.	52.										

AVG= 100.209 MAX= 190.000
MIN= 50.000

PER INFLOW

1	248.	1173.	539.	1150.	3523.	1154.	700.	2457.	1585.	-48.	-174.	258.
13	121.	50.	145.	454.	2645.	445.	1856.	1911.	-149.	-180.	381.	8.
25	-52.	-34.	57.	124.	169.	855.	2447.	2908.	1068.	559.	-161.	103.
37	776.	799.	2835.	2570.	1919.	5250.	6211.	6188.	220.	-75.	-113.	-64.
49	3.	1566.	2827.	3383.	2922.	1464.	1334.	1789.	1540.	151.	-92.	-106.
61	134.	846.	1501.	1033.	1573.	3440.	3535.	426.	-24.	-187.	-104.	198.
73	2212.	520.	592.	1332.	1344.	1194.	1071.	673.	-74.	42.	-33.	-136.
85	897.	229.										

AVG= 1090.993 MAX= 6210.600
MIN= -187.000

PER OUTFLOW

1	369.	1077.	604.	1181.	3554.	1176.	713.	2487.	1548.	1216.	1258.	672.
13	401.	418.	670.	678.	445.	391.	397.	929.	629.	1241.	1281.	682.
25	410.	429.	692.	705.	482.	435.	432.	644.	643.	1240.	1276.	684.
37	406.	414.	634.	1687.	1950.	5272.	6223.	6219.	626.	1229.	1273.	683.
49	410.	419.	635.	2414.	2953.	1485.	1347.	1819.	1503.	1213.	1250.	670.
61	402.	414.	644.	633.	419.	2750.	3548.	605.	630.	1242.	1291.	691.
73	401.	403.	638.	632.	418.	518.	1083.	703.	628.	1236.	1278.	686.
85	407.	418.										

AVG= 1134.199 MAX= 6223.309
MIN= 369.178

PER CASE=LOC.TYP

1	.10	.03	.10	.03	.03	.03	.03	.03	.03	.10	.10	.10
13	.10	.10	.10	.10	.10	.10	.10	.03	.10	.10	.10	.10
25	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
37	.10	.10	.10	.03	.03	.03	.03	.03	.10	.10	.10	.10
49	.10	.10	.10	.03	.03	.03	.03	.03	.03	.10	.10	.10
61	.10	.10	.10	.10	.10	.03	.03	.10	.10	.10	.10	.10
73	.10	.10	.10	.10	.10	.03	.03	.03	.10	.10	.10	.10
85	.10	.10										

AVG= .080 MAX= .100
MIN= .030

PER LEVEL

1	1.984	2.000	1.998	2.000	2.000	2.000	2.000	2.000	2.000	1.827	1.632	1.577
13	1.540	1.497	1.433	1.409	1.672	1.681	1.868	2.000	1.897	1.704	1.579	1.490
25	1.430	1.374	1.296	1.225	1.190	1.247	1.504	1.803	1.853	1.756	1.561	1.484
37	1.532	1.585	1.878	2.000	2.000	2.000	2.000	2.000	1.944	1.766	1.577	1.480
49	1.426	1.575	1.867	2.000	2.000	2.000	2.000	2.000	2.000	1.853	1.670	1.569
61	1.533	1.592	1.709	1.767	1.907	2.000	2.000	1.981	1.893	1.699	1.509	1.444
73	1.680	1.699	1.699	1.796	1.909	2.000	2.000	2.000	1.906	1.743	1.564	1.457
85	1.521	1.500										

AVG= 1.741 MAX= 2.000
MIN= 1.190

PER EVAPORATION

1	183.	-1921.	-2942.	-2954.	-1732.	-1343.	-756.	-1868.	2210.	3683.	3509.	1450.
13	156.	-1618.	-2418.	-2381.	-1468.	-1202.	-701.	-1830.	2174.	3542.	3396.	1409.
25	150.	-1538.	-2278.	-2207.	-1259.	-983.	-597.	-1658.	2088.	3547.	3419.	1403.
37	153.	-1645.	-2687.	-2899.	-1793.	-1343.	-756.	-1868.	2190.	3611.	3437.	1406.
49	150.	-1607.	-2676.	-2894.	-1732.	-1343.	-756.	-1868.	2210.	3698.	3550.	1459.
61	156.	-1648.	-2608.	-2704.	-1641.	-1324.	-756.	-1863.	2166.	3537.	3346.	1376.
73	157.	-1732.	-2655.	-2713.	-1650.	-1324.	-756.	-1868.	2177.	3573.	3413.	1396.
85	152.	-1613.										

AVG= -148.229 MAX= 3698.450
MIN= -2953.951

PER EOP STORAGE

1	911191.	918800.	917778.	918800.	918800.	918800.	918800.	918800.	918800.	837441.	745884.	719790.
13	702398.	682118.	652251.	640861.	764517.	769012.	856576.	918800.	870342.	779412.	720698.	679156.
25	650615.	624618.	587864.	554347.	538216.	565016.	685515.	826366.	849571.	804124.	712332.	676345.
37	698998.	723534.	861576.	918800.	918800.	918800.	918800.	918800.	892447.	808670.	720034.	674194.
49	649014.	718867.	856327.	918800.	918800.	918800.	918800.	918800.	918800.	849792.	763694.	716058.
61	699435.	726792.	782082.	809352.	875080.	918800.	918800.	909677.	868608.	777186.	688066.	657373.
73	768587.	777250.	777071.	822826.	875893.	918800.	918800.	918800.	874838.	797897.	713874.	663590.
85	693561.	683893.										

AVG= 797112.695 MAX= 918800.000
MIN= 538218.086

PER ELEVATION AVG

1	599.23	599.23	599.46	599.46	599.50	599.50	599.50	599.50	599.50	596.58	590.12	585.41
13	583.62	582.07	580.02	578.15	582.93	586.18	591.71	597.27	597.76	592.62	586.82	582.70
25	579.81	577.34	574.50	571.32	568.96	569.50	576.22	587.31	593.60	592.76	587.49	582.25
37	581.70	583.64	590.19	597.45	599.50	599.50	599.50	599.50	598.55	594.54	586.00	582.47
49	579.51	581.39	589.81	597.26	599.50	599.50	599.50	599.50	599.50	597.03	591.26	585.99
61	583.35	583.79	587.18	590.43	593.92	597.93	599.50	599.17	597.37	592.47	585.39	580.47
73	583.78	588.67	589.00	590.75	594.45	597.96	599.50	599.50	597.92	593.48	587.30	581.78
85	580.95	581.78										

AVG= 590.279 MAX= 599.500
MIN= 568.964

****

**** LOC 44 EAGLETOWN SERVED BY 25

PER	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
CUM LOCAL Q													
1	16.	59.	29.	57.	171.	58.	37.	124.	85.	7.	1.	18.	65
13	9.	4.	9.	23.	130.	25.	94.	97.	2.	0.	28.	7.	66
25	1.	0.	6.	9.	11.	43.	121.	146.	60.	36.	1.	3.	67
37	0.	432.	0.	0.	1022.	0.	0.	490.	0.	33.	0.	7.	68
49	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	69
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	70
73	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	71
85	0.	0.	0.										

AVG= 40.826 MAX= 1022.000
MIN= 0.000

PER NATURAL FLOW

1	332.	1284.	618.	1257.	3750.	1266.	811.	2691.	1860.	146.	14.	412.
13	198.	106.	204.	527.	2831.	524.	2024.	2118.	43.	7.	596.	151.
25	17.	18.	113.	183.	236.	952.	2642.	3164.	1318.	782.	27.	242.
37	844.	1283.	2885.	2620.	2997.	5304.	6285.	6788.	410.	145.	74.	79.
49	71.	1618.	2877.	3433.	2978.	1518.	1408.	1899.	1730.	338.	95.	30.
61	202.	898.	1551.	1083.	1629.	3494.	3609.	536.	167.	0.	83.	334.
73	2280.	572.	642.	1382.	1400.	1248.	1145.	783.	116.	229.	154.	0.
85	965.	281.										

AVG= 1232.028 MAX= 6788.200
MIN= 0.000

PER REGULATED FLOW

1	385.	1136.	633.	1238.	3725.	1234.	750.	2611.	1633.	1223.	1259.	690.
13	410.	422.	679.	701.	575.	416.	491.	1026.	631.	1241.	1309.	689.
25	411.	429.	698.	714.	493.	478.	553.	790.	703.	1276.	1277.	687.
37	406.	846.	634.	1687.	2972.	5272.	6223.	6709.	626.	1262.	1273.	690.
49	410.	419.	635.	2414.	2953.	1485.	1347.	1819.	1503.	1213.	1250.	670.
61	402.	414.	644.	633.	419.	2750.	3548.	605.	630.	1242.	1291.	691.
73	401.	403.	638.	632.	418.	518.	1083.	703.	628.	1236.	1278.	686.
85	407.	418.										

AVG= 1175.025 MAX= 6708.583
MIN= 385.178

PER Q BY US RES,DIVS

PER												
1	369.	1077.	604.	1181.	3554.	1176.	713.	2487.	1548.	1216.	1258.	672.
13	401.	418.	670.	678.	445.	391.	397.	929.	629.	1241.	1281.	682.
25	410.	429.	692.	705.	482.	435.	432.	644.	643.	1240.	1276.	684.
37	406.	414.	634.	1687.	1950.	5272.	6223.	6219.	626.	1229.	1273.	683.
49	410.	419.	635.	2414.	2953.	1485.	1347.	1619.	1503.	1213.	1250.	670.
61	402.	414.	644.	633.	419.	2750.	3548.	605.	630.	1242.	1291.	691.
73	401.	403.	638.	632.	418.	518.	1083.	703.	628.	1236.	1278.	686.
85	407.	418.										

AVG= 1134.199 MAX= 6223.309
MIN= 369.178

****

COMPUTATION INTERVAL IN HOURS= 6

***** FLOOD NUMBER 2 *****

NFLRD= 2 NFLCON= 0
IFLRD = 2 IFLCON= 1
FLOWS MULTIPLIED BY 1.000

UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

****

**** LOC 25 BROKEN BOW DAM SERVED BY 25

STARTING TIME= 1
HOUR= 6,DAY= 1,MON=12,YEAR=1971.

SERVING 25 44

PER CUM LOCAL Q

PER										
1	580.	526.	460.	390.	250.	400.	700.	1050.	1520.	1650.
11	1400.	1375.	1350.	1440.	1580.	1710.	1900.	2500.	3000.	2900.
21	2800.	3500.	4000.	4750.	5500.	7500.	13000.	14500.	14000.	11500.
31	9500.	8500.	15000.	50000.	102000.	138000.	166000.	123000.	60000.	28000.
41	12000.	8500.	7500.	7000.	6000.	5000.	3500.	3000.	3000.	3000.
51	3500.	4000.	5000.	5500.	6000.	7000.	7500.	10000.	10000.	7500.
61	5000.	4500.	4000.	4000.	3500.	2500.	2000.	2000.	1800.	1630.
71	1660.	1700.	1730.	1780.	1720.	1650.	1560.	1500.	1210.	1050.
81	800.	640.	640.	640.	640.	640.	660.	680.	700.	720.
91	640.	600.	530.	480.	485.	490.	495.	500.	630.	750.
101	900.	1000.	810.	700.	630.	540.	620.	750.	870.	1000.
111	1080.	1150.	1230.	1300.	1350.	1400.	1500.	1610.	1610.	1600.
121	1600.	1610.	1620.	1600.						

AVG= 8219.040 MAX= 166000.000
MIN= 250.000

PER NATURAL FLOW

PER										
1	580.	526.	460.	390.	250.	400.	700.	1050.	1520.	1650.
11	1400.	1375.	1350.	1440.	1580.	1710.	1900.	2500.	3000.	2900.
21	2800.	3500.	4000.	4750.	5500.	7500.	13000.	14500.	14000.	11500.
31	9500.	8500.	15000.	50000.	102000.	138000.	166000.	123000.	60000.	28000.
41	12000.	8500.	7500.	7000.	6000.	5000.	3500.	3000.	3000.	3000.
51	3500.	4000.	5000.	5500.	6000.	7000.	7500.	10000.	10000.	7500.
61	5000.	4500.	4000.	4000.	3500.	2500.	2000.	2000.	1800.	1630.
71	1660.	1700.	1730.	1780.	1720.	1650.	1560.	1500.	1210.	1050.
81	800.	640.	640.	640.	640.	640.	660.	680.	700.	720.
91	640.	600.	530.	480.	485.	490.	495.	500.	630.	750.

101	900.	1000.	810.	700.	630.	540.	620.	750.	870.	1000.
111	1080.	1150.	1230.	1300.	1350.	1400.	1500.	1610.	1610.	1600.
121	1600.	1610.	1620.	1600.						

AVG= 8219.040 MAX= 166000.000
MIN= 250.000

PER	POWER REQUIRED									
1	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.	10.	44742.
11	134227.	44742.	10.	27964.	83892.	27964.	10.	27964.	83892.	27964.
21	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.	10.	44742.
31	134227.	44742.	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.
41	10.	27964.	83892.	27964.	10.	27964.	83892.	27964.	10.	44742.
51	134227.	44742.	10.	44742.	134227.	44742.	10.	27964.	83892.	27964.
61	10.	27964.	83892.	27964.	10.	44742.	134227.	44742.	10.	44742.
71	134227.	44742.	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.
81	10.	44742.	134227.	44742.	10.	27964.	83892.	27964.	10.	27964.
91	83892.	27964.	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.
101	10.	44742.	134227.	44742.	10.	44742.	134227.	44742.	10.	44742.
111	134227.	44742.	10.	27964.	83892.	27964.	10.	27964.	83892.	27964.
121	10.	44742.	134227.	44742.						

AVG= 49164.789 MAX= 134226.581
MIN= 10.000

PER	POWER GENERATED									
1	5792.	44742.	134227.	44742.	5790.	44742.	134227.	44742.	5790.	44742.
11	134227.	44742.	5794.	27964.	83892.	27964.	5800.	27964.	83892.	27964.
21	5812.	44742.	134227.	44742.	5830.	44742.	134227.	44742.	5886.	44742.
31	134227.	44742.	5941.	44742.	134227.	44742.	214666.	392783.	573589.	703390.
41	704754.	705010.	705010.	704925.	704755.	704471.	704045.	703506.	702938.	702371.
51	701831.	701349.	700951.	700639.	700384.	700214.	700129.	700214.	700442.	700527.
61	700328.	699959.	672091.	636982.	629613.	573210.	586791.	530445.	696738.	696024.
71	695303.	694585.	693871.	693162.	692452.	691735.	691008.	690273.	689519.	688738.
81	687935.	687108.	683821.	672581.	661550.	650723.	640078.	629487.	619126.	608993.
91	599075.	594855.	594176.	593491.	592804.	592118.	591431.	590746.	590067.	589402.
101	588751.	445570.	134227.	44742.	6392.	44742.	134227.	44742.	6392.	74289.
111	134227.	51301.	102442.	108330.	112536.	116742.	125154.	134406.	134406.	133565.
121	133565.	134406.	135248.	133565.						

AVG= 377881.499 MAX= 705009.892
MIN= 5790.154

PER	POW.SHORTAGE									
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
111	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
121	0.	0.	0.	0.						

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER	MIN DESIRED FLOW									
1	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
11	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
21	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
31	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.

41	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
51	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
61	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
71	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
81	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
91	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
101	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
111	86.	86.	86.	86.	86.	86.	86.	86.	86.	86.
121	86.	86.	86.	86.						

AVG= 86.000 MAX= 86.000
MIN= 86.000

PER	SHORTAGE									
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
111	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
121	0.	0.	0.	0.						

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER	DIVERSION Q									
1	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
11	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
21	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
31	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
41	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
51	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
61	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
71	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
81	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
91	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
101	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
111	50.	50.	50.	50.	50.	50.	50.	50.	50.	50.
121	50.	50.	50.	50.						

AVG= 50.000 MAX= 50.000
MIN= 50.000

PER	INFLOW									
1	530.	476.	410.	340.	200.	350.	650.	1000.	1470.	1600.
11	1350.	1325.	1300.	1390.	1530.	1660.	1850.	2450.	2950.	2850.
21	2750.	3450.	3950.	4700.	5450.	7450.	12950.	14450.	13950.	11450.
31	9450.	8450.	14950.	49950.	101950.	137950.	165950.	122950.	59950.	27950.
41	11950.	8450.	7450.	6950.	5950.	4950.	3450.	2950.	2950.	2950.
51	3450.	3950.	4950.	5450.	5950.	6950.	7450.	9950.	9950.	7450.
61	4950.	4450.	3950.	3950.	3450.	2450.	1950.	1950.	1750.	1580.
71	1610.	1650.	1680.	1730.	1670.	1600.	1510.	1450.	1160.	1000.
81	750.	590.	590.	590.	590.	590.	610.	630.	650.	670.
91	590.	550.	480.	430.	435.	440.	445.	450.	580.	700.
101	850.	950.	760.	650.	580.	490.	570.	700.	820.	950.
111	1030.	1100.	1180.	1250.	1300.	1350.	1450.	1560.	1560.	1550.
121	1550.	1560.	1570.	1550.						

AVG= 8169.040 MAX= 165950.000
MIN= 200.000

PER OUTFLOW

PER										
1	86.	597.	1771.	597.	86.	597.	1772.	597.	86.	597.
11	1771.	597.	86.	377.	1110.	377.	86.	376.	1108.	376.
21	86.	595.	1763.	594.	86.	592.	1754.	590.	86.	586.
31	1735.	584.	86.	578.	1687.	556.	2556.	4556.	6556.	8000.
41	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
51	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
61	8000.	8000.	7680.	7280.	7200.	6560.	6720.	6080.	8000.	8000.
71	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
81	8000.	8000.	7971.	7847.	7726.	7606.	7489.	7374.	7261.	7150.
91	7042.	7000.	7000.	7000.	7000.	7000.	7000.	7000.	7000.	7000.
101	7000.	5305.	1606.	542.	86.	542.	1606.	542.	86.	893.
111	1606.	620.	1228.	1298.	1348.	1398.	1498.	1608.	1608.	1598.
121	1598.	1608.	1618.	1598.						

AVG= 4395.967 MAX= 8000.000
MIN= 86.000

PER CASE=LOC.TYP

PER										
1	0.00	.10	.10	.10	0.00	.10	.10	.10	0.00	.10
11	.10	.10	0.00	.10	.10	.10	0.00	.10	.10	.10
21	0.00	.10	.10	.10	0.00	.10	.10	.10	0.00	.10
31	.10	.10	0.00	.10	.10	.10	.10	.10	0.00	.10
41	.01	.01	.01	.01	.01	.01	.02	.02	.02	.01
51	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
61	.01	.01	44.00	44.00	44.00	44.00	44.00	44.00	.01	.01
71	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
81	.01	.01	.06	.06	.06	.06	.06	.06	.06	.06
91	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
101	.06	.03	.10	.10	0.00	.10	.10	.10	0.00	.03
111	.10	.03	.03	.03	.03	.03	.03	.03	.03	.03
121	.03	.03	.03	.03						

AVG= 2.172 MAX= 44.000
MIN= 0.000

PER LEVEL

PER										
1	1.501	1.501	1.499	1.499	1.499	1.499	1.498	1.498	1.500	1.501
11	1.501	1.501	1.503	1.504	1.504	1.506	1.508	1.510	1.512	1.514
21	1.517	1.520	1.523	1.527	1.533	1.540	1.552	1.567	1.581	1.593
31	1.601	1.609	1.625	1.677	1.783	1.928	2.105	2.235	2.294	2.316
41	2.321	2.321	2.321	2.320	2.317	2.314	2.309	2.304	2.298	2.293
51	2.288	2.283	2.280	2.277	2.275	2.274	2.273	2.276	2.278	2.277
61	2.274	2.270	2.266	2.262	2.258	2.254	2.249	2.244	2.237	2.230
71	2.223	2.216	2.209	2.203	2.196	2.189	2.182	2.174	2.167	2.159
81	2.151	2.143	2.135	2.127	2.119	2.112	2.104	2.097	2.090	2.083
91	2.075	2.068	2.061	2.054	2.047	2.040	2.033	2.025	2.018	2.011
101	2.005	2.000	1.999	1.999	2.000	2.000	1.999	1.999	2.000	2.000
111	1.999	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
121	2.000	2.000	2.000	2.000						

AVG= 1.973 MAX= 2.321
MIN= 1.498

PER EOP STORAGE

PER										
1	684133.	684093.	683438.	683330.	683406.	683304.	682767.	682986.	683692.	684210.
11	684020.	684401.	685023.	685545.	685773.	686430.	687324.	688372.	689306.	690552.
21	691893.	693329.	694433.	696490.	699164.	702590.	708162.	715055.	721951.	727358.
31	731205.	735126.	742518.	767021.	816760.	884913.	965960.	1024694.	1051196.	1061115.
41	1063100.	1063349.	1063102.	1062607.	1061617.	1060130.	1057900.	1055422.	1052943.	1050465.
51	1048235.	1046252.	1044765.	1043527.	1042530.	1042041.	1041794.	1042786.	1043779.	1043532.
61	1042045.	1040311.	1038487.	1036861.	1035127.	1033015.	1030675.	1028652.	1025579.	1022421.
71	1019277.	1016154.	1013045.	1009961.	1006846.	1003699.	1000506.	997283.	993916.	990470.
81	986900.	983250.	979615.	976041.	972527.	969072.	965686.	962366.	959113.	955924.
91	952749.	949575.	946366.	943132.	939901.	936672.	933445.	930221.	927062.	923962.

101	920936.	918800.	918404.	918482.	918750.	918748.	918258.	918360.	918748.	918800.
111	918538.	918800.	918800.	918800.	918800.	918800.	918800.	918800.	918800.	918800.
121	918800.	918800.	918800.	918800.						

AVG= 903967.443 MAX=1063348.709 MIN= 682766.934

PER	ELEVATION AVG									
1	581.40	581.41	581.38	581.35	581.34	581.34	581.32	581.30	581.34	581.39
11	581.41	581.41	581.45	581.50	581.53	581.57	581.63	581.71	581.79	581.88
21	581.99	582.10	582.21	582.34	582.53	582.78	583.15	583.66	584.23	584.74
31	585.12	585.43	585.90	587.21	590.14	594.56	599.96	604.74	607.53	608.73
41	609.12	609.19	609.19	609.17	609.12	609.04	608.92	608.76	608.60	608.44
51	608.28	608.15	608.03	607.94	607.87	607.82	607.80	607.82	607.89	607.91
61	607.85	607.75	607.63	607.52	607.40	607.28	607.13	606.99	606.82	606.62
71	606.41	606.21	606.00	605.80	605.60	605.39	605.18	604.97	604.75	604.53
81	604.30	604.06	603.82	603.57	603.33	603.10	602.86	602.63	602.41	602.19
91	601.97	601.75	601.53	601.31	601.08	600.86	600.63	600.41	600.19	599.97
101	599.75	599.57	599.49	599.47	599.49	599.50	599.48	599.46	599.48	599.50
111	599.49	599.49	599.50	599.50	599.50	599.50	599.50	599.50	599.50	599.50
121	599.50	599.50	599.50	599.50						

AVG= 597.868 MAX= 609.194 MIN= 581.304

****

**** LOC 44 EAGLETOWN SERVED BY 25

PER	CUM LOCAL Q									
1	230.	220.	220.	210.	220.	220.	210.	205.	200.	215.
11	220.	220.	215.	200.	190.	185.	190.	200.	220.	235.
21	250.	300.	330.	380.	800.	1000.	1100.	656.	500.	600.
31	1000.	1600.	2200.	2950.	3300.	3400.	3300.	3100.	2400.	1800.
41	1000.	300.	200.	100.	16.	16.	16.	16.	100.	160.
51	200.	220.	400.	600.	750.	800.	850.	850.	750.	750.
61	1000.	1500.	1800.	2100.	2300.	2600.	2800.	3000.	180.	163.
71	165.	170.	175.	180.	170.	165.	155.	150.	120.	105.
81	80.	64.	64.	64.	65.	65.	65.	70.	70.	72.
91	64.	60.	53.	48.	49.	49.	50.	50.	63.	75.
101	90.	100.	80.	70.	65.	50.	65.	75.	90.	100.
111	110.	115.	125.	130.	135.	140.	105.	100.	92.	85.
121	80.	75.	72.	70.						

AVG= 530.177 MAX= 3400.000 MIN= 16.000

PER	NATURAL FLOW									
1	810.	773.	713.	635.	540.	545.	760.	1080.	1485.	1800.
11	1745.	1608.	1578.	1595.	1700.	1830.	1995.	2400.	2970.	3185.
21	3100.	3450.	4080.	4755.	5925.	7500.	11350.	14406.	14750.	13350.
31	11500.	10600.	13950.	35450.	79300.	123400.	155300.	147600.	93900.	45800.
41	21000.	10550.	8200.	7350.	6516.	5516.	4266.	3266.	3100.	3160.
51	3450.	3970.	4900.	5850.	6500.	7300.	8100.	9600.	10750.	9500.
61	7250.	6250.	6050.	6100.	6050.	5600.	5050.	5000.	2080.	1878.
71	1810.	1850.	1890.	1935.	1920.	1850.	1760.	1680.	1475.	1235.
81	1005.	784.	704.	704.	705.	705.	715.	740.	760.	782.
91	744.	680.	618.	553.	532.	537.	543.	548.	628.	765.
101	915.	1050.	985.	825.	730.	635.	645.	760.	900.	1035.
111	1150.	1230.	1315.	1395.	1460.	1515.	1555.	1655.	1702.	1690.
121	1680.	1680.	1687.	1680.						

AVG= 8745.105 MAX= 155300.000 MIN= 531.500

PER REGULATED FLOW

1	316.	562.	1404.	1394.	562.	562.	1395.	1390.	542.	557.
11	1404.	1404.	557.	431.	933.	928.	421.	431.	962.	977.
21	481.	640.	1509.	1559.	1140.	1339.	2273.	1828.	838.	936.
31	2160.	2759.	2535.	3282.	4433.	4522.	4856.	6656.	7956.	9078.
41	9000.	8300.	8200.	8100.	8016.	8016.	8016.	8016.	8100.	8160.
51	8200.	8220.	8400.	8600.	8750.	8800.	8850.	8850.	8750.	8750.
61	9000.	9500.	9640.	9580.	9540.	9480.	9440.	9400.	7220.	8163.
71	8165.	8170.	8175.	8180.	8170.	8165.	8155.	8150.	8120.	8105.
81	8080.	8064.	8050.	7973.	7852.	7731.	7613.	7501.	7387.	7277.
91	7160.	7081.	7053.	7048.	7049.	7049.	7050.	7050.	7063.	7075.
101	7090.	6253.	3535.	1144.	379.	364.	1139.	1149.	404.	590.
111	1359.	1228.	1049.	1393.	1458.	1513.	1553.	1653.	1700.	1688.
121	1678.	1678.	1685.	1678.						

AVG= 4920.048 MAX= 9639.982
MIN= 316.000

PER Q SPACE AVAIL.

1	9684.	9438.	8596.	8606.	9438.	9438.	8605.	8610.	9458.	9443.
11	8596.	8596.	9443.	9569.	9067.	9072.	9579.	9569.	9038.	9023.
21	9519.	9360.	8491.	8441.	8860.	8661.	7727.	8172.	9162.	9064.
31	7840.	7241.	7465.	6718.	5567.	5478.	5144.	3344.	2044.	922.
41	1000.	1700.	1800.	1900.	1984.	1984.	1984.	1984.	1900.	1840.
51	1800.	1780.	1600.	1400.	1250.	1200.	1150.	1150.	1250.	1250.
61	1000.	500.	360.	420.	460.	520.	560.	600.	2780.	1837.
71	1835.	1830.	1825.	1820.	1830.	1835.	1845.	1850.	1880.	1895.
81	1920.	1936.	1950.	2027.	2140.	2269.	2387.	2499.	2613.	2723.
91	2840.	2919.	2947.	2952.	2951.	2951.	2950.	2950.	2937.	2925.
101	2910.	3747.	6465.	8856.	9621.	9636.	8861.	8851.	9596.	9410.
111	8641.	8772.	8951.	8607.	8542.	8487.	8447.	8347.	8300.	8312.
121	8322.	8322.	8315.	8322.						

AVG= 5079.952 MAX= 9684.000
MIN= 360.018

PER Q BY US RES,DIVS

1	86.	342.	1184.	1184.	342.	342.	1185.	1185.	342.	342.
11	1184.	1184.	342.	231.	743.	743.	231.	231.	742.	742.
21	231.	340.	1179.	1179.	340.	339.	1173.	1172.	338.	336.
31	1160.	1159.	335.	332.	1133.	1122.	1556.	3556.	5556.	7278.
41	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
51	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
61	8000.	8000.	7840.	7480.	7240.	6880.	6640.	6400.	7040.	8000.
71	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.	8000.
81	8000.	8000.	7986.	7909.	7787.	7666.	7548.	7431.	7317.	7205.
91	7096.	7021.	7000.	7000.	7000.	7000.	7000.	7000.	7000.	7000.
101	7000.	6153.	3455.	1074.	314.	314.	1074.	1074.	314.	490.
111	1249.	1113.	924.	1263.	1323.	1373.	1448.	1553.	1608.	1603.
121	1598.	1603.	1613.	1608.						

AVG= 4389.870 MAX= 8000.000
MIN= 86.000

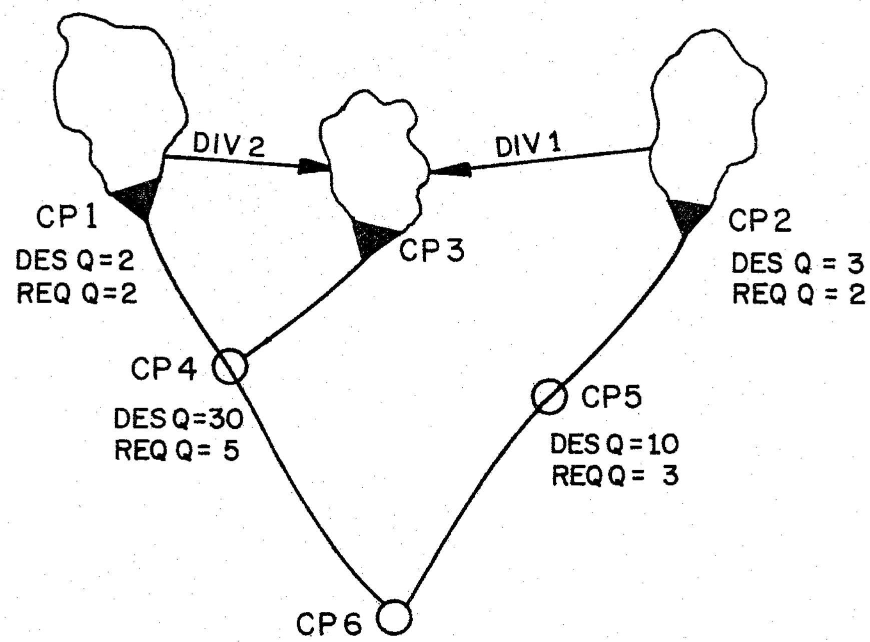
PER FLOOD BY RES

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
51	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
81	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
91	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
101	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
111	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

```
121     0.     0.     0.     0.

                                                                        AVG=     0.000  MAX=     0.
                                                                                        MIN=     0.
*************************************************************************************************************************

*************************************************************************************************************************

** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON QA CARD
```

7. TEST PROBLEM 6

a. The system for this test problem is diagramed below. The storage levels for the three reservoirs vary during the 12 months of the year and two of the reservoirs divert any excess flow above the top of conservation pool to the third reservoir (limited by the diversion capacity). The operation is for two years of monthly flow data with evaporation considered (J6 card). The output option (J2.6) was left undefined, therefore the output represents the full default printout. Also, user designed output was requested on J8 cards.



b. Although the RT cards show the detailed routing criteria for flood routings, the monthly time interval (IPER = 720 hours on J1.2) causes no routing to be used because the time interval is greater than the maximum time value for routing (NOROUT = 24 on J2.8).

c. The format for the flow data on the IN cards was 12 flows per card (including the identification and date on each card) as specified on the BF card (field 1=1) even though the output list of the data uses 10 flows per line of print. No IN cards were used for local inflow to location 4, 5, and 6. Local flow at 4 was computed as a ratio of flows at location 1 (refer to fields 3 and 4 of the CP card), local flow at 5 was computed as a ratio of flows at location 2 and local flows at location 6 were assumed to be zero.

d. Reservoir 2 is operating for itself and for control points 5 and 6. The requirements at 2 consist of a desired flow of 3 cfs and a required flow of 2 cfs. Control point 5 has desired and required flow requirements of 10 and 3 cfs respectively. There are no minimum flow requirements at control point 6. A review of the CASE output at 2 shows when the reservoir was releasing minimum flow for itself (CASE = .00) and when it was releasing for downstream control point 5 (CASE = 5.00).

The output labeled SHORTAGE shows how much deficiency there is for minimum desired and required flows. The last period of operation for Control Point 1 shows a 7 cfs shortage on the minimum required flow, but the minimum required flow of 3 cfs was met. The reservoir level for Reservoir 2 on the last period shows the reservoir to be in the buffer pool (Level < 2.00), therefore the release should be reduced to meet the minimum required flow.

Reservoirs 1 and 3 were both operated to meet their own requirements and the downstream requirements at Control Point 4. No shortages appear at any of those three locations.

e. After the output of Reservoir Releases and Regulated Flows, the added output requested by the J8 cards was provided. The first table provided Outflow, Case, and Level for the three reservoirs and the second provided the Natural and Regulated flows for the three downstream control points. The following three tables show values of the Sum, Maximum, Average, Period of Maximum (MPER), and Minimum values for different flow types at reservoirs and nonreservoirs. The last two tables show summaries of the average values of requested parameters at reservoirs and nonreservoirs. The program input description for the J8 card describes the various tables available and lists the parameters available for display.

```
HEC-5C SIMULATION OF FLOOD CONTROL
     AND CONSERVATION SYSTEMS
     UPDATED  OCT. 3 , 1975
RES.= 10    CPTS.= 15    PERS.= 50    DIVS.= 11    PWR.=  9

T1      TWO YEARS OF MONTHLY CONSERVATION OPERATION            TEST 6
T2      STORAGE LEVELS VARY BY MONTH
T3      UVAS, CHESBRO,AND HAYES RESERVOIRS        1952-1954 INFLOWS
J1       48.00     720.00      5.00      3.00      4.00     24.00      2.00      1.00      0.00      0.00
J2        0.00       1.00      1.00      0.00      1.00     -0.00     -1.00      1.00      0.00     -0.00
J4       10.00      -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
J6       12.00      30.00      1.80       .80       .50       .50      1.70      1.40      2.00      2.80
J6        3.30       4.00      4.00      2.90     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
J8        2.10       3.10      1.10      2.12      3.12      1.12      2.13      3.13      1.13     -0.00
J8        5.02       5.04      4.02      4.04      6.02      6.04     -0.00     -0.00     -0.00     -0.00
J8       -1.02       2.02      5.02      4.09      3.03     -0.00     -0.00     -0.00     -0.00     -0.00
J8       -5.07       5.19      1.05      2.06      2.04      5.04     -0.00     -0.00     -0.00     -0.00
J8       -1.02       2.02      5.02      4.09      3.03     -0.00     -0.00     -0.00     -0.00     -0.00


RL        2.00    3500.00      0.00      0.00   1000.00   4000.00   7600.00  10000.00     -0.00     -0.00
RL        2.00       1.00     -1.00      0.00      0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        2.00       2.00     -1.00      0.00   1000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        2.00       3.00      0.00      0.00   6000.00   5000.00   4000.00   4000.00   4000.00   5000.00
RL        2.00       3.00     -0.00     -0.00   7500.00   7500.00   7500.00   7500.00   7500.00   7000.00
RL        2.00       4.00     -1.00      0.00   7600.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        2.00       5.00     -1.00      0.00  10000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RO        2.00       5.00      6.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS        9.00       0.00   3500.00   3700.00   4000.00   6000.00   7000.00   8000.00   9000.00  10000.00
RQ        9.00     100.00    750.00    751.00    800.00   1000.00   1000.00   2200.00  11700.00  13000.00
RA        9.00       0.00    162.00    163.00    175.00    225.00    240.00    265.00    290.00    325.00
RE        9.00     465.00    503.00    505.00    509.00    519.00    523.00    527.00    530.00    533.00
RD       -1.00     500.00    875.00    876.00   1000.00   1100.00   1100.00   1100.00   1200.00   1200.00

CP        2.00   13000.00     -0.00     -0.00     -0.00     -0.00      3.00      2.00      0.00     -0.00
ID   CP 2  IS  CHESBRO RESERVOIR                  -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT        2.00       5.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
DR        2.00       3.00      1.20      0.00     -0.00      1.00     -2.00      0.00     -0.00     -0.00

CP        5.00   10000.00      2.00      2.00      0.00      0.00     10.00      3.00     -0.00     -0.00
ID   CP 5  IS  LLAGAS AT S M                      -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT        5.00       6.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00


RL        1.00    4000.00      0.00      0.00   2000.00   4000.00  10000.00  15000.00     -0.00     -0.00
RL        1.00       1.00     -1.00      0.00      0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        1.00       2.00     -1.00      0.00   2000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        1.00       3.00      0.00      0.00   9998.00   5000.00   4000.00   4000.00   5000.00   6000.00
RL        1.00       3.00     -0.00     -0.00  10000.00  10000.00  10000.00  10000.00  10000.00  10000.00
RL        1.00       4.00     -1.00      0.00  10000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL        1.00       5.00     -1.00      0.00  15000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RO        2.00       4.00      6.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS        9.00    3000.00   4000.00   5000.00   6000.00   7000.00   8000.00   9000.00  10000.00  11000.00
RQ        9.00     900.00   1000.00   1500.00   1700.00   2000.00  22000.00   2500.00   3500.00   5000.00
RA        9.00     130.00    140.00    180.00    201.00    220.00    260.00    260.00    260.00    260.00
RE        9.00     453.00    460.00    466.00    472.00    476.00    481.00    485.00    487.00    490.00
RD       -1.00     900.00   1000.00   1000.00   1500.00   1800.00   2000.00   2100.00   2200.00   2300.00
```

```
CP          1.00   20000.00      0.00      0.00      0.00      0.00     -0.00      2.00     -0.00     -0.00
ID  CP 1    IS  UVAS RESERVOIR                      -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT          1.00       4.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
DR          1.00       3.00      1.20      0.00     -0.00      1.00     -2.00      0.00     -0.00     -0.00

RL          3.00    2700.00      0.00      0.00  10000.00  35000.00  45000.00  63000.00     -0.00     -0.00
RL          3.00       1.00     -1.00      0.00      0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL          3.00       2.00     -1.00      0.00  10000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL          3.00       3.00      0.00      0.00  25000.00  20000.00  18000.00  15000.00  18000.00  25000.00
RL          3.00       3.00     -0.00     -0.00  40000.00  40000.00  40000.00  40000.00  35000.00  30000.00
RL          3.00       4.00     -1.00      0.00  45000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RL          3.00       5.00     -1.00      0.00  50000.00     -0.00     -0.00     -0.00     -0.00     -0.00
RO          2.00       4.00      6.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RS          6.00    6000.00  10000.00  14000.00  28000.00  45000.00  65000.00     -0.00     -0.00     -0.00
RQ          6.00     300.00    500.00    800.00   1000.00   1100.00   1500.00     -0.00     -0.00     -0.00
RA          6.00     110.00    190.00    270.00    400.00    500.00    570.00     -0.00     -0.00     -0.00
RE          6.00     360.00    383.00    400.00    440.00    480.00    520.00     -0.00     -0.00     -0.00

CP          3.00    1500.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID  CP 3    IS HAYES VALLEY RES                     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT          3.00       4.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP          4.00    6000.00      1.00      2.00     -0.00     -0.00     30.00      5.00     -0.00     -0.00
ID  CP 4    IS  UVAS AT GILROY                      -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT          4.00       6.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

CP          6.00   20000.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ID CP 6 PAJARO ' GILROY                             -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
RT          6.00       0.00      1.20     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00
ED          1.00      -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00     -0.00

    NRES=     3  NCPT=     6  NCPTR=     0

BF          1.00      48.00     48.00     -0.00 52010000.00   -0.00     -0.00     -0.00     -0.00     -0.00
IN     152           403.0      97.0     186.0      38.0      13.0       6.0       2.0       1.0      -0.0      -0.0
                       2.0      90.0     130.0      20.0      44.0      20.0      13.0       6.0       1.0       1.0
                       1.0      -0.0       2.0       2.0      25.0      74.0      62.0      47.0      13.0       5.0
                       1.0      -0.0      -0.0      -0.0       6.0      36.0      38.0      31.       20.0      17.0
                      10.0       3.0       1.0      -0.0      -0.0      -0.0       1.0     473.0
                                                                                                     SUM=      1941.
IN     252           206.0      34.0      82.0      18.0       7.0       2.0       1.0      -0.0      -0.0      -0.0
                      -0.0      36.0      57.0       8.0      12.0       6.0       3.0       1.0       1.0      -0.0
                      -0.0      -0.0      -0.0      -0.0       6.0      32.0      22.0      15.0       3.0       1.0
                      -0.0      -0.0      -0.0      -0.0      -0.0      12.0      19.0      13.0      10.0       6.0
                       5.0      -0.0       1.0      -0.0      -0.0      -0.0      -0.0      80.0
                                                                                                     SUM=       699.
IN     352             5.0       5.0      20.0      20.0      20.0      20.0      20.0      20.0      20.0      20.0
                      20.0       5.0       5.0       5.0      20.0      20.0      20.0      20.0      20.0      20.0
                      20.0      20.0      20.0       5.0       5.0       5.0      20.0      20.0      20.0      20.0
                      20.0      20.0      20.0      20.0      20.0       5.0       5.0       5.0      20.0      20.0
                      20.0      20.0      20.0      20.0      20.0      20.0      20.0       5.0
                                                                                                     SUM=       780.
EJ     -0             -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0      -0.0
```

```
J1    NPER    IPER      NL     NL1     NLM    EPER   NLBUF  ILOCAL  INFLOW   IOPMP
        24     720       5       3       4      24       2       1       0       0
J2   CNSTI   CFLOD  IFCAST  RATCHG   NFLRD  IPRINT  FLONAT  NOROUT   NCPTR   TRACE
      1.00    1.00      -1    1.00       1     511     -1.      24       0     -0.
J3  METRIC   ECFCT    DATE  BCRFAC  COSFAC  IPRECN  IANDAM  ISCHED  IPRIO   IPLOTJ
         0   1.0052010000.    1.00    1.00       0       0       0       0       0
J4   ISTMO
        10
J6  NEVRAT      EVDUR  EVRAT(I)
        12        30.    1.80     .80     .50     .50    1.70    1.40    2.00    2.80
                         3.30    4.00    4.00    2.90
```

USER ID	COMP ID	QMAX	RTFR	RTTO	RTMD	X	K	LAG	LOCP	RTLQ	QLAG	QMIND	QMINR	
2	1	13000.	2.	5.	1.20	-0.00	-0.000	-0	-0	-0.000	-0.	3.	2.	CP 2 IS CHESBRO RESE
5	4	10000.	5.	6.	1.20	-0.00	-0.000	-0	2	2.000	0.	10.	3.	CP 5 IS LLAGAS AT S
1	2	20000.	1.	4.	1.20	-0.00	-0.000	-0	0	0.000	0.	2.	2.	CP 1 IS UVAS RESERVO
3	3	1500.	3.	4.	1.20	-0.00	-0.000	-0	-0	-0.000	-0.	-0.	-0.	CP 3 IS HAYES VALLEY
4	5	6000.	4.	6.	1.20	-0.00	-0.000	-0	1	2.000	-0.	30.	5.	CP 4 IS UVAS AT GILR
6	6	20000.	6.	0.	1.20	-0.00	-0.000	-0	-0	-0.000	-0.	-0.	-0.	CP 6 PAJARO ! GILROY

USER ID	COMP ID	STOR1	STORL-1	-2	-3	-4	-5	ISERV(M,K)-		
2	1	3500.	0.	1000.	6000.	7600.	10000.	1	4	6
		DUR 2	0.	1000.	5000.	7600.	10000.			
		3	0.	1000.	4000.	7600.	10000.			
		4	0.	1000.	4000.	7600.	10000.			
		5	0.	1000.	4000.	7600.	10000.			
		6	0.	1000.	5000.	7600.	10000.			
		7	0.	1000.	7500.	7600.	10000.			
		8	0.	1000.	7500.	7600.	10000.			
		9	0.	1000.	7500.	7600.	10000.			
		10	0.	1000.	7500.	7600.	10000.			
		11	0.	1000.	7500.	7600.	10000.			
		12	0.	1000.	7000.	7600.	10000.			
1	2	4000.	0.	2000.	9998.	10000.	15000.	2	5	6
		DUR 2	0.	2000.	5000.	10000.	15000.			
		3	0.	2000.	4000.	10000.	15000.			
		4	0.	2000.	4000.	10000.	15000.			
		5	0.	2000.	5000.	10000.	15000.			
		6	0.	2000.	6000.	10000.	15000.			
		7	0.	2000.	10000.	10000.	15000.			
		8	0.	2000.	10000.	10000.	15000.			
		9	0.	2000.	10000.	10000.	15000.			
		10	0.	2000.	10000.	10000.	15000.			
		11	0.	2000.	10000.	10000.	15000.			
		12	0.	2000.	10000.	10000.	15000.			

3	3	2700.		0.	10000.	25000.	45000.	50000.	3	5	6
		DUR	2	0.	10000.	20000.	45000.	50000.			
			3	0.	10000.	18000.	45000.	50000.			
			4	0.	10000.	15000.	45000.	50000.			
			5	0.	10000.	18000.	45000.	50000.			
			6	0.	10000.	25000.	45000.	50000.			
			7	0.	10000.	40000.	45000.	50000.			
			8	0.	10000.	40000.	45000.	50000.			
			9	0.	10000.	40000.	45000.	50000.			
			10	0.	10000.	40000.	45000.	50000.			
			11	0.	10000.	35000.	45000.	50000.			
			12	0.	10000.	30000.	45000.	50000.			

RESERVOIR DATA

USER ID= 2 COMP ID= 1

RS	STORAGES=	0.	3500.	3700.	4000.	6000.	7000.	8000.	9000.	10000.
RQ	Q CAPACITIES=	100.	750.	751.	800.	1000.	1000.	2200.	11700.	13000.
RA	AREAS=	0.	162.	163.	175.	225.	240.	265.	290.	325.
RE	ELEVATIONS=	465.	503.	505.	509.	519.	523.	527.	530.	533.
RD	DIVERSION Q =	-500.	875.	876.	1000.	1100.	1100.	1100.	1200.	1200.
R1	START-STORAGE	0.	0.	0.	0.	0.	0.	0.	0.	0.

USER ID= 1 COMP ID= 2

RS	STORAGES=	3000.	4000.	5000.	6000.	7000.	8000.	9000.	10000.	11000.
RQ	Q CAPACITIES=	900.	1000.	1500.	1700.	2000.	22000.	2500.	3500.	5000.
RA	AREAS=	130.	140.	180.	201.	220.	260.	260.	260.	260.
RE	ELEVATIONS=	453.	460.	466.	472.	476.	481.	485.	487.	490.
RD	DIVERSION Q =	-900.	1000.	1000.	1500.	1800.	2000.	2100.	2200.	2300.
R1	START-STORAGE	0.	0.	0.	0.	0.	0.	0.	0.	0.

USER ID= 3 COMP ID= 3

RS	STORAGES=	6000.	10000.	14000.	28000.	45000.	65000.			
RQ	Q CAPACITIES=	300.	500.	800.	1000.	1100.	1500.			
RA	AREAS=	110.	190.	270.	400.	500.	570.			
RE	ELEVATIONS=	360.	383.	400.	440.	480.	520.			
R1	START-STORAGE	0.	0.	0.	0.	0.	0.	0.	0.	0.

DIVERSION DATA

DIV NO	TYPE	DIV Q	RET RAT	FROM	TO	METHOD	X	K
1	-2	0.00	1.00	2.00	3.00	1.20	0.00	-0.00
2	-2	0.00	1.00	1.00	3.00	1.20	0.00	-0.00

ROUTING COEFFICIENTS FROM RES 2 TO MY

MY=	5	1.0000
MY=	6	1.0000

ROUTING COEFFICIENTS FROM RES 1 TO MY

MY=	4	1.0000
MY=	6	1.0000

ROUTING COEFFICIENTS FROM RES 3 TO MY

MY=	4	1.0000
MY=	6	1.0000

```
       TWO YEARS OF MONTHLY CONSERVATION OPERATION              TEST 6
       STORAGE LEVELS VARY BY MONTH
       UVAS, CHESBRO,AND HAYES RESERVOIRS       1952-1954 INFLOWS

COMPUTATION INTERVAL IN HOURS= 744

                   ***** FLOOD NUMBER  1 *****                                          UNITS OF OUTPUT

                                                                     ALL FLOWS IN CFS OR CMS
                        NFLRD=        1  NFLCON=       0             EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
                        IFLRD =       1  IFLCON=       1             ELEVATIONS IN FEET OR METERS
                           FLOWS MULTIPLIED BY     1,000             POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH

*****************************************************************************************************************************

**** LOC     2   CP 2  IS  CHESBRO RESERVOIR    SERVED BY     2

                                                                                           STARTING TIME=       1
                                                                                           HOUR= 0,DAY= 0,MIN= 1,YEAR=1952,
                                  SERVING        2     5     6

          JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC     YEAR

PER         CUM LOCAL Q

   1     206.     34.     82.     18.      7.      2.      1.     -0.     -0.     -0.     -0.     36.       52
  13      57.      8.     12.      6.      3.      1.      1.     -0.     -0.     -0.     -0.     -0.       53

                                                                                           AVG=    19.750  MAX=     206.000
                                                                                                           MIN=      -0.000
PER         NATURAL FLOW

   1     206.     34.     82.     18.      7.      2.      1.     -0.     -0.     -0.     -0.     36.
  13      57.      8.     12.      6.      3.      1.      1.     -0.     -0.     -0.     -0.     -0.

                                                                                           AVG=    19.750  MAX=     206.000
                                                                                                           MIN=      -0.000
PER         MIN DESIRED FLOW

   1       3.      3.      3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
  13       3.      3.      3.      3.      3.      3.      3.      3.      3.      3.      3.      3.

                                                                                           AVG=     3.000  MAX=       3.000
                                                                                                           MIN=       3.000
PER         SHORTAGE

   1       0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
  13       0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

                                                                                           AVG=     0.000  MAX=       0.000
                                                                                                           MIN=       0.000
PER         MIN REQUIRED Q

   1       2.      2.      2.      2.      2.      2.      2.      2.      2.      2.      2.      2.
  13       2.      2.      2.      2.      2.      2.      2.      2.      2.      2.      2.      2.

                                                                                           AVG=     2.000  MAX=       2.000
                                                                                                           MIN=       2.000
PER         SHORTAGE
```

```
  1      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.
 13      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

                                                                                      AVG=    0.000  MAX=     0.000
                                                                                                     MIN=     0.000
PER        DIVERSION Q

  1    195.     31.     62.      0.      0.      0.      0.      0.      0.      0.      0.     12.
 13     54.      5.      0.      0.      0.      0.      0.      0.      0.      0.      0.      0.

                                                                                      AVG=   14.907  MAX=   194.757
                                                                                                     MIN=     0.000
PER        INFLOW

  1     11.      3.     20.     18.      7.      2.      1.     -0.     -0.     -0.     -0.     24.
 13      3.      3.     12.      6.      3.      1.      1.     -0.     -0.     -0.     -0.     -0.

                                                                                      AVG=    4.843  MAX=    24.450
                                                                                                     MIN=    -0.000
PER        OUTFLOW

  1      3.      3.      3.      3.      3.      6.      8.     10.     10.     10.     10.      3.
 13      3.      3.      3.      3.      4.      8.      8.     10.     10.     10.     10.      3.

                                                                                      AVG=    6.125  MAX=    10.000
                                                                                                     MIN=     3.000
PER        CASE=LOC.TYP

  1     .03     .03     .03    0.00    0.00    5.00    5.00    5.00    5.00    5.00    5.00     .03
 13     .03     .03    0.00    0.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00    5.00

                                                                                      AVG=    2.924  MAX=     5.000
                                                                                                     MIN=     0.000
PER        LEVEL

  1   3.000   3.000   3.000   2.747   2.777   2.731   2.654   2.549   2.489   2.458   2.422   3.000
 13   3.000   3.000   2.883   2.566   2.550   2.478   2.403   2.301   2.222   2.140   2.025   1.914

                                                                                      AVG=    2.596  MAX=     3.000
                                                                                                     MIN=     1.914
PER        EVAPORATION

  1      7.     25.     22.     35.     52.     61.     71.     66.     44.     24.      9.      6.
 13      7.     25.     21.     32.     44.     50.     57.     51.     30.     14.      4.      2.

                                                                                      AVG=   31.651  MAX=    70.844
                                                                                                     MIN=     1.943
PER        EOP STORAGE

  1   4000.   4000.   5000.   5857.   6051.   5752.   5251.   4570.   3931.   3292.   2687.   4000.
 13   4000.   4000.   4532.   4679.   4573.   4106.   3619.   2954.   2329.   1700.   1101.    914.

                                                                                      AVG= 3870.773  MAX=  6051.176
                                                                                                     MIN=   914.305
PER        ELEVATION AVG

  1  505.67  509.00  511.50  516.14  518.77  518.51  516.51  513.55  510.25  504.11  497.46  501.30
 13  509.00  509.00  510.33  512.03  512.13  510.70  507.17  500.68  493.68  486.87  480.20  475.94

                                                                                      AVG=  505.438  MAX=   518.772
                                                                                                     MIN=   475.939
*************************************************************************************************************

**** LOC     5   CP 5  IS  LLAGAS AT S M         SERVED BY      2
```

PER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR		
PER	CUM LOCAL Q														
1	412.	68.	164.	36.	14.	4.	2.	-0.	-0.	-0.	-0.	72.	52		
13	114.	16.	24.	12.	6.	2.	2.	-0.	-0.	-0.	-0.	-0.	53		
												AVG=	39,500	MAX=	412,000
														MIN=	-0,000
PER	NATURAL FLOW														
1	618.	102.	246.	54.	21.	6.	3.	-0.	-0.	-0.	-0.	108.			
13	171.	24.	36.	18.	9.	3.	3.	-0.	-0.	-0.	-0.	-0.			
												AVG=	59,250	MAX=	618,000
														MIN=	-0,000
PER	MIN DESIRED FLOW														
1	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.			
13	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.			
												AVG=	10,000	MAX=	10,000
														MIN=	10,000
PER	SHORTAGE														
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.			
												AVG=	,292	MAX=	7,000
														MIN=	0,000
PER	MIN REQUIRED Q														
1	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.			
13	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.	3.			
												AVG=	3,000	MAX=	3,000
														MIN=	3,000
PER	SHORTAGE														
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
												AVG=	0,000	MAX=	0,000
														MIN=	0,000
PER	REGULATED FLOW														
1	415.	71.	167.	39.	17.	10.	10.	10.	10.	10.	10.	75.			
13	117.	19.	27.	15.	10.	10.	10.	10.	10.	10.	10.	3.			
												AVG=	45,625	MAX=	415,000
														MIN=	3,000
PER	Q BY US RES,DIVS														
1	3.	3.	3.	3.	3.	6.	8.	10.	10.	10.	10.	3.			
13	3.	3.	3.	3.	4.	8.	8.	10.	10.	10.	10.	3.			
												AVG=	6,125	MAX=	10,000
														MIN=	3,000

****

**** LOC 1 CP 1 IS UVAS RESERVOIR SERVED BY 1

STARTING TIME= 1
HOUR= 0,DAY= 0,MON= 1,YEAR=1952,

SERVING 1 4 6

PER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR		
PER	CUM LOCAL Q														
1	403.	97.	186.	38.	13.	6.	2.	1.	-0.	-0.	2.	90.	52		
13	130.	20.	44.	20.	13.	6.	1.	1.	1.	-0.	2.	2.	53		
												AVG=	44.917	MAX=	403.000
														MIN=	-0.000
PER	NATURAL FLOW														
1	403.	97.	186.	38.	13.	6.	2.	1.	-0.	-0.	2.	90.			
13	130.	20.	44.	20.	13.	6.	1.	1.	1.	-0.	2.	2.			
												AVG=	44.917	MAX=	403.000
														MIN=	-0.000
PER	MIN DESIRED FLOW														
1	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.			
13	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.			
												AVG=	2.000	MAX=	2.000
														MIN=	2.000
PER	SHORTAGE														
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
												AVG=	0.000	MAX=	0.000
														MIN=	0.000
PER	MIN REQUIRED Q														
1	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.			
13	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.	2.			
												AVG=	2.000	MAX=	2.000
														MIN=	2.000
PER	SHORTAGE														
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.			
												AVG=	0.000	MAX=	0.000
														MIN=	0.000
PER	DIVERSION Q														
1	401.	78.	167.	0.	0.	0.	0.	0.	0.	0.	30.	104.			
13	128.	1.	25.	0.	0.	0.	0.	0.	0.	0.	3.	16.			
												AVG=	39.779	MAX=	400.905
														MIN=	0.000
PER	INFLOW														
1	2.	19.	19.	38.	13.	6.	2.	1.	-0.	-0.	-28.	-14.			
13	2.	19.	19.	20.	13.	6.	1.	1.	1.	-0.	-1.	-14.			
												AVG=	5.138	MAX=	38.000
														MIN=	-28.381
PER	OUTFLOW														
1	2.	2.	2.	2.	3.	6.	8.	8.	8.	2.	2.	2.			
13	2.	2.	2.	2.	3.	7.	10.	9.	9.	8.	2.	2.			
												AVG=	4.430	MAX=	10.001
														MIN=	2.000
PER	CASE=LOC.TYP														

```
   1    .03    .03    .03   0.00   4.00   4.00   4.00   4.00   4.00   0.00    .03    .03
  13    .03   0.00    .03   0.00   4.00   4.00   4.00   4.00   4.00   4.00    .03    .03

                                                                              AVG=     1.845   MAX=     4.000
                                                                                               MIN=     0.000
PER       LEVEL

   1  3.000  3.000  3.000  2.763  2.836  2.824  2.766  2.699  2.630  2.610  3.000  3.000
  13  3.000  2.992  3.000  2.630  2.702  2.684  2.605  2.532  2.469  2.400  3.000  3.000

                                                                              AVG=     2.798   MAX=     3.000
                                                                                               MIN=     2.400
PER       EVAPORATION

   1     6.    23.    22.    37.    61.    72.    87.    85.    56.    33.    13.     7.
  13     6.    23.    22.    35.    54.    66.    75.    70.    49.    28.    12.     7.

                                                                              AVG=    39.531   MAX=    86.667
                                                                                               MIN=     5.833
PER       EOP STORAGE

   1  4000.  5000.  6000.  8105.  8686.  8593.  8124.  7589.  7037.  6881.  5000.  4000.
  13  4000.  4977.  6000.  7036.  7615.  7468.  6839.  6257.  5750.  5202.  5000.  4000.

                                                                              AVG=  6214.995   MAX=  8686.372
                                                                                               MIN=  4000.000
PER       ELEVATION AVG

   1 460.00 463.00 469.00 476.26 482.58 483.56 482.43 480.28 477.57 475.84 471.64 463.00
  13 460.00 462.93 468.93 474.07 477.63 478.71 476.77 474.19 472.01 468.86 466.61 463.00

                                                                              AVG=   472.036   MAX=   483.558
                                                                                               MIN=   460.000
**************************************************************************************************
**** LOC     3   CP 3  IS HAYES VALLEY RES      SERVED BY     3

                                                                              STARTING TIME=      1
                                                                              HOUR= 0,DAY= 0,MON= 1,YEAR=1952.
                                  SERVING      3     4     6

         JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC     YEAR
PER       CUM LOCAL Q

   1     5.     5.    20.    20.    20.    20.    20.    20.    20.    20.    20.     5.       52
  13     5.     5.    20.    20.    20.    20.    20.    20.    20.    20.    20.     5.       53

                                                                              AVG=    16.250   MAX=    20.000
                                                                                               MIN=     5.000
PER       NATURAL FLOW

   1     5.     5.    20.    20.    20.    20.    20.    20.    20.    20.    20.     5.
  13     5.     5.    20.    20.    20.    20.    20.    20.    20.    20.    20.     5.

                                                                              AVG=    16.250   MAX=    20.000
                                                                                               MIN=     5.000
PER       DIVERSION Q

   1  -596.  -109.  -230.     0.     0.     0.     0.     0.     0.     0.   -30.  -116.
  13  -182.    -6.   -25.     0.     0.     0.     0.     0.     0.     0.    -3.   -16.

                                                                              AVG=   -54.686   MAX=     0.000
                                                                                               MIN=  -595.662
PER       INFLOW
```

```
  1   601.   114.   250.    20.    20.    20.    20.    20.    20.    20.    50.   121.
 13   187.    11.    45.    20.    20.    20.    20.    20.    20.    20.    23.    21.

                                                                         AVG=     70.936  MAX=    600.662
PER       OUTFLOW                                                                         MIN=     10.965

  1   401.    60.   135.     0.     1.    12.    18.    20.    22.    56.   135.   153.
 13   235.     0.     0.     0.     1.    11.    18.    19.    19.    22.    35.    53.

                                                                         AVG=     59.363  MAX=    400.511
PER       CASE=LOC.TYP                                                                    MIN=      0.000

  1    .03    .03    .03   0.00   4.00   4.00   4.00   4.00   4.00    .03    .03    .03
 13    .03   0.00   0.00   0.00   4.00   4.00   4.00   4.00   4.00   4.00    .03    .03

                                                                         AVG=      1.845  MAX=      4.000
PER       LEVEL                                                                           MIN=      0.000

  1  3.000  3.000  3.000  2.538  2.573  2.586  2.586  2.698  2.863  3.000  3.000  3.000
 13  3.000  2.686  2.548  2.312  2.348  2.363  2.364  2.435  2.542  2.713  3.000  3.000

                                                                         AVG=      2.715  MAX=      3.000
PER       EVAPORATION                                                                     MIN=      2.312

  1     7.    42.    40.    63.    90.   108.   132.   132.    95.    57.    23.    13.
 13    12.    40.    35.    52.    76.    91.   111.   111.    81.    50.    22.    13.

                                                                         AVG=     62.389  MAX=    132.002
PER       EOP STORAGE                                                                     MIN=      6.958

  1 15000. 18000. 25000. 26127. 27178. 27568. 27572. 27460. 27265. 25000. 20000. 18000.
 13 15000. 15491. 18223. 19361. 20435. 20900. 20912. 20882. 20843. 20698. 20000. 18000.

                                                                         AVG=  21454.796  MAX=  27571.958
PER       ELEVATION AVG                                                                   MIN=  15000.000

  1 376.39 407.14 421.43 433.04 436.15 438.21 438.77 438.62 438.18 434.66 424.29 414.29
 13 407.14 403.56 408.16 413.69 416.85 419.05 419.73 419.71 419.61 419.34 418.14 414.29

                                                                         AVG=    420.018  MAX=    438.771
                                                                                          MIN=    376.368
****************************************************************************************************
**** LOC    4   CP 4  IS  UVAS AT GILROY       SERVED BY    1    3

       JAN    FEB    MAR    APR    MAY    JUN    JUL    AUG    SEP    OCT    NOV    DEC    YEAR
PER       CUM LOCAL Q

  1   806.   194.   372.    76.    26.    12.     4.     2.    -0.    -0.     4.   180.     52
 13   260.    40.    88.    40.    26.    12.     2.     2.     2.    -0.     4.     4.     53

                                                                         AVG=     89.833  MAX=    806.000
PER       NATURAL FLOW                                                                    MIN=     -0.000

  1  1214.   296.   578.   134.    59.    38.    26.    23.    20.    20.    26.   275.
 13   395.    65.   152.    80.    59.    38.    23.    23.    23.    20.    26.    11.
```

AVG= 151.000 MAX= 1214.000
MIN= 11.000

PER MIN DESIRED FLOW

1	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.
13	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.	30.

AVG= 30.000 MAX= 30.000
MIN= 30.000

PER SHORTAGE

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER MIN REQUIRED Q

1	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.
13	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.	5.

AVG= 5.000 MAX= 5.000
MIN= 5.000

PER SHORTAGE

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

AVG= 0.000 MAX= 0.000
MIN= 0.000

PER REGULATED FLOW

1	1209.	256.	509.	78.	30.	30.	30.	30.	30.	58.	141.	335.
13	497.	42.	90.	42.	30.	30.	30.	30.	30.	30.	41.	59.

AVG= 153.627 MAX= 1208.511
MIN= 30.000

PER Q BY US RES,DIVS

1	403.	62.	137.	2.	4.	18.	26.	28.	30.	58.	137.	155.
13	237.	2.	2.	2.	4.	18.	28.	28.	28.	30.	37.	55.

AVG= 63.793 MAX= 402.511
MIN= 2.000

****

**** LOC 6 CP 6 PAJARO @ GILROY SERVED BY 2 1 3

PER CUM LOCAL Q

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1	1218.	262.	536.	112.	40.	16.	6.	2.	0.	0.	4.	252.	52
13	374.	56.	112.	52.	32.	14.	4.	2.	2.	0.	4.	4.	53

AVG= 129.333 MAX= 1218.000
MIN= 0.000

PER NATURAL FLOW

1	1832.	398.	824.	188.	80.	44.	29.	23.	20.	20.	26.	383.
13	566.	89.	188.	98.	68.	41.	26.	23.	23.	20.	26.	11.

AVG= 210.250 MAX= 1832.000
MIN= 11.000

PER REGULATED FLOW

PER												
1	1624.	327.	676.	117.	47.	40.	40.	40.	40.	68.	151.	410.
13	614.	61.	117.	57.	40.	40.	40.	40.	40.	40.	51.	62.

AVG= 199.252 MAX= 1623.511 MIN= 40.000

PER Q BY US RES,DIVS

PER												
1	406.	65.	140.	5.	7.	24.	34.	38.	40.	68.	147.	158.
13	240.	5.	5.	5.	8.	26.	36.	38.	38.	40.	47.	58.

AVG= 69.916 MAX= 405.511 MIN= 5.000

****

RESERVOIR OPERATION BY PERIOD

CUM TIME= 1

RES NO=	2	1	3
DIV Q	195.	401.	-596.
INFLOW	11.	2.	601.
OUTFLOW	3.	2.	401.
EOP STOR	4000.	4000.	15000.
ELEV	506.	460.	376.
CASE=	.03	.03	.03
LEVEL	3.000	3.000	3.000
EQ LEVEL	3.000	3.000	3.000

CUM TIME= 2

RES NO=	2	1	3
DIV Q	31.	78.	-109.
INFLOW	3.	19.	114.
OUTFLOW	3.	2.	60.
EOP STOR	4000.	5000.	18000.
ELEV	509.	463.	407.
CASE=	.03	.03	.03
LEVEL	3.000	3.000	3.000
EQ LEVEL	3.000	3.000	3.000

CUM TIME= 3

RES NO=	2	1	3
DIV Q	62.	167.	-230.
INFLOW	20.	19.	250.
OUTFLOW	3.	2.	135.
EOP STOR	5000.	6000.	25000.
ELEV	511.	469.	421.
CASE=	.03	.03	.03
LEVEL	3.000	3.000	3.000
EQ LEVEL	3.000	3.000	3.000

PERIODS 4-24 OMITTED

RESERVOIR RELEASES BY PERIOD

RES NO	2	1	3
CHAN CAP	13000.	20000.	1500.
MIN DES Q	3.	2.	-1.
MIN REQ Q	2.	2.	-1.
PERIOD			
1	3.	2.	401.
2	3.	2.	60.
3	3.	2.	135.
4	3.	2.	0.
5	3.	3.	1.
6	6.	6.	12.
7	8.	8.	18.
8	10.	8.	20.
9	10.	8.	22.
10	10.	2.	56.
11	10.	2.	135.
12	3.	2.	153.
13	3.	2.	235.
14	3.	2.	0.
15	3.	2.	0.
16	3.	2.	0.
17	4.	3.	1.
18	8.	7.	11.
19	8.	10.	18.
20	10.	9.	19.
21	10.	9.	19.
22	10.	6.	22.
23	10.	2.	35.
24	3.	2.	53.
SUM =	147.	106.	1425.
MAX =	10.	10.	401.
MIN =	3.	2.	0.
MPER=	8.	19.	1.
AVG =	6.	4.	59.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	5	4	6
CHAN CAP	10000.	6000.	20000.
MIN DES Q	10.	30.	-1.
MIN REQ Q	3.	5.	-1.

PERIOD			
1	415.	1209.	1624.
2	71.	256.	327.
3	167.	509.	676.
4	39.	78.	117.
5	17.	30.	47.
6	10.	30.	40.
7	10.	30.	40.
8	10.	30.	40.
9	10.	30.	40.
10	10.	58.	68.
11	10.	141.	151.
12	75.	335.	410.
13	117.	497.	614.
14	19.	42.	61.
15	27.	90.	117.
16	15.	42.	57.
17	10.	30.	40.
18	10.	30.	40.
19	10.	30.	40.
20	10.	30.	40.
21	10.	30.	40.
22	10.	30.	40.
23	10.	41.	51.
24	3.	59.	62.
SUM =	1095.	3687.	4782.
MAX =	415.	1209.	1624.
MIN =	3.	30.	40.
MPER=	1.	1.	1.
AVG =	46.	154.	199.

USER DESIGNED OUTPUT

LOC NO*	2.	3.	1.	2.	3.	1.	2.	3.	1.
PER DY MO YR DW	OUTFLOW	OUTFLOW	OUTFLOW	CASE*LOC	CASE*LOC	CASE*LOC	LEVEL	LEVEL	LEVEL
1 0 1 52 0	3.00	400.51	2.00	.03	.03	.03	3.00	3.00	3.00
2 0 2 52 0	3.00	59.91	2.00	.03	.03	.03	3.00	3.00	3.00
3 0 3 52 0	3.00	135.27	2.00	.03	.03	.03	3.00	3.00	3.00
4 0 4 52 0	3.00	0.00	2.00	0.00	0.00	0.00	2.75	2.54	2.76
5 0 5 52 0	3.00	1.44	2.56	0.00	4.00	4.00	2.78	2.57	2.84
6 0 6 52 0	6.00	11.63	6.37	5.00	4.00	4.00	2.73	2.59	2.82
7 0 7 52 0	8.00	17.79	8.21	5.00	4.00	4.00	2.65	2.59	2.77
8 0 8 52 0	10.00	19.68	8.32	5.00	4.00	4.00	2.55	2.70	2.70
9 0 9 52 0	10.00	21.67	8.33	5.00	4.00	4.00	2.49	2.86	2.63
10 0 10 52 0	10.00	55.91	2.00	5.00	.03	0.00	2.46	3.00	2.61
11 0 11 52 0	10.00	135.03	2.00	5.00	.03	.03	2.42	3.00	3.00
12 0 12 52 0	3.00	153.02	2.00	.03	.03	.03	3.00	3.00	3.00
13 0 1 53 0	3.00	235.38	2.00	.03	.03	.03	3.00	3.00	3.00
14 0 2 53 0	3.00	0.00	2.00	.03	0.00	0.00	3.00	2.69	2.99
15 0 3 53 0	3.00	0.00	2.00	0.00	0.00	.03	2.88	2.55	3.00
16 0 4 53 0	3.00	0.00	2.00	0.00	0.00	0.00	2.57	2.31	2.63
17 0 5 53 0	4.00	1.30	2.70	5.00	4.00	4.00	2.55	2.35	2.70
18 0 6 53 0	8.00	10.65	7.35	5.00	4.00	4.00	2.48	2.36	2.68
19 0 7 53 0	8.00	18.00	10.00	5.00	4.00	4.00	2.40	2.36	2.60
20 0 8 53 0	10.00	18.68	9.32	5.00	4.00	4.00	2.30	2.44	2.53
21 0 9 53 0	10.00	19.31	8.69	5.00	4.00	4.00	2.22	2.54	2.47
22 0 10 53 0	10.00	21.54	8.46	5.00	4.00	4.00	2.14	2.71	2.40
23 0 11 53 0	10.00	34.55	2.00	5.00	.03	.03	2.03	3.00	3.00
24 0 12 53 0	3.00	53.47	2.00	5.00	.03	.03	1.91	3.00	3.00
SUM *	147.00	1424.71	106.33	70.18	44.27	44.27	62.31	65.16	67.14
MAX *	10.00	400.51	10.00	5.00	4.00	4.00	3.00	3.00	3.00
MIN *	3.00	0.00	2.00	0.00	0.00	0.00	1.91	2.31	2.40
MPER*	8.00	1.00	19.00	6.00	5.00	5.00	1.00	1.00	1.00
AVG *	6.12	59.36	4.43	2.92	1.84	1.84	2.60	2.71	2.80

USER DESIGNED OUTPUT

LOC NO=					5.	5.	4.	4.	6.	6.
PER	DY	MO	YR	DW	NATURAL	REGULATE	NATURAL	REGULATE	NATURAL	REGULATE
1	0	1	52	0	618.00	415.00	1214.00	1208.51	1832.00	1623.51
2	0	2	52	0	102.00	71.00	296.00	255.91	398.00	326.91
3	0	3	52	0	246.00	167.00	578.00	509.27	824.00	676.27
4	0	4	52	0	54.00	39.00	134.00	78.00	188.00	117.00
5	0	5	52	0	21.00	17.00	59.00	30.00	80.00	47.00
6	0	6	52	0	6.00	10.00	38.00	30.00	44.00	40.00
7	0	7	52	0	3.00	10.00	26.00	30.00	29.00	40.00
8	0	8	52	0	-0.00	10.00	23.00	30.00	23.00	40.00
9	0	9	52	0	-0.00	10.00	20.00	30.00	20.00	40.00
10	0	10	52	0	-0.00	10.00	20.00	57.91	20.00	67.91
11	0	11	52	0	-0.00	10.00	26.00	141.03	26.00	151.03
12	0	12	52	0	108.00	75.00	275.00	335.02	383.00	410.02
13	0	1	53	0	171.00	117.00	395.00	497.38	566.00	614.38
14	0	2	53	0	24.00	19.00	65.00	42.00	89.00	61.00
15	0	3	53	0	36.00	27.00	152.00	90.00	188.00	117.00
16	0	4	53	0	18.00	15.00	80.00	42.00	98.00	57.00
17	0	5	53	0	9.00	10.00	59.00	30.00	68.00	40.00
18	0	6	53	0	3.00	10.00	38.00	30.00	41.00	40.00
19	0	7	53	0	3.00	10.00	23.00	30.00	26.00	40.00
20	0	8	53	0	-0.00	10.00	23.00	30.00	23.00	40.00
21	0	9	53	0	-0.00	10.00	23.00	30.00	23.00	40.00
22	0	10	53	0	-0.00	10.00	20.00	30.00	20.00	40.00
23	0	11	53	0	-0.00	10.00	26.00	40.55	26.00	50.55
24	0	12	53	0	-0.00	3.00	11.00	59.47	11.00	62.47
				SUM =	1422.00	1095.00	3624.00	3687.04	5046.00	4782.04
				MAX =	618.00	415.00	1214.00	1208.51	1832.00	1623.51
				MIN =	-0.00	3.00	11.00	30.00	11.00	40.00
				MPER=	1.00	1.00	1.00	1.00	1.00	1.00
				AVG =	59.25	45.62	151.00	153.63	210.25	199.25

USER DESIGNED OUTPUT

LOC*	NATURAL	NATURAL	NATURAL	INFLOW	DIVERSIO
	SUM	MAX	AVG	MPER	MIN
RESERVOIR SUMMARY					
2	474.00	206.00	19.75	12.00	0.00
1	1078.00	403.00	44.92	4.00	0.00
3	390.00	20.00	16.25	1.00	-595.66

USER DESIGNED OUTPUT

LOC=	MIN REQU	Q BY US	MIN DESI	SHORTAGE	REGULATE	REGULATE
	AVG	AVG	SUM	MAX	MAX	AVG
NON RESERVOIR DATA						
5	3.00	6.12	240.00	7.00	415.00	45.62
4	5.00	63.79	720.00	0.00	1208.51	153.63
6	0.00	69.92	0.00	0.00	1623.51	199.25

USER DESIGNED OUTPUT

LOC=	NATURAL	NATURAL	NATURAL	INFLOW	DIVERSIO
	SUM	MAX	AVG	MPER	MIN
RESERVOIR SUMMARY					
2	474.00	206.00	19.75	12.00	0.00
1	1078.00	403.00	44.92	4.00	0.00
3	390.00	20.00	16.25	1.00	-595.66

SUMMARY OF AVERAGES FOR RESERVOIRS

LOC=	CUM LOCA	NATURAL	INFLOW	OUTFLOW	CASE=LOC	LEVEL	EOP STOR
2	19.75	19.75	4.84	6.12	2.92	2.60	3870.77
1	44.92	44.92	5.14	4.43	1.84	2.80	6214.99
3	16.25	16.25	70.94	59.36	1.84	2.71	21454.80

SUMMARY OF AVERAGES FOR NON RESERVOIRS

LOC=	CUM LOCA	NATURAL	REGULATE	Q SPACE	Q BY US	FLOOD BY
5	39.50	59.25	45.62	0.00	6.12	0.00
4	89.83	151.00	153.63	0.00	63.79	0.00
6	129.33	210.25	199.25	0.00	69.92	0.00

FLOOD SUMMARY-EACH FLOOD COPY= 1

TWO YEARS OF MONTHLY CONSERVATION OPERATION TEST 6
STORAGE LEVELS VARY BY MONTH
UVAS, CHESBRO,AND HAYES RESERVOIRS 1952-1954 INFLOWS

***** FLOOD NUMBER 1 *****

	FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC 5 CP 5 IS LLAGAS AT	1.001	415. *	1.001	618. *	1.001	412. *	3. *	.17	0.00
LOC 4 CP 4 IS UVAS AT G	1.001	1209. *	1.001	1214. *	1.001	806. *	403. *	0.00	0.00
LOC 6 CP 6 PAJARO ' GILROY	1.001	1624. *	1.001	1832. *	1.001	1218. *	406. *	0.00	0.00

RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC 2 CP 2 IS CHESBRO R	1.024	914.	1.914 *	1.005	6051	3.000 *	1.008	9	13000	3500
LOC 1 CP 1 IS UVAS RESE	1.024	4000.	2.400 *	1.005	8686	3.000 *	1.019	10	20000	4000
LOC 3 CP 3 IS HAYES VALL	1.001	15000.	2.312 *	1.007	27571	3.000 *	1.001	400	1500	2700

MIN SYSTEM STG= 19912 MAX SYSTEM STG= 42308

COPY= 1

MINIMUM VALUES AND SHORTAGES FOR CONSERVATION OPERATION-ALL FLOODS

LOC		DESIRED FLOW SHORTAGE PERIODS	DESIRED FLOW SHORTAGE VOLUME	DESIRED FLOW SHORTAGE INDEX	REQUIRED FLOW SHORTAGE PERIODS	REQUIRED FLOW SHORTAGE VOLUME	REQUIRED FLOW SHORTAGE INDE)
2	CP 2 IS CHESBRO R	0.	0.	0.00	0.	0.	0.00
5	CP 5 IS LLAGAS AT	1.	7.	.17	0.	0.	0.00
1	CP 1 IS UVAS RESE	0.	0.	0.00	0.	0.	0.00
3	CP 3 IS HAYES VALL	0.	-1.	0.00	0.	-1.	0.00
4	CP 4 IS UVAS AT G	0.	0.	0.00	0.	0.	0.00
6	CP 6 PAJARO ' GILROY	0.	-1.	0.00	0.	-1.	0.00

NOTE: -1. INDICATES THAT DESIRED AND/OR REQUIRED FLOWS WERE NOT SPECIFIED FOR GIVEN CONTROL POINT

	RESERVOIRS		FLD.PER	MIN STG	MIN LEVEL
LOC	2	CP 2 IS CHESBRO R	1.024	914.	1.914
LOC	1	CP 1 IS UVAS RESE	1.024	4000.	2.400
LOC	3	CP 3 IS HAYES VALL	1.001	15000.	2.312

HYDROLOGIC EFFICIENCIES

**** LOC 5 CP 5 IS LLAGAS AT S M SERVED BY 2

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	618.	415.	203.0	32.85	.00	.00	0.00	0.00

**** LOC 4 CP 4 IS UVAS AT GILROY SERVED BY 1 3

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	1214.	1209.	5.5	.45	.00	.00	0.00	0.00

**** LOC 6 CP 6 PAJARO ' GILROY SERVED BY 2 1 3

FLOOD NO.	PEAK DISCHARGE REDUCTION (Q RED) NAT Q	REG Q	Q RED	PERCENT Q RED	MAX STAGE REDUCTION (S RED) DEPTH FLOODING NAT	REG	S RED	PERCENT S RED
1	1832.	1624.	208.5	11.38	.00	.00	0.00	0.00

```
**************************************************************************************************************************

          COMPUTER CHECK FOR POSSIBLE ERRORS

                         ***** FLOOD NUMBER  1 *****

POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=       50
**************************************************************************************************************************


** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON QA CARD
```

8. TEST PROBLEM 10

a. The system simulated in this test consists of three reservoir sites and one damage center (see diagram below). Reservoir 3 is deleted from the system model by using a J5 card. This test computes the expected annual flood damages and the net system benefits for the damage center. The economic calculations are computed using six ratios (FC card) of the input hydrograph. The program will operate each of six ratios as a separate flood starting from the same starting conditions.

b. The output for this test shows the input card images, the labeled input, the reservoir releases and regulated flows for each flood, the single flood summary (for each of the 6 floods) which concentrates on flood control, the Flood Summary (for each flood) which shows both flood control and conservation data (2 copies), the maximum value summary for all floods (same format as flood summary), the expected annual damage computations for control point 4, the discharge frequency curve plot for the damage center, a summary of system costs based on input data for the proposed projects (2 copies), and a final economic summary showing total system costs, expected annual damages and reductions and expected annual system net damage reduction benefits.

c. In this hypothetical example it is assumed that reservoir 2 is an existing project (no R$ card) with the expected annual damages for the existing system being read in on the DC card for both damage categories (these values were simply estimated for this example, but could have been computed by a separate run on HEC-5C using only reservoir 2 in the operation. Reservoir 1 is a proposed reservoir with the costs for various flood storages shown on the R$ card for various values of storage on the RS card. A local protection project is also shown at location 4 and its cost is shown on the C$ card for various values of the design discharge of the levee project shown on the QS card. The first field of the C$ card shows the design discharge (40,000 cfs) for the local project used in this run. Damages computed from the DC cards below this discharge for regulated conditions are automatically eliminated. Thus the object of this computer run is to determine the net system benefits for flood control resulting from the additional costs of reservoir 1 and the local protection and the reduction of flood damages from the existing system (reservoir 2) and the total system with the added components.

d. The discharge - (DQ card) - damage (DC cards) - frequency (DF cards) data were prepared to show damages for various flows in the river (without the local protection project) and the natural frequency relationships so that the damages for the natural (called base in output) conditions could be computed. The damage computation output first shows the economic input data (notice that the damages on the DC card were multiplied by a 999 factor on the second field of the J3 card). Following that, the expected annual damages for natural conditions, based on integrating the damage frequency curve, ($2,207), and the expected annual damages from the DB card for the existing damages of $1,500 are printed. Based on the reservoir operation and the resulting regulated flows the modified damages are shown to be $684 and the resulting damage reduction over the existing system ($1,500) was shown as $816. If the reservoir projects had unlimited flood control storage the only flow at the damage center would be the uncontrolled local flow. The corresponding damages for this condition (labeled damages with total control at projects) would be $504 and the reduction would be $996, thus the residual damage (value of increasing flood control storage at reservoir 1 and/or 2) would be $180 (996-816). If all of the damage data is input in $1,000's then the cost data must be also.

e. The discharge frequency curve is plotted by the printer (can be omitted by input control -J3.6). It shows the input frequency-discharge relationship (X), the natural (O), and regulated (M) discharges for the six floods operated. The channel capacity is also shown. The $ symbol at the left margin shows that some of the input discharge-frequency data was equal to or greater than 99.9 exceedence probability (in percent).

The table following the frequency curve shows a summary for expected annual damages for all control points. The next table summarizes the cost data and the last table shows the system economic cost and performance summary. The results show the proposed reservoir 1 and the local protection project at 4 had total annual costs for flood control prevention of $410 and reduced the flood damages from the existing system by $816 and thus had a net benefit of $406 (all data are assumed in this example to be in thousands of dollars, thus $406,000 would be the annual net benefit). The cost data for the reservoir (R$ card) and control point (C$ card) represent project costs allocated to flood control and are multiplied by the cost factor on the fifth field of the J3 card (.1 was used in this hypothetical case to make the uncoordinated hypothetical data provide logical results.

```
    HEC-5C SIMULATION OF FLOOD CONTROL
           AND CONSERVATION SYSTEMS
           UPDATED  OCT. 3 , 1975
    RES.= 10     CPTS.= 15     PERS.= 50     DIVS.= 11     PWR.=  9

T1      EXPECTED ANNUAL DAMAGE CALCULATIONS                      TEST 10
T2      USING FLOOD RATIOS OF .3,1.0,1.5,2.0,3.0,4.0
T3      FONY RIVER BASIN
J1        18.00        6.00        4.00        2.00        3.00       -0.00       -0.00        1.00       -0.00        1.00
J2        -0.00       -0.00       -0.00        1.00       -0.00       38.00       -1.00       -0.00       -0.00       -0.00
J3         0.00      999.00 57060618.00         .03         .10       -0.00        1.00       -0.00       -0.00       -0.00
J5         1.00        3.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00


RL         1.00    50000.00       -0.00        0.00    50000.00   150832.00   200000.00       -0.00       -0.00       -0.00
RO         1.00        2.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         6.00        0.00    50000.00    70000.00   100000.00   150832.00   200000.00       -0.00       -0.00       -0.00
RQ         6.00     5000.00     6000.00     7000.00     8000.00   100000.00   200000.00       -0.00       -0.00       -0.00
R$         6.00        0.00    20000.00    30000.00    50000.00    76000.00   100000.00       -0.00       -0.00       -0.00

CP         1.00     6000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00        2.00
ID RESERVOIR A (CP 1)                                      -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         1.00        2.00         .10        1.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00


RL         2.00   100000.00       -0.00        0.00   100000.00   654576.00  1000000.00       -0.00       -0.00       -0.00
RO         1.00        4.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         7.00        0.00   100000.00   200000.00   400000.00   600000.00   800000.00  1000000.00       -0.00       -0.00
RQ         7.00    18000.00    21000.00    30000.00    40000.00   100000.00   300000.00   500000.00       -0.00       -0.00

CP         2.00    21000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID RESERVOIR B (CP 2)                                      -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         2.00        4.00         .10        3.10       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00


RL         3.00   100000.00       -0.00        0.00   100000.00   755408.00  1000000.00       -0.00       -0.00       -0.00
RO         1.00        4.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RS         7.00        0.00   100000.00   200000.00   400000.00   700000.00   800000.00  1000000.00       -0.00       -0.00
RQ         7.00    10000.00    12000.00    18000.00    30000.00    80000.00   150000.00   500000.00       -0.00       -0.00
R$         7.00        0.00     1000.00     5000.00    10000.00    20000.00    40000.00    60000.00       -0.00       -0.00

CP         3.00    12000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
ID RESERVOIR C (CP 3)                                      -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         3.00        4.00         .10        3.20       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00

CP         4.00    40000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00         .03        2.50
ID CP 4                                                    -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
RT         4.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
QS         4.00    10000.00    20000.00    30000.00    40000.00       -0.00       -0.00       -0.00       -0.00       -0.00
EL        12.00      300.00      350.00      450.00      500.00      550.00      600.00      625.00      650.00      700.00
EL       750.00      800.00      850.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
C$     40000.00     2000.00     4000.00     5000.00     6000.00       -0.00       -0.00       -0.00       -0.00       -0.00
DA         2.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00
DB         2.00      500.00     1000.00       -0.00       -0.00       -0.00       -0.00       -0.00       -0.00       [illegible]
```

DF	17.00	1.00	.90	.80	.70	.60	.50	.40	.30	.25
DF	.20	.15	.10	.05	.02	.01	.01	.00	-0.00	-0.00
DQ	17.00	28800.00	35000.00	42000.00	50500.00	60500.00	73000.00	90000.00	114000.00	130000.00
DQ	150000.00	180000.00	230000.00	323000.00	490000.00	640000.00	840000.00	1000000.00	-0.00	-0.00
DC	1.00	.05	.08	.10	.11	.14	.19	.29	.38	.48
DC	.60	.80	1.21	2.20	4.20	5.38	6.12	6.50	-0.00	-0.00
DC	2.00	.10	.17	.22	.30	.40	.52	.75	1.10	1.45
DC	1.90	2.80	4.90	9.80	12.20	13.32	14.17	14.66	-0.00	-0.00
ED	1.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

NRES= 3 NCPT= 4 NCPTR= -0

BF	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	6.00
FC	.30	1.00	1.50	2.00	3.00	4.00				

```
J1    NPER    IPER      NL     NL1     NLM    EPER   NLBUF  ILOCAL  INFLOW   IOPMP
        18       6       4       2       3      18       1       1      -0       1
J2   CNSTI   CFLOD  IFCAST  RATCHG   NFLWD  IPRINT  FLONAT  NOROUT   NCPTR   TRACE
       .30    1.00       4    1.00       1      38     -1.       0      -0     -0.
J3  METRIC   ECFCT    DATE  BCRFAC  COSFAC  IPRECN  IANDAM  ISCHED   IPRIO  IPLOTJ
         0 999.0057060618.     .03     .10      -0       1      -0      -0      -0
J5   NRDEL        PALSPA(I)
         1              3.

USER ID COMP ID     QMAX    RTFR    RTTO    RTMD      X       K     LAG    LQCP   RTLQ  QLAG  QMIND  QMINR

      1       1    6000.     1.      2.     .10    1.00  -0.000     -0      -0 -0.000   -0.    -0.    -0. RESERVOIR A (CP 1)

      2       2   21000.     2.      4.     .10    3.10  -0.000     -0      -0 -0.000   -0.    -0.    -0. RESERVOIR B (CP 2)

      3       3   12000.     3.      4.     .10    3.20  -0.000     -0      -0 -0.000   -0.    -0.    -0. RESERVOIR C (CP 3)

      4       4   40000.     4.      0.   -0.00   -0.00  -0.000     -0      -0 -0.000   -0.    -0.    -0. CP 4

USER ID COMP ID     STOR1   STORL-1      -2        -3        -4        -5       ISERV(M,K)=

     1       1     50000.        0.    50000.   150832.   200000.        0.        1       2

     2       2    100000.        0.   100000.   654576.  1000000.        0.        2       4

     3       3         0.        0.        0.        0.        0.        0.        3

RESERVOIR DATA

USER ID=       1   COMP ID=        1

RS   STORAGES=              0.     50000.     70000.    100000.    150832.    200000.
RQ   Q CAPACITIES=       5000.      6000.      7000.      8000.    100000.    200000.
RA   AREAS=                 0.         0.         0.         0.         0.         0.
RE   ELEVATIONS=            0.         0.         0.         0.         0.         0.
R1   START-STORAGE          0.         0.         0.         0.         0.         0.         0.         0.         0.
USER ID=       2   COMP ID=        2

RS   STORAGES=              0.    100000.    200000.    400000.    600000.    800000.   1000000.
RQ   Q CAPACITIES=      18000.     21000.     30000.     40000.    100000.    300000.    500000.
RA   AREAS=                 0.         0.         0.         0.         0.         0.         0.
RE   ELEVATIONS=            0.         0.         0.         0.         0.         0.         0.
R1   START-STORAGE          0.         0.         0.         0.         0.         0.         0.         0.         0.
USER ID=       3   COMP ID=        3

RS   STORAGES=              0.    100000.    200000.    400000.    700000.    800000.   1000000.
RQ   Q CAPACITIES=    1000000.   1000000.   1000000.   1000000.   1000000.   1000000.   1000000.
RA   AREAS=                 0.         0.         0.         0.         0.         0.         0.
RE   ELEVATIONS=            0.         0.         0.         0.         0.         0.         0.
R1   START-STORAGE          0.         0.         0.         0.         0.         0.         0.         0.         0.
ROUTING COEFFICIENTS FROM RES        1 TO MY
      MY=       2    1.0000
ROUTING COEFFICIENTS FROM RES        2 TO MY
      MY=       4     .3333      .3333      .3333
```

```
EXPECTED ANNUAL DAMAGE CALCULATIONS                                    TEST 10
USING FLOOD RATIOS OF .3,1.0,1.5,2.0,3.0,4.0
FONY RIVER BASIN

COMPUTATION INTERVAL IN HOURS=   6

                ***** FLOOD NUMBER  1 *****

          NFLRD=        1  NFLCON=       6
          IFLRD =       1  IFLCON=       1
              FLOWS MULTIPLIED BY      .300
```

```
                 UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	300.	900.	900.
2	600.	1500.	1800.
3	900.	2100.	8100.
4	5400.	7200.	18000.
5	6000.	12000.	31500.
6	6000.	21000.	23400.
7	6000.	10499.	18000.
8	6000.	14700.	13500.
9	6000.	21000.	9900.
10	6000.	21000.	7200.
11	6000.	21000.	5400.
12	6000.	21000.	3600.
13	4359.	21000.	3600.
14	2585.	21000.	2700.
15	2746.	21000.	1800.
16	3069.	5260.	900.
17	925.	1525.	600.
18	396.	846.	300.
SUM =	69280.	224530.	151200.
MAX =	6000.	21000.	31500.
MIN =	300.	846.	300.
MPER=	5.	6.	5.
AVG =	3849.	12474.	8400.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	2400.
2	3200.
3	8400.
4	11100.
5	19400.
6	34700.
7	40000.
8	40000.
9	34000.
10	33900.

```
11        34200.
12        36000.
13        30300.
14        27300.
15        25500.
16        19053.
17        11362.
18         3794.

  SUM = 414608.

  MAX =  40000.

  MIN =   2400.

  MPER=      8.

  AVG =  23034.

COMPUTATION INTERVAL IN HOURS=   6

                ***** FLOOD NUMBER  2 *****

             NFLRD=        1  NFLCON=        6
             IFLRD =       1  IFLCON=        2
                FLOWS MULTIPLIED BY      1.000
```

```
                UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	1000.	3000.	3000.
2	2000.	5000.	6000.
3	3000.	0.	27000.
4	0.	0.	60000.
5	6000.	0.	105000.
6	6000.	0.	78000.
7	6000.	0.	60000.
8	6000.	0.	45000.
9	6000.	0.	33000.
10	6000.	0.	24000.
11	6000.	0.	18000.
12	6000.	0.	12000.
13	6000.	21000.	12000.
14	6000.	21000.	9000.
15	6000.	21000.	6000.
16	6000.	21000.	3000.
17	6000.	21000.	2000.
18	6000.	21000.	1000.
SUM =	90000.	134000.	504000.
MAX =	6000.	21000.	105000.
MIN =	0.	0.	1000.
MPER=	5.	13.	5.
AVG =	5000.	7444.	28000.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	8000.
2	10667.
3	25667.
4	26667.
5	41000.
6	71000.
7	85000.
8	82000.
9	62000.
10	50000.

```
 11        44000.
 12        50000.
 13        38000.
 14        35000.
 15        36000.
 16        32000.
 17        28000.
 18        25167.

   SUM = 750167.

   MAX =  85000.

   MIN =   8000.

   MPER=      7.

   AVG =  41676.

COMPUTATION INTERVAL IN HOURS=    6

                 ***** FLOOD NUMBER   3 *****

               NFLRD=        1  NFLCON=        6
               IFLRD =       1  IFLCON=        3
                  FLOWS MULTIPLIED BY      1.500
```

```
                UNITS OF OU PUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS=IN KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	1500.	4500.	4500.
2	3000.	7499.	9000.
3	4500.	0.	40500.
4	6000.	0.	90000.
5	6000.	0.	157500.
6	6000.	0.	117000.
7	6000.	0.	90000.
8	33658.	0.	67500.
9	30000.	0.	49500.
10	24000.	0.	36000.
11	6000.	0.	27000.
12	6000.	0.	18000.
13	6000.	0.	18000.
14	6000.	21000.	13500.
15	6000.	21000.	9000.
16	6000.	21000.	4500.
17	6000.	21000.	3000.
18	6000.	21000.	1500.
SUM =	168658.	116999.	756000.
MAX =	33658.	21000.	157500.
MIN =	1500.	0.	1500.
MPER=	8.	14.	5.
AVG =	9370.	6500.	42000.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	12000.
2	16000.
3	38500.
4	40000.
5	61500.
6	106500.
7	127500.
8	123000.
9	93000.
10	75000.

```
   11        66000.
   12        75000.
   13        46500.
   14        38500.
   15        36500.
   16        37500.
   17        31500.
   18        27250.

     SUM =1051749.

     MAX = 127500.

     MIN =  12000.

     MPER=       7.

     AVG =  58430.

COMPUTATION INTERVAL IN HOURS=   6

                  ***** FLOOD NUMBER  4 *****

             NFLRD=         1  NFLCON=         6
             IFLRD =        1  IFLCON=         4
                FLOWS MULTIPLIED BY      2.000
```

UNITS OF OUTPUT

```
ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	2000.	0.	6000.
2	0.	0.	12000.
3	6000.	0.	54000.
4	6000.	0.	120000.
5	6000.	0.	210000.
6	6000.	0.	156000.
7	76658.	0.	120000.
8	70658.	0.	90000.
9	64658.	21000.	66000.
10	6000.	21000.	48000.
11	0.	21000.	36000.
12	0.	21000.	24000.
13	6000.	21597.	24000.
14	683.	30683.	18000.
15	2000.	20000.	12000.
16	2000.	8000.	6000.
17	2000.	21000.	4000.
18	4306.	21000.	2000.
SUM =	260964.	206280.	1008000.
MAX =	76658.	30683.	210000.
MIN =	0.	0.	2000.
MPER=	7.	14.	5.
AVG =	14498.	11460.	56000.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	10000.
2	14000.
3	46000.
4	50000.
5	82000.
6	142000.
7	170000.
8	164000.
9	131000.
10	114000.

```
11       109000.
12       121000.
13        83199.
14        66427.
15        54093.
16        41561.
17        30333.
18        25000.

   SUM =1453613.

   MAX = 170000.

   MIN =  10000.

   MPER=       7.

   AVG =  80756.

COMPUTATION INTERVAL IN HOURS=   6

                 ***** FLOOD NUMBER  5 *****

               NFLRD=        1  NFLCON=        6
               IFLRD =       1  IFLCON=        5
                  FLOWS MULTIPLIED BY      3.000
```

```
                    UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-IN KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	3000.	0.	9000.
2	6000.	0.	18000.
3	6000.	0.	81000.
4	6000.	0.	180000.
5	6000.	21000.	315000.
6	78658.	21000.	234000.
7	116761.	21000.	180000.
8	114239.	21000.	135000.
9	63032.	170275.	99000.
10	35968.	193808.	72000.
11	15000.	178779.	54000.
12	12000.	106418.	36000.
13	9000.	81000.	36000.
14	6000.	51000.	27000.
15	3000.	30000.	18000.
16	3000.	12000.	9000.
17	3000.	14999.	6000.
18	3921.	21000.	3000.
SUM =	490579.	943279.	1512000.
MAX =	116761.	193808.	315000.
MIN =	3000.	0.	3000.
MPER=	7.	10.	5.
AVG =	27254.	52404.	84000.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	15000.
2	21000.
3	69000.
4	75000.
5	130000.
6	227000.
7	276000.
8	267000.
9	256758.
10	278361.

```
11      312954.
12      309668.
13      215066.
14      142473.
15       99000.
16       64000.
17       40000.
18       28500.

  SUM =2826779.

  MAX = 312954.

  MIN =  15000.

  MPER=      11.

  AVG = 157043.

COMPUTATION INTERVAL IN HOURS=   6

                    ***** FLOOD NUMBER  6 *****

             NFLRD=        1  NFLCON=       6
             IFLRD =       1  IFLCON=       6
                FLOWS MULTIPLIED BY     4.000
```

```
                    UNITS OF OUTPUT

ALL FLOWS IN CFS OR CMS
EVAPORATION AND STORAGES IN ACRE FEET OR 1000 CU METERS
ELEVATIONS IN FEET OR METERS
POWER IN 1000 KWH EXCEPT WHEN IPER LE 24 HOURS-I. KWH
```

RESERVOIR RELEASES BY PERIOD

RES NO	1	2	3
CHAN CAP	6000.	21000.	12000.
MIN DES Q	-1.	-1.	-1.
MIN REQ Q	-1.	-1.	-1.
PERIOD			
1	6000.	0.	12000.
2	6000.	0.	24000.
3	6000.	0.	108000.
4	6000.	21000.	240000.
5	16658.	21000.	420000.
6	122795.	21000.	312000.
7	163830.	21000.	240000.
8	157239.	184074.	180000.
9	112135.	291604.	132000.
10	52000.	303709.	96000.
11	20000.	266473.	72000.
12	16000.	216218.	48000.
13	12000.	173250.	48000.
14	8000.	74951.	36000.
15	4000.	40000.	24000.
16	4000.	16000.	12000.
17	4000.	12000.	8000.
18	4000.	21000.	4000.
SUM =	720658.	1683280.	2016000.
MAX =	163830.	303709.	420000.
MIN =	4000.	0.	4000.
MPER=	7.	10.	5.
AVG =	40037.	93516.	112000.

REGULATED FLOWS AT CONTROL POINTS BY PERIOD

C.P. NO.	4
CHAN CAP	40000.
MIN DES Q	-1.
MIN REQ Q	-1.
PERIOD	
1	20000.
2	28000.
3	92000.
4	107000.
5	178000.
6	305000.
7	361000.
8	403358.
9	413559.
10	459796.

11	463262.
12	462133.
13	342647.
14	238806.
15	156067.
16	87650.
17	50667.
18	33000.

SUM =4201946.

MAX = 463262.

MIN = 20000.

MPER= 11.

AVG = 233441.

FLOOD SUMMARY-EACH FLOOD COPY= 1

EXPECTED ANNUAL DAMAGE CALCULATIONS TEST 10
USING FLOOD RATIOS OF .3,1.0,1.5,2.0,3.0,4.0
FONY RIVER BASIN

***** FLOOD NUMBER 1 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE INDEX DES	REQ
LOC	4 CP 4	1.008	40000. *	1.008	61200. *	1.007	25500. *	14500. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1 RESERVOIR A (CP 1)	1.004	50000.	2.000 *	1.008	61305	2.112 *	1.005	6000	6000	50000
LOC	2 RESERVOIR B (CP 2)	1.018	100000.	2.000 *	1.009	125736	2.046 *	1.006	21000	21000	100000
LOC	3 RESERVOIR C (CP 3)	1.018	0.	2.000 *	1.001	0	2.000 *	1.005	31500	12000	0

MIN SYSTEM STG= 150000 MAX SYSTEM STG= 187041

***** FLOOD NUMBER 2 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE INDEX DES	REQ
LOC	4 CP 4	2.007	85000. *	2.008	204000. *	2.007	85000. *	0. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1 RESERVOIR A (CP 1)	2.003	50000.	2.000 *	2.010	134794	2.841 *	2.005	6000	6000	50000
LOC	2 RESERVOIR B (CP 2)	2.002	100000.	2.000 *	2.013	356863	2.463 *	2.013	21000	21000	100000
LOC	3 RESERVOIR C (CP 3)	2.018	0.	2.000 *	2.001	0	2.000 *	2.005	105000	12000	0

MIN SYSTEM STG= 150000 MAX SYSTEM STG= 491657

***** FLOOD NUMBER 3 *****

		FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE INDEX DES	REQ
LOC	4 CP 4	3.007	127500. *	3.008	306000. *	3.007	127500. *	0. *	0.00	0.00

	RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1 RESERVOIR A (CP 1)	3.003	50000.	2.000 *	3.008	150832	3.000 *	3.008	33658	6000	50000

LOC	2	RESERVOIR B (CP 2)	3.001	100000.	2.000 *	3.014	528763	2.773 *	3.014	21000	21000	100000
LOC	3	RESERVOIR C (CP 3)	3.018	0.	2.000 *	3.001	0	2.000 *	3.005	157500	12000	0

MIN SYSTEM STG= 150000 MAX SYSTEM STG= 679595

***** FLOOD NUMBER 4 *****

			FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	4	CP 4	4.007	170000. *	4.008	408000. *	4.007	170000. *	0. *	0.00	0.00

		RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1	RESERVOIR A (CP 1)	4.001	50000.	2.000 *	4.007	150832	3.000 *	4.007	76658	6000	50000
LOC	2	RESERVOIR B (CP 2)	4.001	102975.	2.005 *	4.013	654576	3.000 *	4.014	30683	21000	100000
LOC	3	RESERVOIR C (CP 3)	4.018	0.	2.000 *	4.001	0	2.000 *	4.005	210000	12000	0

MIN SYSTEM STG= 152975 MAX SYSTEM STG= 805408

***** FLOOD NUMBER 5 *****

			FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	4	CP 4	5.011	312954. *	5.008	612000. *	5.007	255000. *	57954. *	0.00	0.00

		RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1	RESERVOIR A (CP 1)	5.002	50000.	2.000 *	5.007	167314	3.335 *	5.007	116761	6000	50000
LOC	2	RESERVOIR B (CP 2)	5.001	104463.	2.008 *	5.009	695751	3.119 *	5.010	193808	21000	100000
LOC	3	RESERVOIR C (CP 3)	5.018	0.	2.000 *	5.001	0	2.000 *	5.005	315000	12000	0

MIN SYSTEM STG= 154462 MAX SYSTEM STG= 863065

***** FLOOD NUMBER 6 *****

			FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	SHORTAGE DES	INDEX REQ
LOC	4	CP 4	6.011	463262. *	6.008	816000. *	6.007	340000. *	123262. *	0.00	0.00

		RESERVOIRS	FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP	STOR1
LOC	1	RESERVOIR A (CP 1)	6.001	49008.	1.980 *	6.007	191183	3.821 *	6.007	163829	6000	50000

LOC	2	RESERVOIR B (CP 2)	6.001	106942.	2.013 *	6.009	816529	3.469 *	6.010	303708	21000	100000
LOC	3	RESERVOIR C (CP 3)	6.018	0.	2.000 *	6.001	0	2.000 *	6.005	420000	12000	0
		MIN SYSTEM STG=		155950	MAX SYSTEM STG=		1007712					

COPY= 1

***** MAX VALUES FOR MULTY FLOODS *****

			FLD.PER	MAX REG Q *	FLD.PER	MAX NAT Q *	FLD.PER	MAX LOC Q *	Q BY RES *	WEIGHTED SHORTAGE DES	INDEX REQ
LOC	4	CP 4	6.011	463262. *	6.008	816000. *	6.007	340000. *	123262. *		

RESERVOIRS			FLD.PER	MIN STG	MIN LEVEL *	FLD.PER	MAX STG	MAX LEVEL *	FLD.PER	MAX REL	CHAN CAP
LOC	1	RESERVOIR A (CP 1)	6.001	49008.	1.980 *	6.007	191183	3.821 *	6.007	163829	6000
LOC	2	RESERVOIR B (CP 2)	3.001	100000.	2.000 *	6.009	816529	3.469 *	6.010	303708	21000
LOC	3	RESERVOIR C (CP 3)	6.018	0.	2.000 *	6.001	0	2.000 *	6.005	420000	12000

EXPECTED ANNUAL FLOOD DAMAGE SUMMARY
CONTROL POINT NUMBER 4

BASE CONDITION FREQUENCY-FLOW-DAMAGE DATA

FREQ	PEAK	SUM	TYPE 1	TYPE 2	TYPE
.9990	28800.	149.85	49.95	99.90	
.9000	35000.	249.75	79.92	169.83	
.8000	42000.	319.68	99.90	219.78	
.7000	50500.	409.59	109.89	299.70	
.6000	60500.	539.46	139.86	399.60	
.5000	73000.	709.29	189.81	519.48	
.4000	90000.	1038.96	289.71	749.25	
.3000	114000.	1478.52	379.62	1098.90	
.2500	130000.	1928.07	479.52	1448.55	
.2000	150000.	2497.50	599.40	1898.10	
.1500	180000.	3596.40	799.20	2797.20	
.1000	230000.	6103.89	1208.79	4895.10	
.0500	323000.	11988.00	2197.80	9790.20	
.0200	490000.	16383.60	4195.80	12187.80	
.0100	640000.	18681.30	5374.62	13306.68	
.0050	840000.	20269.71	6113.88	14155.83	
.0020	1000000.	21138.84	6493.50	14645.34	

EXPECTED ANNUAL DAMAGES	SUM	TYPE 1	TYPE 2
BASE COND-COMPUTED	2206.91	523.61	1683.31
BASE COND- INPUT	0.00	-0.00	-0.00
EXIST SYSTEM-INPUT	1500.00	500.00	1000.00

BASE CONDITION FLOOD DAMAGES

NO.	FLOW	EXCD FREQ	PROB INT	SUM	TYPE 1	TYPE 2	TYPE
1	61200.	.594	.642	326.82	91.11	235.71	
2	204000.	.123	.269	728.27	165.94	562.33	
3	306000.	.056	.046	443.59	83.55	360.04	
4	408000.	.031	.022	316.22	70.92	245.30	
5	612000.	.011	.013	219.25	59.74	159.50	
6	816000.	.006	.008	172.76	52.33	120.43	

	SUM	TYPE 1	TYPE 2
BASE COND DAMAGES	2206.91	523.61	1683.31
EXST SYST DAMAGES	1500.00	500.00	1000.00

MODIFIED CONDITIONS FLOW-DAMAGE DATA

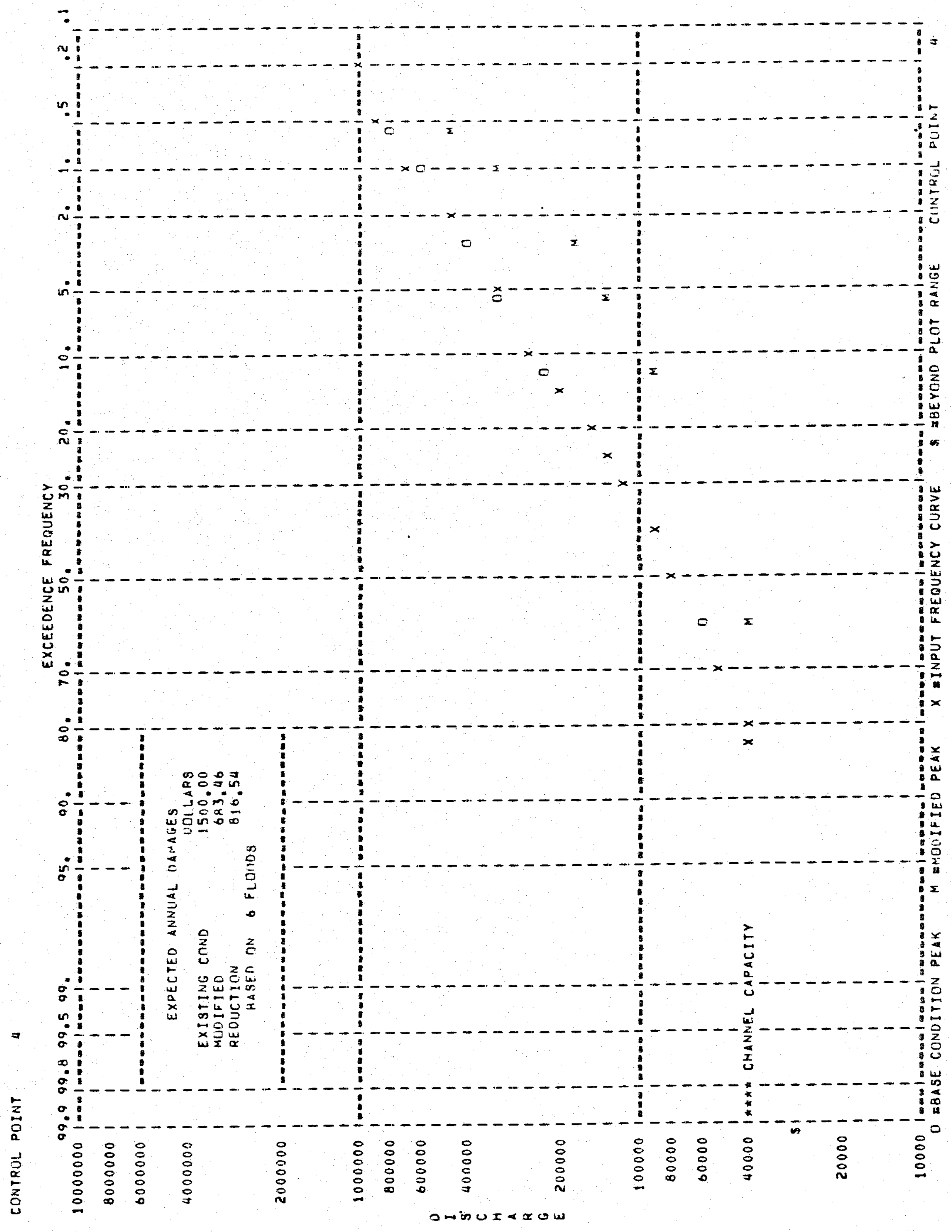
FREQ	PEAK	SUM	TYPE 1	TYPE 2	TYPE
.9990	28800.	0.00	0.00	0.00	
.8268	40000.	299.70	94.19	205.51	
.8000	42000.	319.68	99.90	219.78	
.7000	50500.	409.59	109.89	299.70	
.6000	60500.	539.46	139.86	399.60	
.5000	73000.	709.29	189.81	519.48	
.4000	90000.	1038.96	289.71	749.25	
.3000	114000.	1478.52	379.62	1098.90	
.2500	130000.	1928.07	479.52	1448.55	
.2000	150000.	2497.50	599.40	1898.10	
.1500	180000.	3596.40	799.20	2797.20	
.1000	230000.	6103.89	1208.79	4895.10	
.0500	323000.	11988.00	2197.80	9790.20	
.0200	490000.	16383.60	4195.80	12187.80	
.0100	640000.	18681.30	5374.62	13306.68	
.0050	840000.	20269.71	6113.88	14155.83	
.0020	1000000.	21138.84	6493.50	14645.34	

MODIFIED CONDITIONS FLOOD DAMAGES

NO.	FLOW	EXCD FREQ	PROB INT	SUM	TYPE 1	TYPE 2	TYPE
1	40000.	.594	.642	86.68	24.91	61.77	
2	85000.	.123	.269	184.29	49.29	135.00	
3	127500.	.056	.046	76.39	19.35	57.04	
4	170000.	.031	.022	75.71	16.88	58.82	
5	312954.	.011	.013	112.03	21.63	90.41	
6	463262.	.006	.008	148.35	40.64	107.71	
	MODIFIED DAMAGES			683.46	172.71	510.75	
	DAMAGE REDUCTION			816.54	327.29	489.25	

UNCONTROLLED LOCAL FLOW FLOOD DAMAGES

NO.	FLOW	EXCD FREQ	PROB INT	SUM	TYPE 1	TYPE 2	TYPE
1	25500.	.594	.642	5.06	1.59	3.47	
2	85000.	.123	.269	157.62	42.96	114.66	
3	127500.	.056	.046	76.39	19.35	57.04	
4	170000.	.031	.022	71.92	16.26	55.66	
5	255000.	.011	.013	81.93	16.09	65.85	
6	340000.	.006	.008	111.08	23.80	87.29	
	DAMAGES W/ TOTAL CONTROL AT PROJECTS			504.00	120.04	383.96	
	REDUCTION POSSIBLE W/ TOTAL CONTROL			996.00	379.96	616.04	
	RESIDUAL DAMAGES			179.45	52.67	126.78	


CONTROL POINT 4
EXCEEDENCE FREQUENCY
99.9 99.8 99.5 99. 95. 90. 80. 70. 50. 30. 20. 10. 5. 2. 1. .5 .2 .1
DISCHARGE
10000000 8000000 6000000 4000000 2000000 1000000 800000 600000 400000 200000 100000 80000 60000 40000 20000 10000
EXPECTED ANNUAL DAMAGES
DOLLARS
EXISTING COND 1500.00
MODIFIED 683.46
REDUCTION 816.54
BASED ON 6 FLOODS
**** CHANNEL CAPACITY
O =BASE CONDITION PEAK M =MODIFIED PEAK X =INPUT FREQUENCY CURVE $ =BEYOND PLOT RANGE CONTROL POINT 4

SUMMARY OF SYSTEM'S EXPECTED ANNUAL FLOOD DAMAGES

CONTROL POINT	DAMAGES: BASE (EXIST) CONDITION	DAMAGES: MODIFIED CONDITIONS	DAMAGES: UNCONTROL LOCAL COND	DAMAGE REDUCTION: MODIFIED CONDITIONS	DAMAGE REDUCTION: TOTAL CONTROL AT PROJECTS	DAMAGE REDUCTION: RESIDUAL
4	1500,00	683,46	504,00	816,54	996,00	179,45
TOTAL	1500,00	683,46	504,00	816,54	996,00	179,45

SUMMARY OF SYSTEM COSTS

CONTROL POINT	PROJECT TYPE	CAPITAL COST	ANNUAL O,M,&R COST	TOTAL ANNUAL COST
1.	RESERVOR	7600.00	152.00	380.00
4.	LOCAL	600.00	15.00	30.00

SYSTEM ECONOMIC COST AND PERFORMANCE SUMMARY
(EXCLUSIVE OF EXISTING SYSTEM COSTS)

TOTAL SYSTEM CAPITAL COST * * * * * * *	8200.00	
TOTAL SYSTEM ANNUAL OPERATING MAINTENANCE, AND REPAIR COST * * * *	167.00	
TOTAL SYSTEM ANNUAL COST * * * * * * *		410.00
EXPECTED ANNUAL DAMAGES - EXISTING SYSTEM	1500.00	
EXPECTED ANNUAL DAMAGES - PROPOSED SYSTEM	683.46	
EXPECTED ANNUAL DAMAGE REDUCTION		816.54
EXPECTED ANNUAL SYSTEM NET DAMAGE REDUCTION BENEFITS		406.54

SUMMARY OF SYSTEM COSTS

CONTROL POINT	PROJECT TYPE	CAPITAL COST	ANNUAL O,M,&R COST	TOTAL ANNUAL COST
1.	RESERVOR	7600.00	152.00	380.00
4.	LOCAL	600.00	15.00	30.00

SYSTEM ECONOMIC COST AND PERFORMANCE SUMMARY
(EXCLUSIVE OF EXISTING SYSTEM COSTS)

TOTAL SYSTEM CAPITAL COST * * * * * * *	8200.00	
TOTAL SYSTEM ANNUAL OPERATING MAINTENANCE, AND REPAIR COST * * * *	167.00	
TOTAL SYSTEM ANNUAL COST * * * * * * *		410.00
EXPECTED ANNUAL DAMAGES - EXISTING SYSTEM	1500.00	
EXPECTED ANNUAL DAMAGES - PROPOSED SYSTEM	683.46	
EXPECTED ANNUAL DAMAGE REDUCTION		816.54
EXPECTED ANNUAL SYSTEM NET DAMAGE REDUCTION BENEFITS		406.54

```
****************************************************************************************************************************
          COMPUTER CHECK FOR POSSIBLE ERRORS

                        ***** FLOOD NUMBER  1 *****
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50

                        ***** FLOOD NUMBER  2 *****
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50

                        ***** FLOOD NUMBER  3 *****
RATE/CHANGE ERROR,RES=        1 PER=       11
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50

                        ***** FLOOD NUMBER  4 *****
RATE/CHANGE ERROR,RES=        1 PER=       10
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50

                        ***** FLOOD NUMBER  5 *****
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50

                        ***** FLOOD NUMBER  6 *****
POSSIBLE ERRORS FOUND=        0 ALLOWABLE ERROR CHECK=      50
****************************************************************************************************************************

** CASE=X,Y, WHERE X=CONTROLLING LOCATION AND Y=NUMBER FUTURE PERIOD CONTROLLING
EXCEPT WHEN X=0
THEN, TYPE OF RELEASE IS BASED ON RESERVOIR ITSELF,Y=
     Y=00 MINIMUM DESIRED FLOW WAS RELEASED
     Y=01 MAXIMUM RESERVOIR RELEASE
     Y=02 BASED ON MAX RATE OF CHANGE
     Y=03 BASED ON NOT DRAWING BELOW TOP CONSERVATION POOL
     Y=04 BASED ON NOT EXCEEDING TOP FLOOD POOL
     Y=05 BASED ON EQUAL LEVELS-TANDEM RESERVOIRS
     Y=06 BASED ON MAX RELEASE DUE TO OUTLET CAPACITY
     Y=07 BASED ON RELEASE FOR LEVEL 1
     Y=08 MINIMUM REQUIRED FLOW WAS RELEASED
     Y=09 BASED ON RELEASES FOR BUFFER LEVEL
     Y=10 BASED ON POWER DEMAND
     Y=11 MIN FLOW SINCE HIGHEST RES CANT RELEASE
     Y=99 RELEASE GIVEN ON QA CARD
```

EXHIBIT 4

OPERATING RULES USING RESERVOIR LEVELS

HEC-3; HEC-5C

Release priorities between reservoirs are an important reservoir operating criterion which must be specified for most system operations. To illustrate the technique used in computer programs HEC-3 and HEC-5C, the following example has been prepared. Assume the information shown below in Table 1 is known for each of four reservoirs which constitute a reservoir system. Figure 1 shows the various reservoir levels graphically.

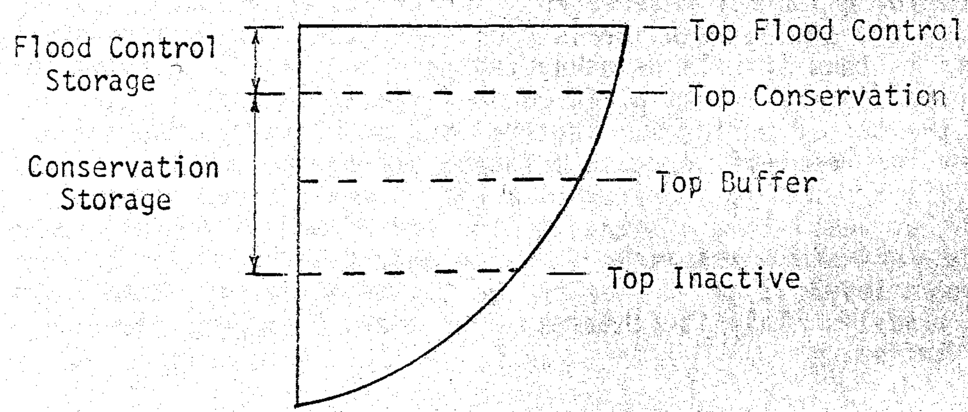
TABLE 1

Reservoir Storage Levels

Reservoir Number	Storages, Cumulative (ac-ft) Top Inactive	Top Buffer	Top Cons	Top FC
1	1,000	5,000	50,000	100,000
2	5,000	10,000	100,000	200,000
3	10,000	20,000	150,000	500,000
4	50,000	100,000	200,000	700,000

FIGURE 1

Reservoir Storage Levels



It is desired to operate this system according to the following:

1. Release all flood control storage to maintain the same degree of risk.

2. Release reservoir 1 conservation storage above top of buffer, first.

3. Next release reservoirs 2 and 3 conservation storage above top of buffer.

4. Next release reservoir 4 conservation storage above top of buffer.

5. Release conservation storage below top of buffer equally.

To specify these operating criteria in HEC-3 and HEC-5C, each storage level in each reservoir is assigned an integer number from 1 to a maximum of 8. The number of levels used is the minimum number required to specify the desired operating rules. In this example, six levels were found to be necessary. The lowest level, level 1, corresponds to the top of inactive pool; the highest level, level 6, corresponds to the top of flood control pool; see Table 2. The computer program makes releases from storage between the highest and next highest level until the water stored between these levels is exhausted, then it goes to the next lower level, and so on in descending order. All reservoirs with storage between the same successive pair of levels make releases where possible to maintain the same degree of risk. The specific criteria depends upon the system configuration.

Level 2 through 5, in this example, are assigned in such a way that the system operates as desired. Since operating rule 1 desires that all reservoirs release from flood control storage equally, by assigning level 5 to the top of conservation (bottom of flood control) for all reservoirs this rule is achieved. Operating rule 2 desires that all conservation storage from reservoir 1, above top of buffer, be released first. By assigning level 4 to the top of buffer for reservoir 1, and top of conservation for all other reservoirs this rule is achieved. This limits the available storage between levels 4 and 5 to the conservation storage in reservoir 1, thus it will be exhausted before water is released below level 4. Operating rule 3 is achieved in a similar manner, by assigning level 3 to the top of buffer for reservoirs 2 and 3 and to the top of conservation for reservoir 4. Conservation storage volume is provided between levels 3 and 4 for reservoirs 2 and 3, but not for reservoirs 1 and 4. Lastly, level 2 is assigned to the top of buffer for all reservoirs. This meets rule 4 since reservoir 4 is the only reservoir with storage volume between levels 2 and 3. Below the top of buffer all reservoirs are to release equally. This is achieved since level 2 for all reservoirs is the top of buffer.

TABLE 2

Assigned Storage Levels

Level 1	Res 1	Res 2	Res 3	Res 4
6	100,000	200,000	500,000	700,000
5	50,000	100,000	150,000	200,000
4	5,000	100,000	150,000	200,000
3	5,000	10,000	20,000	200,000
2	5,000	10,000	20,000	100,000
1	1,000	5,000	10,000	50,000

To summarize, Figure 2 shows the level numbers assigned to each reservoir level for each reservoir. These numbers and corresponding reservoir storage volumes are specified as input on the RL card. During simulation the system operates as follows: any water stored between levels 5 and 6 is released from each reservoir; when the water stored between levels 5 and 6 has all been released, water between levels 4 and 5 is released -- in this example only reservoir 1 has a storage volume between these levels; when the volume stored between 4 and 5 is exhausted, releases are made from storage between levels 3 and 4, this means from reservoirs 2 and 3; next storage between levels 2 and 3 is exhausted, hence, reservoir 4 releases are made from; and lastly storage between levels 1 and 2 is released. This technique for specifying reservoir operating rules has proved to be an effective way to handle most operating criteria.

FIGURE 2

Reservoir System Priority of Operation

Level	Res 1	Res 2	Res 3	Res 4
Top of Flood Control	6	6	6	6
Top of Conservation	5	4,5	4,5	3,4,5
Top of Buffer	2,3,4	2,3	2,3	2
Top of Inactive	1	1	1	1

EXHIBIT 5

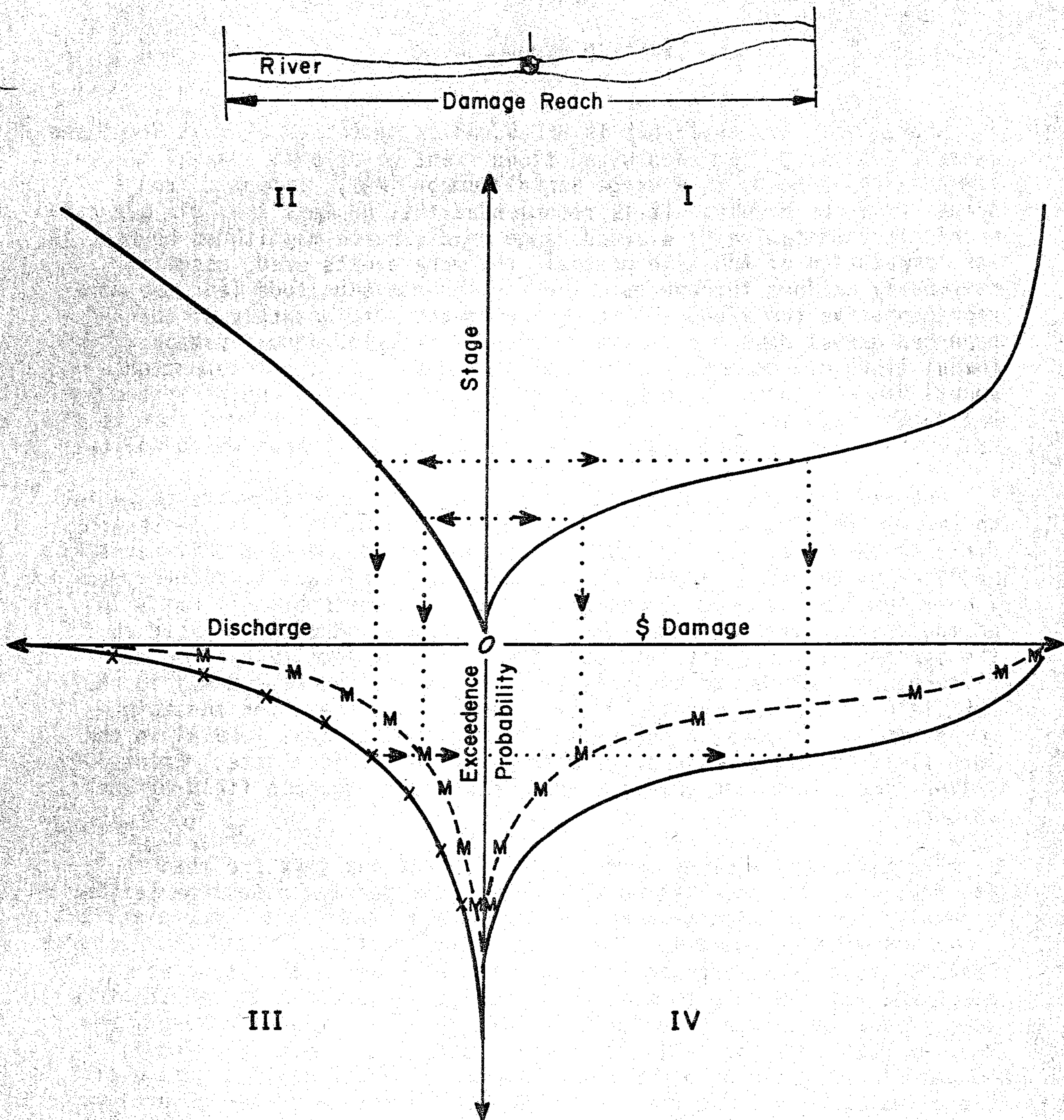
EXPECTED ANNUAL DAMAGE

1. Subroutines are available in HEC-5C which permit an evaluation of the damages resulting from each given flood event or expected annual damage, commonly referred to as average annual damage (AAD), computed from a number of flood events. It is recommended that no less than six separate events representative of a broad range of discharge magnitudes be used in the computation of AAD. In general, the more events used, assuming reasonably uniform increments between discharge magnitude (and the more representative the flood volumes), the greater the accuracy of the expected annual damage estimate obtained. Expected annual damage computations are then compared with input data relating to expected annual project costs to compute and summarize expected annual system net damage reduction benefits. The procedures and techniques used to calculate these estimates are discussed in the paragraphs which follow.

2. The required input data and options relating to damage are contained on the DA, DB, DF, DQ, and DC cards as modified by ECFCT in the second field of the J3 card. Cost data are contained on the R$ and C$ cards as modified by COSFAC in field 5 of the J3 card. The capital recovery factor (BCRFAC) is used to convert the present worth project costs to an equivalent average annual cost of the capital investment based on the appropriate interest rate and life of the project. This can be different for different projects by inputting values of (CRFAC) in the 9th field of the applicable CP card. The annual operation and maintenance cost is input as a percentage of the capital cost (OMPER) in the 10th field of the CP card corresponding to the project site. Print options for the damage analysis are contained in the 6th field of the J3 card.

3. The basic assumptions in the damage or AAD analysis are that (1) damage is a single valued function of the maximum discharge (either regulated, unregulated or uncontrolled local), and (2) a flood event has a fixed exceedence frequency that is a unique function of maximum discharge. Damages are often expressed as a function of stage but a stage vs discharge relationship must be used outside the program to convert this to a discharge-damage relationship. The computer program converts the related data from the fields of the DF card (exceedence frequency), DQ card (corresponding discharge), and DC cards (associated damage of specified category) and develops a damage-exceedence frequency array. The integration of this array or curve represents the expected annual damage for one condition of discharge, either unregulated, local project improvement, etc. A graphical schematic presentation of this is shown in Figure 5-01.

Index or control point representative of discharge in the damage reach



LEGEND

× Eight index flood events; unregulated discharge.

M **Modified by flood control reservoir regulation.**

Figure 5-01

4. The integration routine for estimating the area inside the quadrant IV damage-probability curve shown in Figure 5-01 is accomplished for natural (unregulated) conditions by subdividing the input frequency array into probability increments ranging from 1 percent to .05 percent (about 120 segments in total) depending on the part of the curve being defined. Discharges for each segment are interpolated logarithmically using the input discharge-frequency data. Damages are determined for each segment by a linear interpolation of the input discharge-damage data using the derived discharge for each segment. If the largest value of discharge (DQ card) has an exceedence probability greater than .001, the last two given discharge-frequency values are used to extrapolate estimated probabilities to the .001 annual exceedence probability (1,000-year event). The accumulated product of exceedence probability increment (difference between two adjacent probabilities) and damage becomes the estimate of natural (unregulated) expected annual damage. The modified conditions discharge frequency curve, reflecting the effect of flood control storage, is developed from the peak discharge for each flood by assigning the regulated maximum discharge the same exceedence probability as its unregulated counterpart. The modified flow value for each probability increment is obtained by logarithmic interpolation of the ratio of modified to natural discharge of adjacent index floods and applying this ratio to the unregulated discharge value. If the smallest regulated index flood event is below channel capacity and causes damage, the lower end of the modified frequency curve is extrapolated to non-damaging discharge based on the two lowest flood events. If the smallest regulated flood event is above channel capacity the modified frequency curve is extrapolated (using last two flood events) to channel capacity and then follows channel capacity to the unregulted curve. If the largest regulated event has an exceedence probability greater than .001, (discharge is less than a 1000 year flood), the outer end of the regulated curve is extrapolated to converge on the unregulated curve (no reduction) at the .001 probability. The damage analysis is ended at the .001 probability unless flood values beyond this point are input. Subtraction of the regulated expected annual damage from the unregulated expected annual damage provides the AAD reduction. If an existing project has previously been evaluated, establishing a base condition against which future projects are to be compared, this base condition expected annual damage value can be input on the DB cards and all current comparisons will be computed from this existing condition input.

5. If a local protection project such as a levee is to be evaluated, the design discharge can be input in the first field of the C$ card and the damages resulting from all discharges smaller than or equal to the design discharge are set to zero. If the discharge-damage relation is significantly changed by the project, e.g., channel enlargement, a second set of DC cards may be input. Then, each damage category would have two sets of DC cards representing preproject and local project conditions.

6. The following data are displayed in the printer output as requested (J3.6) for unregulated, regulated (modified) and uncontrolled local conditions: input data, maximum discharge and exceedence probability for each index flood, probability increment assigned to each flood, weighted annual damage by category, and total annual damage. The discharge frequency curves are plotted if desired and the project costs as well as expected annual net damage reduction (benefits) are summarized. If the DA.1 field is negative, the estimated damage for one or more flood events will be computed by table lookup rather than computing expected annual damage. Exhibit 3, Test Problem 10, is an example problem with economic input and output.

EXHIBIT 6

DESCRIPTION OF PROGRAM OUTPUT

The sequence of possible output from the program is (1) printout of input data, (2) computation of incremental local flows, (3) results of system operations arranged by downstream sequence of control points, (4) results of reservoir operation arranged by sequence of time periods, (5) summary of releases from reservoirs and actual flow at all other control points, arranged by period, (6) user designed output based on J8 card input, (7) plotted hydrographs at specified control points, (8) summary of flooding occurring during each flood event, (9) summary of averages for all reservoirs, (10) flood event summaries for multiflood events, (11) economic input data and damage computation, (12) summary of damages or average annual damages, system costs and net benefits, (14) summary of discharge and stage reduction at each nonreservoir control point for each flood event, (15) computer check for possible errors, and (16) listing of case designations defining reservoir releases. A detailed description of the items that appear in the output is given below.

a. Printout of Input Data. The information on data cards T1-EJ is printed out as coded. Flow data cards are only listed if requested. Basic system data are recapitulated in a labeled summary of input data. Included in the summary are (1) the labeled job card information, including default values in cases where values are not specified; (2) linking of control points with routing data and data from CP and ID cards; (3) reservoir storages for each level and the reservoir operation points; (4) reservoir data tables for storages, outlet capacities, areas, elevations, diversions, and starting storages; (5) diversion data if used; and (6) routing coefficients from reservoirs to operating control points.

b. Incremental Local Flow. If incremental local flows are being computed (from natural or observed data), the observed and routed flows can be shown for all control points. Data labeled "Incremental Local Flows Computed" are listed twice for each control point. The first group shows the computed values obtained by subtracting the sum of the upstream routed hydrographs from the observed or natural hydrograph and the second group shows the adjusted values. The adjustment is made to eliminate any resulting negative local flows and to preserve the correct volume. All negative flows are set to zero and the negative volume is proportioned to the positive values.

Printer plots of the local flow hydrographs, if requested, are provided during the local flow calculations. Up to four hydrographs can be plotted. By priority, they are: routed, observed, local, and upstream inflow. The program logic sequence produces the computed local hydrograph for the control point immediately downstream from the control point where the plot was requested. Therefore, the user must request the plots for the control points just upstream from the points where the local flow hydrograph is desired.

c. Output Arranged by Sequence of Control Points. The output is preceded by a heading that identifies the flood event and provides a listing of the output units. The items in the heading are as follows:

FLOOD NUMBER - The basic flood event identifier, based on the sequence of floods input to, or generated by the program.

NFLRD - The number of flood events read for the job (J2.5). This would subsequently be the number of EJ cards in the input deck since each set of IN cards require an EJ card.

IFLRD - The sequence number of the flow series read (NFLRD) which is currently being printed out.

NFLCON - The number of flood ratios to be used (FC card) for the current flood event.

IFLCON - The sequence number of the ratio used (of NFLCON) for the current printout.

FLOWS MULTIPLIED BY - The ratio which is multiplied times all flows on IN cards for current output.

Next to the heading is a printout showing UNITS OF OUTPUT. All flows are in cubic feet per second (CFS) or cubic meters per second (CMS) and represent the average flow during a period. Evaporation and storages are in acre-feet or thousand cubic meters (1000 CU METERS). Elevations are in feet or meters. Power is in thousand kilowatt-hours (1000 KWH) unless the computation interval is less than or equal to 24 hours, then the output is in kilowatt-hours.

Following the heading the normal sequential program output is listed (if requested on J2 card) in the sequence the control points were read (downstream order). The printed output for each of the following items is for all periods with 10 or 12 periods per line of output. When the time interval used is 720 hours as in conservation analysis, the output is 12 periods per line instead of 10. The average, maximum, and minimum values are also provided for all of the output variables.

(1) Control Point Identification

Example 1

```
*** LOC 6 RESERVOIR A - SERVED BY 5,6
                        SERVING 6, 15, 16, 18
```

The control point identified as 6, which is a reservoir, is being operated for control points 6, 15, 16, and 18. The reservoir 6 is itself being served by an upstream reservoir (number 5) as well as by itself.

Example 2

*** LOC 18 ROSSER GAGE SERVED BY 1, 2, -3, 4, -5, 6, 7

The control point identified as 18 is a control point (not a reservoir) and has the following reservoirs upstream from it: 1, 2, 3, 4, 5, 6, and 7. The upstream reservoirs 3 and 5 (indicated by negative numbers) are not being operated for location 18.

R,C (2) CUM LOCAL FLOW - The cumulative local flow for each period is the flow above the current control point and below all upstream reservoirs that have at least one acre-foot (or 1,000 cubic meters) of flood control storage.

R,C (3)[1] NATURAL FLOW - The flow that would occur without any reservoirs in the basin. The calculation and output of natural flows is an optional program feature.

R (4)[1] POWER REQUIRED - The power requirements at the reservoir as defined by input. Units of output are 1000 KWH unless the time interval is 24 hours or less.

R (5)[1] POWER GENERATED - The power generated by the reservoir, in 1000 KWH unless time periods are 24 hours or less.

R (6)[1] POW. SHORTAGE - The difference between Power Required and Power Generated. Units of output would be the same as (4) and (5).

R,C (7)[1] MIN DESIRED Q - The minimum desired flow at the current control point, i.e., demand to be met as long as reservoirs are above top of buffer pool.

R,C (8)[1] SHORTAGE - The amount by which regulated flow at the current control point falls short of the minimum desired flow.

R,C (9)[1] MIN REQUIRED Q - The minimum required flow at the current control point, i.e., demand to be met as long as reservoirs are above level 1.

R,C (10)[1] SHORTAGE - The amount by which regulated flow at the current control point falls short of the minimum required flow.

R,C Output for both reservoirs and nonreservoir control points.
R Output for reservoir only.
1 Output will be omitted if input data is omitted.

R,C (11)[1] DIVERSION - The algebraic sum of all diversions from the control point (positive) or to the control point (negative). The regulated flow at the control point or inflow into the reservoir includes the effects of the diversions both from and to the control point.

R (12) INFLOW - The inflow hydrograph to a reservoir. The inflow values are equal to the cumulative local flows plus the routed upstream reservoir releases minus any diversions at the reservoir or upstream points.

C (13)[1] CHANNEL CAPACITY - When channel capacity varies at a control point (CC card is used) the channel capacity is shown for each time period.

C (14) REGULATED FLOW - The simulated flow at a control point based on local inflow, upstream reservoir releases, and diversions from and to the control point.

R (15) OUTFLOW - The average reservoir outflow.

R (16) CASE = LOC.TYP - The reason for making the reservoir release is shown for each time period as a two-part code such as 9.1 or 18.3.

The number to the left of the decimal indicates the downstream controlling location. If the controlling location is the reservoir itself no number will be printed to the left of the decimal. The number to the right of the decimal, when operating for a downstream location, is the number of time periods in the future at the downstream control point. For example, the 18.3 indicates that the flow 3 periods ahead at control point 18 was used to determine the final reservoir release. When there is no number to the left of the decimal, the number on the right indicates the following.

00 Release was governed by minimum desired flow requirements.

01 Release was constrained by channel capacity at the reservoir.

02 The release was governed by the maximum permitted rate-of-change from the preceding release.

03 The release was calculated to exactly empty flood control storage.

04 The release was made to eliminate or minimize storage of water above the top of the flood control pool.

R,C Output for both reservoirs and nonreservoir control points.
R Output for reservoir only.
C Output for nonreservoir control point only.
1 Output will be omitted if input data is omitted.

05 The release was made to bring the reservoir into balance with a downstream tandem reservoir.

06 The release was constrained by the outlet capacity.

07 The release was based on LEVEL 1 limitation (top of inactive storage).

08 Release was governed by minimum required flow.

09 Release was based on buffer level constraint.

10 Release was based on primary energy power demand.

11 Flood control releases cannot be made until highest priority reservoir is releasing. (ISCHED = 1 on J3.8) Release only for minimum flow requirements.

99 Release was specified on QA cards as input.

R (17) LEVEL - The index level for each time period is shown. An index level of NL1 from the J1 card indicates the top of the conservation pool and the index level of NLM from the J1 card indicates the top of the flood control pool. Thus, a level of 1.750, when NL1 and NLM are 1 and 2, respectively, would show that 75 percent of the flood control storage is being used.

R (18) EQ LEVEL - The equivalent level of all upstream reservoirs in tandem operation with the current reservoir (omitted when no reservoirs are in tandem).

R (19)[1] EVAPORATION - The volume of water lost to evaporation in AF or 1000 cubic meters is shown for each time period for routing intervals greater than or equal to 24 hour.

R (20) EOP STORAGE - The end of period storage in the reservoir is shown for each time period.

R,C (21)[1] ELEVATION - When elevation data is provided at a reservoir or control point, the average elevation for each time period is shown. Channel elevation or stage is based on the regulated flow while the reservoir elevation is based on the average reservoir storage.

R Output for reservoir only.
R,C Output for both reservoirs and nonreservoir control points.
C Output for nonreservoir control point only.
1 Output will be omitted if input data is omitted.

C (22) Q SPACE AVAIL. - The channel capacity minus the regulated flow gives the space available in the channel for additional reservoir releases. Negative values indicate the amount of flooding (in excess of channel capacity). This output is omitted when monthly routings are used.

C (23) Q BY US RES,DIVS - This hydrograph is the result of all upstream reservoir releases and diversion return flows routed to the current control point. It is the difference between Regulated Flow and Cumulative Local Flow.

C (24) FLOOD BY RES - The amount of flooding caused by releases from all upstream reservoirs and diversion return flows is shown for each time period. The total flooding shown in this item does not reflect flooding from the cumulative uncontrolled local flow (item 2). This output is omitted when monthly routings are used.

d. Reservoir Operation by Sequence of Time Periods. When requested, the following items are shown for all reservoirs for each time period.

(1) RES NO - The identification number of the reservoir.

(2) DIV Q - The sum of all diversions from and to the control point.

(3) INFLOW - The reservoir inflow.

(4) OUTFLOW - The reservoir outflow.

(5) EOP STORAGE - The end of period reservoir storage in acre feet or 1000 cubic meters.

(6) ELEV - The elevation corresponding to the average reservoir storage.

(7) CASE = LOC. TYP - The controlling criteria for determining the reservoir release.

(8) LEVEL - The reservoir index level.

(9) EQ LEVEL - Equivalent level of tandem reservoirs.

e. Reservoir Releases by Period/Regulated Flows at Control Points by Period.

(1) RES NO/C.P. NO. - The identification number of the reservoir or control point.

C Output for nonreservoir control point only.

(2) CHAN CAP - The nondamaging channel capacity in cfs (or cubic meters per second) at the reservoir or control point.

(3) MIN DES Q - Minimum desired flow at the specified locations (-1 if not defined).

(4) MIN REQ Q - Minimum required flow at the specified location (-1 if not defined).

(5) Reservoir Releases or Regulated Flows for Each Time Period, at all reservoir or control points, in cfs (or cubic meters per second).

(6) The sum, maximum value, minimum value, period of the maximum value (MPER), and average value for each reservoir and control point.

f. User Designed Output. Tables of output can be designed by using up to 5 different J8 cards (see input description). Output can be time distributed variables or summary data at any control point or reservoir.

g. Flow Plots. For each reservoir and control point for which plotted results are requested, a series of flow hydrographs is generated. The hydrographs and their associated plotting symbols are regulated flow (R), unregulated flow (N), cumulative local flow (L) and inflow (I). The scale for each plot is automatically determined by the program and is based on the range of the flows to be plotted. The units of flow used in the plots are cfs or cubic meters per second. A user selected plot scale can be specified, which will override the program determined scale.

h. Single Flood Summary.

Control Points

For each control point, the following is given:

(1) MAX REG Q - Maximum regulated discharge.

(2) MAX NAT - Maximum unregulated (natural) discharge.

(3) MAX UNC - Maximum discharge from the uncontrolled drainage area below all reservoirs which have flood control storage.

(4) Q BY RES - The difference between the MAX REG Q and MAX UNC which shows the remaining possible reduction in peak discharge if all reservoirs had unlimited flood control storage.

(5) NO FLOODS/TOTAL - Total number of periods during which regulated discharges exceeded channel capacity.

(6) VOL FLOODS/TOTAL - Total volume of flooding (in excess of channel capacity) in cfs* - periods.

(7) NO FLOODS/FROM RES - Number of flood periods where reservoir releases contributed to the flooding.

(8) VOL FLOODS/FROM RES - Volume of flooding (in excess of channel capacity) in cfs* - periods caused by the reservoir releases.

(9) PER FLOODS/FROM RES - First and last periods during which flooding by reservoir occurs.

(10) CH CAP - Nondamaging channel capacity.

Reservoirs

For each reservoir, the following is given:

(1) STOR1 - The starting reservoir storage.

(2) MAX STG - The maximum storage during the flood.

(3) MAX LEVEL - The maximum reservoir level during the flood.

(4) 1ST PER & LAST PER. - The first and last period the reservoir was at the top of flood control pool during the flood.

(5) MAX INFLOW - The maximum reservoir inflow.

(6) MAX REL. - The maximum reservoir release.

(7) CHAN CAP. - The channel capacity at the reservoir.

i. Summary of Averages for Reservoirs and Nonreservoirs. Average values are given for the following variables for each reservoir: (1) CUM LOCA - cumulative local flow, (2) NATURAL - natural flow, (3) INFLOW, (4) OUTFLOW, (5) CASE = LOC, (6) LEVEL, and (7) EOP STOR - end of period storage.

Average values are given for the following variables for each non-reservoir: (1) CUM LOCA - cumulative local flow, (2) NATURAL - natural flow, (3) REGULATE - regulated flow, (4) Q SPACE - space available in the channel for additional reservoir releases, (5) Q BY US - flow from upstream reservoir releases and diversions, and (6) FLOOD BY - flows greater than channel capacity by upstream releases.

---

*Or cubic meters/second

j. Multiflood Summaries (Conservation and Flood Control).

(1) The summary described below is done for each flood event in turn (FLOOD SUMMARY - EACH FLOOD) and then the maximums and minimums for all flood events are shown (MAX VALUES FOR MULTIFLOODS).

(2) The multiflood summary is a summary of the significant features of each event. For each control point, the maximum regulated flow (MAX REG Q), the maximum natural flow (MAX NAT Q) and the maximum cumulative local flow (MAX LOCAL Q) are presented. The flood number and the time period* during that flood when each maximum occurred are shown beside the maximum flow value. Also, listed for each control point is the total contribution of upstream reservoirs to the maximum regulated flow at the control point (Q BY RES), and an indicator of shortages in desired or required minimum flow at the control point (SHORTAGE INDEX/DES/REQ). In the event that there were no minimum flow requirements, the indicator is -1. If a minimum flow was specified but the requirement was not met, the shortage index is printed out. The shortage index is defined as the sum of the squares of annual shortages prorated to a 100 year period where annual shortages are expressed as a decimal fraction of demand.

For each reservoir, the minimum storage (MIN STG), minimum level (MIN LEVEL), maximum storage (MAX STG), maximum level (MAX LEVEL) and maximum release (MAX REL) are listed as well as the flood number and the period associated with each maximum. Nondamaging channel capacity (CHAN CAP) and the initial storage in the reservoir (STOR1) are also listed.

Finally, the minimum combined storage (MIN SYSTEM STG) and the maximum combined storage (MAX SYSTEM STG) that were reached by the system reservoirs during the flood event are listed.

(3) The flood summary for multiple floods is presented with the same format as the individual flood summaries with the exception that the shortage index is a weighted value of the shortage indices of each contributing flood. The different flood indices are weighted on the basis of the number of periods in each flood.

k. Flood Frequency and Damage Data. This output is a compilation of flood flow-frequency-damage data for the system and consists of:

(1) Data Printout - The exceedence frequency, peak flow, and damage data for base conditions, provided as input to the program, is listed in order of increasing flood peaks:

---

*Time period - a 2.014 indicates that the event was reached on the 14th time period of flood 2.

Column 1: Probabilities of exceedence corresponding to each input flood peak in column 2.

Column 2: Input peak flows corresponding to exceedence probabilities in column 1.

Column 3: The sum of the damages for all types corresponding to flood peaks in column 2. Damages are listed in the same units as input to the program (e.g., dollars, thousands of dollars, etc.) and multiplied by escalation factor ECFCT(J3.2).

Columns 4-12: Damages for types 1 to J (DA.1), e.g., urban, rural transportation, times ECFCT. Damage types are in the same order as the DC cards from which the data is read.

(2) Expected Annual Damages - If the number of damage categories (J in field DA.1) is positive, expected annual damages are computed based on the input discharge-frequency-damage data and the results are printed on the line labelled BASE COND-COMPUTED. If expected annual damages for base conditions have been input (DA card), these values are listed as BASE COND-INPUT. If expected annual damages for the existing system have been input (DB card), these values are listed as EXISTING SYSTEM-INPUT.

(3) Base Condition Flood Damages - This output includes the flood event number with the unregulated peak flow and the exceedence frequency, probability interval and damage values associated with that event. The unregulated peak flows have been arranged from smallest to largest. The exceedence frequency for the event is determined by logarithmic interpolation of the input flow-frequency data. The probability interval for the event represents the probability between the midpoints of adjacent events. If expected annual damages are computed (J in field DA.1 is positive), the damage values represent the incremental portion between adjacent events. If damages only are computed (J in field DA.1 is negative), the values are the damages for the event interpolated from the input discharge-damage relation and the probability interval is set to 1.0.

(4) Modified Conditions Flow-Damage Data. If a design discharge, DESQ(C$.1) is provided for a local project or a second set of DC cards are input, the modified flow-frequency-damage data are listed.

(5) Modified Conditions Flood Damages. Modified conditions refers to the system with all reservoirs and local projects in operation. This output has the same format as for the base conditions output except that there is an additional line of output showing damage reduction (the amount by which damages are reduced from the existing system damages.

(6) Uncontrolled Local Flow Flood Damages. Uncontrolled local flows refers to those flows which reach the control point without passing through a reservoir, that is, flows for which there are no available controls. Damages with total control at projects refers to the damages that would occur if all upstream reservoirs had sufficient capacity to prevent releases contributing to peak flows downstream. Thus, damages with total control is equivalent to damages from uncontrolled local flow. RESIDUAL DAMAGES is the amount by which damages could be further reduced in the existing system if all reservoirs had sufficient capacity.

l. Flood Frequency Plots. The input exceedence frequency-discharge data, the peak flows for input flood events under base conditions, and the reduced flows resulting from modified conditions are plotted on the exceedence frequency curve. An expected annual damages summary is also printed out on the plot. If a single flood event is input to the program the damage values for the modified system are for the single event.

m. Summary of Damages and Damage Reductions. For each damage control point, the total damages for base conditions, modified conditions and uncontrolled local flows, the damage reductions expected from modified conditions and from total control at projects, and residual damages are summarized. If multiple floods are input to the program, the printout values are either damages for these specific floods (DA.1 is negative) or are expected annual damages (DA.1 is positive). If a single flood event is input, the values are damages for the single event.

n. Summary of System Costs. For each control point for which a project is being considered, the project type and project costs are listed. The project type will be indicated as either a reservoir or a local protection work. Costs include initial (capital) costs and annual (operation, maintenance and replacement) costs.

o. System Economic Cost and Performance Summary. Total capital and annual costs include the combined costs of all proposed projects. EXPECTED ANNUAL DAMAGES - EXISTING SYSTEM are the expected annual damages of the system in the base condition, computed from the discharge-frequency curve. Alternatively, the EXPECTED ANNUAL DAMAGES for the existing system may be the sum of the input values by means of Base Damage Cards (DB cards). EXPECTED ANNUAL DAMAGE - PROPOSED SYSTEM is based on a modified discharge-frequency curve which is derived from flows computed for multiple input flood events. The total system annual costs and expected annual damage reduction is summarized and the net damage reduction benefits computed. If a single flood event is input to the program this portion of the output is deleted.

p. Peak Discharge and Stage Reduction Summary. The reduction in discharge and stage at each control point as a result of reservoir operation is tabulated and expressed as a ratio of storage and project costs.

q. Computer Check for Possible Errors. Results of program operation are scanned for possible reservoir operation errors. If a constraint is violated, an error message is printed out. The basic message has the form "POSSIBLE ERROR, CP = , IP = , ACT Q = , MIN Q = , RES NO = , LEVEL = , ABOVE LEVEL = , REL = , PER = ." The message states that a possible error was found at a control point CP ata time period IP. The actual flow (ACT Q) and minimum desired or required flow (MIN Q) are listed for that control point at that time period. The last five items identify the reservoir (RES NO) that was the source of the possible erroneous release, the period (PER) in which the release (REL) was made, the level of the reservoir at the end of that period (LEVEL) and the next lower integer level (ABOVE LEVEL). One of three additional messages is also printed out:

(1) "MINIMUM FLOW NOT SUPPLIED" - The desired or required flow at the current control point was not satisfied and one or more reservoirs had storage that could have eliminated or reduced the shortage.

(2) "FLOODING CAUSED BY RESERVOIR" - Flooding at the current control point was caused at least in part by nonessential releases from an upstream reservoir.

(3) "RESERVOIR RELEASE INCORRECTLY BASED ON D.S. FLOW" - Reservoir releases were made to provide a target flow at the downstream control point as indicated by the "CASE." The downstream flow is either larger than or less than the target flow considering the contingency factor and a 5% allowable departure. When the reservoir is in flood control operation, the downstream flow should be at channel capacity (allowing for a contingency factor). If the reservoir is in conservation operation, the downstream flows should satisfy minimum desired or required flows.

r. Case Definitions. A brief table is presented at the end of the output defining the case designations used by the program. Item C (16) of this exhibit provides a description of the different case values.

EXHIBIT 7

INPUT DESCRIPTION

HEC-5C

SIMULATION OF FLOOD CONTROL AND CONSERVATION SYSTEMS

This exhibit contains a detailed description of each variable on each input card. A Functional Use Index which can be used to determine which input variables are required for specific tasks appears first. Following this Functional Use Index is a table of contents for all HEC-5C data cards. The summary of input cards at the end of this exhibit shows the sequential arrangement of cards and also serves as a table of contents by showing, in field 10, the page numbers where the variables are described in this exhibit.

Variable locations for each input card are shown by field number. The cards are normally divided into ten fields of eight columns each except field 1. Variables occurring in field 1 may normally only occupy card columns 3-8 since card columns 1 and 2 are reserved for the required identification characters. The different values a variable may assume and the conditions for each are described for each variable. Some variables simply indicate whether a program option is to be used or not by using numbers such as -1, 0, 1. Other variables contain numbers which express the variable magnitude. For these a + sign if shown in the description under "value" and the numerical value of the variable is entered as input. Where the variable value is to be zero the variable may be left blank since a blank field is read as zero.

If decimal points are not punched in the data, all numbers must be right justified in the field. Any number without a sign considered positive.

Location of variables on cards are sometimes referred to by an abbreviated designation, such as J1.4 representing the fourth field of the J1 card.

HEC-5C

FUNCTIONAL USE INDEX

Task	Cards Used
1. BASIC APPLICATIONS	
a. Required Cards by Group	
(1) General Data	T1-T3, J1, ED, EJ
(2) Reservoir Data	RL, RO, RS, RQ
(3) Control Point Data (including reservoir)	CP, ID, RT
(4) Flow Data	IN
b. Variable Locations by Function	
(1) Diversions	RD-RS, DR, QD-QS
(2) Natural Flow	J2.7, NQ
(3) Routing Data	RT, QS, SQ
(4) Channel Capacities	CP.2, CC-QS
(5) Minimum Flows	CP.7, CP.8, QM, MR, QA
(6) Number of Periods of Routing	J1.1, J1.6, BF.2
(7) Reservoir Level Data	J1.3, J1.4, J1.5, J1.7, RL
2. VARIABLE LOCATIONS FOR MISCELLANEOUS PROGRAM OPTIONS	
a. Multiple Floods	J2.5, BF.3, BF.10, FC, R1
b. Monthly Conservation Operation	J1.7, J2.8, J6, RA, R3 CP.7, CP.8, EV
c. Mixed Computational Interval	J1.2, J2.8, BF
d. Hydropower	RE, P1, PR, PD, PH, PQ, PT, PP, PS, PE, PV
e. Reservoir and Control Point Cost Data	J3.4, J3.5, R$, CP.9, CP.10, C$
f. Flood Damage Data	J3.2, J3.6, DA, DB, DF, DQ, DC
g. Deletion of Reservoir or Subsystem	J5, J2.9
h. Print Options	J2.6, ID.10, J3.6
i. Plot Options	J3.10, ID.9
j. Trace of Intermediate Answers	J2.10, TC, TP

HEC-5C DATA CARDS

Table of Contents

A. TITLE CARDS

** T1, T2, T3 Cards

Job title cards. Three cards required. Both alphabetic and numeric information may be placed on these cards. Information on these cards will be printed out as job title on the first page of the output.

B. JOB CARDS (general data applying to entire computer run)

** J1 Card - First Job Card - all integers

Field	Variable	Value	Description
1	(1) NPER	+	Number of values on each set of flow data cards (cards IN, NQ, QA, etc.) for Flood 1 (between the ED card and the first EJ card).
2	IPER	+	Time interval (Δt) in hours between flows and on which all computations for all floods are based, unless changed by 7th field of BF card. Use 720 for monthly routing.
3	NL	+	Number of index levels used in apportioning reservoir releases among reservoirs. Minimum of 2; maximum of 7. Normally 5 levels are used.
4	NL1	+	Index level on RL cards (Index L of array STORL(M,L,K)) corresponding to the top of the conservation pool for all reservoirs. Normally = 3.
5	NLM	+	Index level on RL cards corresponding to the top of the flood pool for all reservoirs. Normally = 4.

**Required cards

(1) If NPER exceeds the dimension limits of KPER (and EPER is not used) the routing will be automatically divided into several periods (called floods), however the output will still appear as one flood.

Current dimension limits are printed out at the top of computer run. For the UNIVAC 1108, the limits are for 50 time periods (KPER), 15 control points (KNCPT), 10 reservoirs (KRES), 11 diversions (KDIV), and 9 power plants (KPWR).

J1 Card - Continued

Field	Variable	Value	Description
6	EPER	0	NPER (J1.1) periods of routing will be made.
		+	Last computation period will be EPER. This option is used to limit operation to a fewer number of periods than on the flow cards without changing the flow data. Use (KPER-1) or less (49 on UNIVAC 1108).
7	NLBUF	0	Index level = 1.
		+	Index level on RL cards corresponding to the top of buffer pool. Above this level, minimum desired flows will be made; and below this level, minimum required flows will be made (see text for definitions). Normally = 2.
8	ILOCAL	1 or 0	Local flows specified on IN cards are incremental; that is, they represent local flow between adjacent control points.
		10(1)	Compute incremental local flows from observed gages (IN cards) and observed reservoir releases (QA cards) and STOP (do not operate system). Reservoirs used in data must correspond to reservoirs in operation during flood. Output for this computation will be printed only if code 64 is requested by field 6 of J2 card.
		15(1)	Same as 10 except operate system also.
		20(1)	Incremental local flows are calculated from natural flows, on IN cards, and then the system is operated.
		25(1)	Same as 20 except do not operate the system.

(1) A negative value for ILOCAL will provide punched card output for the computed local flows.

J1 Card - Continued

Field	Variable	Value	Description
9	INFLOW	0	Input flow data is average for the period. Normally used.
		1	Input flow data is end-of-period on cards IN and NQ. QA and MR cards are always average values.
10	IOPMD	0	Reservoir releases will be made equal to inflow above top flood control pool up to outlet capacity.
		1	Same as above except that prereleases equal to channel capacity at the dam site will be made as soon as it can be determined that the reservoir will exceed the flood control storage using IFCAST(J2.3).
		2	Same as 1 except prereleases can be larger or smaller than channel capacity. Constant releases are determined for future periods so that the top of the flood control pool will be just reached within the forecast period, IFCAST (J2.3 or RL.3).

** J2 Card - Second Job Card

Field	Variable	Value	Description
1	CNSTI	0	Factor is assumed = 1.0.
		+	Factor which is multiplied times all inflows and local flows (Card IN). When several ratios of the given flows (IN cards) are to be computed the constants on the BF or FC card will be used.
2	CFLOD	0-1	Constant is assumed = 1.0.
		>1	Coefficient greater than or equal to 1 by which local flows are multiplied as a contingency allowance in the determination of upstream flood control releases. If this value is 1.2 a 20 percent forecasting error is assumed for IFCAST periods. This 20% error will be used for both flood control and conservation.

**Required Card

J2 Card - Continued

Field	Variable	Value	Description
3	IFCAST	0	A foresight equal to, 24/IPER, on all inflows and local flows will be used in system operation.
		+	IFCAST periods of foresight on inflows and local flows will be used in system operation for all reservoirs unless a different value is specified on the RL Card (RL.3). If both long and short time interval operations are made, IFCAST is only applied to the short time interval operation (daily or less).
4	RATCHG	0	The maximum rate of change, during IPER (J1.2), of reservoir release will be assumed as .5 times the designated channel capacity (CP.2).
		+	The maximum rate of change of reservoir release during IPER(J1.2), expressed as a ratio of the channel capacity (CP.2).
5	NFLRD	0	Flow data for only one flood will be read.
		+	NFLRD sets of flow data will be read on Cards IN, etc. Multiple ratios (FC card) can be used for each flood read. A series of "floods" (NPER items of IPER duration for a given flood) can be used to simulate a period of record by using monthly periods for some or all of the "floods" with short period routings as necessary.

J2 Card - Continued

Field	Variable	Value	Description
6	PRINT	0-511	The sum of the codes representing the desired output is used for PRINT. More than one copy can be obtained by specifying a number up to 9 to the right of the decimal (i.e., 38.2 would provide 2 copies of output coded 2, 4, and 32). Input cards T1-ED are always printed for batch jobs.

Code	Option
0	All output listed below.
1	Summary of maximum events for each flood and a summary of averages for reservoirs and nonreservoirs.
2	Summary of maximum and minimum values for each event and for all events. Also summary of monthly operations.
4	Output error check.
8	Normal sequential output by control point, by variable, by time period.
16	Reservoir data by period (all floods).
32	Reservoir releases and control point regulated flows by time period (all floods).
64	Computation of incremental local flows from natural or observed conditions.
128	Flow cards.
256	Hydrologic efficiencies (must also ask for code 2).

J2 Card - Continued

Field	Variable	Value	Description
7	FLONAT	0	Natural or unregulated flows, flows that would have existed if no reservoirs were upstream, will not be computed. However, they can be read on NQ cards. If ILOCAL = 20(J1.8) natural flows will be printed from the IN card data.
		-1	Natural flows will be calculated and printed (omit NQ cards). If ILOCAL = 20, natural flows printed out will be based on adjusted computed local flows (no negative locals).
8	NOROUT	0	Indicator is assumed equal to 24 hours.
		+	Indicator used to differentiate between short interval operation that would use routing and forecasting, and long interval conservation operation in which no routing and forecasting would be used. Channel routing and forecasting will not be made if IPER(J1.2 or BF.7) is greater than NOROUT.
9	NCPTR	0	All control points will be used in the system.
		+	Identification number of last control point to be used in this run of the system. Option is used to operate a subsystem when data is coded for a large system. The total number of control points can exceed the dimension limits (KNCPT) as long as subsystem specified does not. The first RL card should be for the upstream starting point. NCPTR must be a nonreservoir.

J2 Card - Continued

Field	Variable	Value	Description
10	TRACE(1)	0	Trace level is assumed = 15 if TC or TP card is used.
		1	Very small volume of trace showing how reservoir releases were determined.
		11	Trace of release computation (see TC and TP Cards).
		15	Comprehensive trace (see TC and TP cards).
		17	Same as 15 except additional trace for diversions and routing coefficients.
		20	Comprehensive trace including Modified Puls trace.

(1) No trace will be provided unless a TC or TP card is also used.

* J3 Card - Third Job Card

Field	Variable	Value	Description
1	METRIC	0	Input and output are in English units.
		1	Input and output are in metric units.
2	ECFCT	0	No damage data will be used (cards DA-DC omitted) or factor "ECFCT" will be assumed = 1.
		+	Factor to be multiplied times all damage data on the DC cards.
3	FLDAT	0	No date will be printed out.
		+	Date of beginning of time period for first flow on IN cards. The eight digit code is for the year, month, day and hour. December 31, 1933, at 10 a.m., is 33123110. The month shown will be used for the starting month of evaporation (J6), diversion data (QD)and reservoir levels (additional RL cards) unless specified on J4.1.
4	BCRFAC	0	Capital recovery factor, if used, will be specified on the CP card.
		+	Capital recovery factor, used when data is omitted from 9th field of CP card, which is multiplied by the present worth of reservoir or control point costs to obtain the annual cost of the capital investment based on desired interest rate.
5	COSFAC	0	Any cost data will be multiplied by 1.0.
		+	Cost data on cards R$ and C$ will be multiplied by COSFAC.
6	IPRECN	0	All types of economic output will be printed including frequency plot.
		-1	All economic output except frequency plot.
		1	Economic summary table (only) will be printed.
		2	Economic summary and summary by category (only) will be printed.

*Optional Card

J3 Card - Continued

Field	Variable	Value	Description
7	IDAMTP	0	No flood damages will be computed.
		-1	Flood damages for all floods operated by the system will be determined (expected) annual damages will not be estimated).
		1	Expected Annual Damages will be calculated for natural conditions, for uncontrolled local flows, and for regulated conditions. The probability for each regulated flood will be assumed equal to the probability of the natural event.
		2-100(1)	Expected Annual Damages will be calculated for the same three conditions as above. Probabilities for regulated conditions will be based on rearranging the flood events at each control point in the order of magnitude and assigning plotting positions based on IDAMTP years of record. This option should be used when both monthly and short-interval routings are made.
8	ISCHED	0	Do not use scheduling.
		1	Use scheduling. No releases will be made from a reservoir unless all higher priority reservoirs in parallel are also releasing. The sum of the releases from all upstream reservoirs during any time period is not allowed to exceed damaging channel capacity at any downstream control point.

(1) Expected to be available in library deck by 1 September 1975.

J3 Card - Continued

Field	Variable	Value	Description
9	IPRIO[1]	0-15	The sum of the codes representing the desired priorities in the operation is used for IPRIO.
		Code[2]	
		0	Normal priorities will be made as indicated below by criteria in parenthesis.
		1	When flooding is occurring at a downstream location, primary power releases will still be made at upstream reservoirs (instead of curtailing the power releases).
		2	Primary power releases will be made as long as the reservoir storage level is above level 1 (in lieu of top of buffer level).
		4	All specified diversions from reservoirs will be made as long as the reservoir is above level 1 (instead of top of buffer pool) except where diversions are a function of reservoir storage.
		8	When flooding is occurring at a downstream location, minimum desired flow releases will be made contributing to the flooding (instead of making no releases).

---

(1) Expected to be available in library deck by 1 September 1975.

(2) If any of the codes (1-8) are not selected, operational priority for that item will be based on normal priority as shown in parenthesis.

J3 Card - Continued

Field	Variable	Value	Description
10	IPLOTJ	0	Hydrographs will not be plotted unless requested for a given control point by IPLOT(ID.9).
		1-4	IPLOTJ (up to 4) hydrographs will be plotted (printer plot) for all control points (unless specified on ID.9) based on the value of IPLOTJ as follows: (1) Regulated hydrograph only. (2) Natural and regulated hydrographs. (3) Natural, regulated and uncontrolled local hydrographs. (4) Natural, regulated and uncontrolled local and inflow hydrographs.
		5-8	The four hydrographs listed above will be plotted as well as (IPLOTJ-4) hydrographs for computed incremental local flows. (ILOCAL ≥ 10 on J1.8.) Additional plotted hydrographs based on value of IPLOTJ are: (5) Routed hydrograph (6) Observed hydrograph (7) Computed local flow (8) Inflow hydrograph
		>10	Vertical scale for plots can be set for all plots by coding the discharge scale (flow units/inch) plus the plot level desired. A 2007 value will use 2000 cfs or CUMECS per inch scale and plot the 4 control point hydrographs plus three local flow hydrographs.

* J4 Card - Fourth Job Card

Field	Variable	Value	Description
1	ISTMO	0	Starting month for all monthly data is based on FLODAT (J3.3 or BF.5).
		+	Starting month (1 = January) for all monthly data, such as evaporation (J6 card), diversions (QD card), power demands (PR card), and storage levels (RL cards). With this input, flow data does not have to start with the same month as the monthly data set.
2-10			Not used.

*Optional Card

* J5 Card - Reservoirs Deleted - Fifth Job

Field	Variable	Value	Description
1	NRDEL	+	Number of reservoir identification numbers to be read on J5 card starting in field 2. Maximum of 29.
2+	RESDEL(I)	+	Reservoir identification number (same as field 1 of RL card) of all reservoirs which are to be operated with outflows equal to inflow instead of using the criteria shown on cards RL-RQ. The computer will automatically change the storages on the RL card to zero, will eliminate the downstream control points the reservoir was to have operated for on RO card and will change the outlet capacities on RQ card to 1,000,000 cfs. RO card must be manually changed if an upstream reservoir operates for the deleted reservoir (see RO.2) or cards RL-RQ must be removed.

* J6 Card - Basin Evaporation Data - Sixth Job Card (normally two cards)

Field	Variable	Value	Description
1	NEVAT	+	Number of evaporation rates on J6 cards. Maximum of KEVAP (currently 12). Normally = 12.
2	EVDUR	+	Duration, in days, for each evaporation rate on these cards (3-14). Normally 30 days.
3-14	EVRAT(K)	+	Net evaporation minus precipitation rate in inches (millimeters) per month over the reservoir area for NEVAT periods. The first "EVDUR" of the routing will use EVRAT(1), etc. Therefore, if all flow cards (IN, etc.) start in October (for 1st flood), EVRAT(1) must be for October. Variable ISTMO(J4.1) can be used to differentiate the starting month for this data from the date used for the routing of flows.

*Optional Card

* <u>J7 Card</u> - To be used later.

* <u>J8 Card</u> - User Determined Output Format (0-5 cards)

Optional card to design format of additional output. Each card used will specify output variables to be printed for up to 10 columns.

<u>Data by Period</u> (first field is positive)

Each field of the card used should contain the control point location (to the left of the decimal) and variable code (to the right of the decimal). For example, a 10.10, 15.10, 10.12, 15.12, 10.13, 15.13 in fields 1-6 would print six vertical columns for each period of the routing showing in order: the outflows for reservoirs 10 and 15 (code 10 = outflow), cases (code =12) for reservoirs 10 and 15 and levels (code =13) for reservoirs 10 and 15.

<u>Summary Data by Control Point</u> (first field is negative)

Each field of the card used should contain the code for the type of summary (to the left of the decimal) and variable code (to the right of the decimal). Codes for the summary data are: 1=SUM, 2=Maximum, 3=Minimum, 4=Period of Maximum, and 5=Average. The first card requesting summary data (first field is negative) will provide data for reservoirs and if a second summary card is used, the data would be for nonreservoir control points. A maximum of two sets of cards (4 cards) can be used in this manner with cards 1 and 3 for reservoir data and 2 and 4 for nonreservoir data. For example, a -1.02, 2.02, 5.02 in the first three fields would provide the sum, maximum, and average of the natural flows for all reservoirs. If the next J8 card also requested summary data (negative value in the first field) the summary data would be for nonreservoir control points.

Variable codes to be used are:

.01 Cumulative Local Flow
.02 Natural Flow
.03 Diversion
.04 Regulated Flow (nonreservoir)
.05 Min. Desired Flow
.06 Min. Desired Flow Shortage
.07 Min. Required Flow
.08 Min. Required Flow Shortage
.09 Reservoir Inflow
.10 Reservoir Outflow
.11 Reservoir EOP Storage
.12 Reservoir Case
.13 Reservoir Level
.14 Reservoir Eq. Level
.15 Required Power Demand
.16 Generated Power
.17 Channel Capacity
.18 Q Space
.19 U.S. Res/Div. Flow
.20 Flooding by Reservoir
.21 Evaporation
.22 Elevation
.23 Power Shortage
.24 Incremental Local Flow

---

*Optional Card

* TC Card - Trace Card - Control Points

All control points will be traced if this card is omitted, and if a TP card is used.

Field	Variable	Value	Description
1	NTRAMX	+	Number of values of MXTRA(I) on TC card.
2-10	MXTRA(I)	+	Identification numbers of selected control points to be traced for periods shown on TP card with level of trace from J2.10.

* TP Card - Trace Card - Time Periods

All time periods will be traced if this card is omitted and a TC card is used.

Field	Variable	Value	Description
1	NTRACE	+	Number of values of ITRAP(I) on TP cards.
2		0	If NTRACE = 1, a general trace before and after operation by period will be generated, but no trace will be generated from system operation.
2-10	ITRAP(I)	+	Selected time period numbers for trace specified on J2.10. If it is desired to trace period 10 of flood 2, use 10.02. These values can exceed the dimension limit KPER.

Note

If both TC and TP cards are omitted trace will not be printed for any time period or control point regardless of value of TRACE (J2.10).

---

*Optional Card

C. Reservoir Cards (2) - Cards RL, RO, RS, and RQ are required for all reservoirs, omit for nonreservoirs. The most upstream control point on each tributary must be a reservoir.

RL Card - Reservoir Target Levels

Field	Variable	Value	Description
1	MM	+	Integer identification number for the control point (user number). The computer will generate the subscript M for internal identification (computer I.D. number).
2	STOR1	+	Initial storage of reservoir MM in acre-feet or 1000 cubic meters.
3	IFCST(M)	0	The foresight shown on J2 card (field 3) for inflows and local flows will be used for reservoir MM when short interval routings are made (when IPER (J1.2 or BF.7) is less than or equal to NOROUT (J2.8)).
		+	IFCST(M) periods of foresight for inflows and local flows will be used for reservoir MM when IPER is less than or equal to NOROUT.
4-10	STORL(M,L)	+	Reservoir capacities for control point MM in acre-feet or 1000 cubic meters for each of NL levels (J1.3) starting with level 1. Level NLBUF(J1.7) is the top of buffer pool. Level NL1(J1.4) is the top of conservation pool. Level NLM(J1.5) is the top of flood control pool.

##Required cards for reservoirs

(2) Cards RL-DC are repeated for each control point (reservoir or damage center) in turn in downstream order until all control points have been specified. The maximum number of control points depends on computer used but is = KCPT, including reservoirs. The maximum number of reservoirs is KRES. If a control point is not a reservoir, cards RL-R3 and P1-PE are omitted, and only control point cards CP-DC are used. If a reservoir is not a power plant, omit cards P1-PE. All control points above each confluence must be specified before the confluence control point.

*Additional RL Cards

Additional RL cards can be used when reservoir levels change during the year. These cards will be read after the first RL card (storage data will be ignored on first card if more than one card is read). NL(J1.3) groups (one or two cards each) of additional RL cards will be read in increasing order of level.

Field	Variable	Value	Description
1(1)	L	+	Level Number (1-7).
2(1)	M	+	Control point identification number.
3	IRPT	0	Storages will be read for all 12 months. Two RL cards are required for this level.
		-1	Storage in field 5 will be used for all months. Second RL card for this level will be omitted.
4	FACTR	0	All storages are read in acre-feet or thousands of cubic meters.
		+	Storage on fields 5-10 will be multiplied by FACTR.
5-10	STORL	+	Reservoir storage for each month for level L. The first six values of storage appear on the first card in fields 5-10 and the remaining six values (if used) must be in fields 5-10 of the second card (fields 1-4 are omitted). The first monthly value must be for the starting month of the flow data unless variable ISTMO(J4.1) is used. More than one acre-foot of flood control storage should be shown for the first month if downstream CUMULATIVE LOCAL FLOW should not include local flows above this reservoir.

*Optional Cards

(1) Fields 1 and 2 are not read by HEC-5C, but are read by HEC-3. (Both programs can use same RL cards if prepared as described above.)

RO Card - Reservoir Operation Points

Field	Variable	Value	Description
1	NSERV	+	Number of downstream control points for which reservoir MM is operated to prevent flooding or to provide low flows. If MM has flood control storage, this value should be equal to one or more. An unlimited number of points may be used, however, each additional point increases computer time.
2+	ISERV(M,K)	+	Control point numbers for which reservoir MM is operated. NSERV values in any order. None of these control points can be reservoirs without flood storage. If MM is an upstream tandem reservoir, it should be operated for the downstream reservoir, but not for any control points below that.

RS Card - Storage Capacities

Field	Variable	Value	Description
1	NK	+	Number of values of STOR(M,K) and QCAP(M,K).
		-	Number of values of STOR as above (negative). Also values of STOR(M,K) are in 1000's of units on input cards and will be multiplied by 1000 by the computer.
2-10	STOR(M,K)	+	Reservoir capacity in acre-feet or 1000 cubic meters for control point MM, corresponding to RQ card values. NK values. Dimension limit for K, for cards RS, RQ, RA, RE, RD, and R$ is KNCAPT (currently = 18). First storage value should be zero and two successive values should not be equal.

##Required cards for reservoirs

RQ Card - Outlet Capacities

Field	Variable	Value	Description
1	NK	+	Number of values of STOR(M,K) and QCAP(M,K).
2-10	QCAP(M,K)	+	Outlet capacity for control point MM in cfs or cubic meters per second. NK values. First value should be equal or greater than the minimum outflow desired.
		-1	Unlimited outlet capacity at STOR(M,K). This option sets the outflow equal to the inflow when reservoir reaches the value of STOR which corresponds to a QCAP which is negative.

* RA Card - Reservoir Areas

Field	Variable	Value	Description
1	NK	+	Number of values of AREA(M,K) on this card and STOR(M,K) on RS card.
2-10	AREA(M,K)	+	Reservoir areas in acres or thousands of square meters for control point MM corresponding to RS card storages. NK values.

* RE Card - Reservoir Elevations

Field	Variable	Value	Description
1	NK	+	Number of values of EL(M,K) on this card and STOR(M,K) on RS card.
2-10	EL(M,K)	+	Reservoir elevations for control point MM corresponding to RS card storages. NK values.

##Required cards for reservoir

*Optional Card

* RD Card - Reservoir Storages vs Diversions or Minimum Releases

Field	Variable	Value	Description
1	DVEXC	0,+	All diversions are made based on reservoir storage.
		-1	Diversions are equal to the excess flood waters above the top of conservation up to the outlet capacity of the diversion pipe (FDQ). The second value on this card must be greater than 0.0.
		-10	Minimum reservoir releases are shown for FDQ values as functions of reservoir storages (RS card). Induced surcharge envelope curve values (minimum reservoir releases during emergency conditions) can be shown on RD and RS cards and maximum reservoir releases vs reservoir storages on RQ and RS cards. For this option (DVEXC = -10) only do not use DR cards since reservoir releases determined from this option will not appear as diversions.
2-10	FDQ(M,K)	+	Diversion discharges from reservoir M corresponding to values of STOR(M,K) on RS card. If field 1 is -1, field 2 must be greater than zero (use .01 or greater). NK values.

* R$ Card - Reservoir Costs

Field	Variable	Value	Description
1	NK	+	Number of reservoir costs on this card and storages on the RS card. Maximum of 18.
2-10	COEF	+	Reservoir capital costs (present worth) corresponding to the storages on the RS card. The storage at the top of flood control pool (RL card storage corresponding to level NLM from the 5th field of the J1 card) will be used as the reference level for storage in determining the cost of the project from the RS and R$ cards. Values should be in the same units as damages (i.e., $, $1,000, etc.).

*Optional Card

* R1 Card - Starting Storages

Field	Variable	Value	Description
1	NSTOR1	+	Number of starting storages on R1 card.
2-10	TSTOR1(K)	+	NSTOR1 values of starting storages for multiple flood runs. Used only if NFLRD(J2.5) or NFLCON(J4) is positive and the starting storage is changed.

* R2 Card - Additional Reservoir Data

Field	Variable	Value	Description
1	RTCHGR	0	The rate of change on J2 card is used.
		+	The allowable rate of change of release during IPER(J1.2), in cfs or cubic meters per second, when the release from reservoir MM increases from the previous period.
2	RTCHGF	0	The rate of change on J2 card is used.
		+	The allowable rate of change of release during IPER(J1.2), in cfs or cubic meters per second, when the release from reservoir MM decreases from the previous period.
3	EVRTO	0,+	If greater than zero, factor is multiplied times the evaporation rates on EV or J6 cards.
4-10			Not used.

---

*Optional Card

* R3 Card - Reservoir Evaporation

Optional data for varying the evaporation for reservoir M only on a monthly basis instead of using the basin evaporation on card J6. Evaporation which varies from year to year must be read on an EV card.

Field	Variable	Value	Description
1	NEVRAM(M)	12	Number of evaporation rates on this card. Enter the number 12.
2	EVDURM	30	Duration for each evaporation rate on these cards. Duration must equal EVDUR (J6 card) which is expressed in days. Use 30 days.
3-14	EVRATM(K,M)	+	Net evaporation minus precipitation rates in inches (mm) over the reservoir area for 12 monthly periods. The first month of the routing will use the first evaporation value unless modified by ISTMO(J4.1).

*Optional Card

D. Power Reservoir Data (cards P1-PE)

P1 Card - First Power Card

This card specified physical characteristics of a powerplant located at this control point. Omit cards P1-PE if no powerplant exists at this control point; next card will be CP card for this control point.

Field	Variable	Value	Description
1	OVLOD	+	Overload ratio for the power installation. Usually 1.15 in the United States. If left blank, program assumes 1.15.
2	PWRMX	+	Installed powerplant nameplate capacity in kilowatts. Station service units are usually excluded.
3	TLWEL	0	Zero or blank indicates that a tailwater vs reservoir release relationship will be read on the PQ and PT cards.
		+	Tailwater elevation plus hydraulic loss in feet (or meters). For hydroelectric projects providing "peaking" power, this should be a "block-loading" or average "on-line" tailwater elevation that would be expected normally during periods of power generation.
4	IDPR	0	Zero or blank indicates that there is no downstream reservoir whose elevation affects tailwater elevation at this powerplant.
		+	Control point number of downstream reservoir whose elevation affects tailwater elevation at this powerplant. Program adds 2.0 feet (.6 meters) for hydraulic loss to elevation of downstream reservoir to obtain tailwater elevation and uses that or TLWEL (field 3) depending on which is highest for computing power head.

#Required card for all reservoirs with powerplants

P1 Card - Continued

Field	Variable	Value	Description
5	IPOW	0	Zero or blank specified that power peaking capability function will not be used. This, in effect, means that the only limitation of power output will be the powerplant nameplate capacity.
		1	Value of 1 indicated that a peaking capability vs reservoir storage relationship will be read in on cards PP and PS and used to calculate the turbine-generator capability as a function of reservoir storage. This option is used when head fluctuations are primarily dependent on headwater fluctuations.
		2	Value of 2 indicated that a peaking capability vs reservoir release relationship will be read in on cards PP and PS and used to calculate the turbine-generator capability as a function of reservoir release. This option is used when the head fluctuations are primarily dependent on changes in tailwater.
6	EFFCY	0	Standard ratio of .86 is used.
		+	Powerplant efficiency at this installation expressed as a ratio. Specification of a positive value implies that efficiency is constant throughout the range of operating heads anticipated.
		-1	If -1 is specified, powerplant efficiency vs reservoir storage relationship is specified on PE card.
		-2	If -2 is specified, KW/CFS (or KW/m^3/sec) coefficient vs reservoir storage relationship is specified on PE card.
7	QLKG(M)	0,+	Leakage through or under dam or powerhouse in cfs or cubic meters per second. Used to specify water which continuously passes the dam but cannot be used for power generation.
8-10			Not used.

PR

PD

PH

PR Card - Power Requirements - Monthly

This card specifies the monthly at-site power requirements for this project for each year. Two cards are required.

Field	Variable	Value	Description
1-10	POWRM	+	Monthly at-site power requirement in thousand kwh. Specify 12 values in successive order, one value per field. The first month for this data must be the same as the first evaporation period (J6 or R3 card). See ISTMO(J4.1).
		-	At-site power requirement as plant factor ratio times -1.0. Specify 12 values as above.

* PD Card - Power Requirements - Daily

This optional card specifies percentages (expressed as ratios) of the total weekly power requirements for each day of the week (7 values required).

Field	Variable	Value	Description
1-7	POWRD	+	Daily ratios of at-site power requirements. Sum of the 7 values must equal 1.0. The first value is for Sunday. The starting day of the week for each flood is assumed as Sunday unless specified on the BF card (8th field).

* PH Card - Power Requirements - Multihourly

This optional card specified percentages (expressed as ratios) of the total daily power requirements for each time interval (IPER) within a day.

Field	Variable	Value	Description
1	N	+	Number of ratios to be read starting in field 2. Number of values = 24/IPER (short interval routing period), i.e., for a six hour routing interval, 4 values would be required.
2+	POWRH	+	Ratios of the daily power requirements for each time period (IPER) within the day. First value represents the period from midnight to IPER past midnight. Sum of the values should equal 1.0.

#Required for each powerplant

*Optional Card

* PQ Card - Power Releases[1]

Field	Variable	Value	Description
1-10	QT	+	Reservoir outflow in cfs (or m^3/sec). Begin with lowest value in field 1 and specify values in increasing order. Values should cover the range of discharges expected. Program uses linear interpolation between points, so values should be selected so that linear interpolation is reasonably accurate. If less than ten values are needed, the unneeded fields should be left blank.

* PT Card - Power Tailwater

The number of values on this card must be the same as the number of values on the PQ card.

Field	Variable	Value	Description
1-10	TL	+	Tailwater elevation in feet (or meters) corresponding to reservoir outflow in same fields on the PQ card.

* PP Card - Power Peaking Capability[2]

Field	Variable	Value	Description
1-10	PKPWR	+	Maximum peaking capability in kilowatts. The capability must correspond to the specified values on the PS card. Program uses linear interpolation in this table so values should be selected so that linear interpolation is reasonably accurate.

*Optional Card

(1) Cards PQ and PT are used to specify the tailwater-discharge relationship at this powerplant instead of using TLWEL (P1 card, field 3). Up to ten values can be used to define the relationship.

(2) Cards PP and PS define the relationship between peaking capability and either reservoir storage or reservoir outflow. P1 card, field 5 must be equal to 1 or 2 to determine type of data being read. Up to ten values can be used to define the relationship.

* PS Card - Power Storages (or Releases)

The data on this card can be either reservoir releases or reservoir storages. Reservoir storages are specified if IPOW (P1 card, field 5) is 1, and reservoir releases are specified if IPOW is 2. The number of values on this card must be the same as the number of the PP card. The largest should be larger than the highest storage or largest release anticipated and the smallest value should be smaller than the lowest storage or smallest release anticipated.

Field	Variable	Value	Description
1-10	CQOEL	+	Reservoir storage in acre-feet (or thousand cubic meters) if IPOW (P1 card, field 5) is 1, or reservoir release in cfs (or m^3/sec) if IPOW is 2. Begin with smallest value in the first field and specify values in increasing order. Values must correspond to peaking capabilities in same field on the PP card.

* PE Card - Power Efficiencies vs Storage

This card is used to specify the relationship between reservoir storage and either plant efficiency ratio or KW/CFS coefficient instead of using a fixed efficiency of EFFCY (P1 card, field 6). If EFFCY is specified at -1, plant efficiency ratios are specified on this card. If EFFCY is specified as -2, KW/CFS (or KW/m^3/sec) coefficients are specified. The number of values on this card must be the same as the number of values on the RS card.

Field	Variable	Value	Description
1-10	EFCY	+	Plant efficiency ratio if EFFCY (P1 card, field 6) is -1 or KW/CFS (or KW/m^3/sec) coefficient if IFFCY is -2. Values must correspond to storage capacities in same field on the RS card.

---

*Optional Card

E. Control Point Cards (Cards CP-DC) - Cards CP, ID, and RT are required for all control points including reservoirs.

** CP Card - Control Point Card

Field	Variable	Value	Description
1	MM	+	Any integer indentification number. Must be equal to MM of the RL card if this control point is a reservoir.
2	QMX(M)	+	Maximum flow in cfs or cubic meters per second desired at control point MM (nondamaging capacity).
3	LQCP(M)	0	Flows for MM are read from card IN.
		+	IN cards do not have to be read for control point MM; instead, flows for MM can be based on values on card IN for the same or another control point LQCP(M) which is in system. Factor RTLQ(M) is multiplied times the flows on the IN cards and lagged by QLAG(M).
4	RTLQ(M)	0	Flows for MM are read as card IN.
		+	Ratio which is multiplied by flows at LQCP(M) to obtain flows at location MM.
5	QLAG(M)	0	No lag.
		+ or -	Number of periods local flows are to be lagged forward in time (+) or backward (-) expressed in IPER(J1.2) units.
6	CFLD(M)	0	Factor CFLOD(J2.2) will be used for contingency factor.
		+	Contingency factor (equal to one or more) for forecasting cumulative local flows at control point M.

**Required Card

CP Card - Continued

Field	Variable	Value	Description
7	QMIND(M)	+	Minimum desired flow at control point M for NPER periods. MR card for this control point will override this flow if it is used. Minimum desired flows will be made as long as upstream reservoirs are above level NLBUF(J1.7).
8	QMINR(M)	+	Minimum required flows at control point M for all periods. The target flows will be reduced from the desired flows to the required flows when upstream reservoirs fall below level NLBUF(J1.7). No releases will be made below level 1.
9	CRFAC	0	Capital recovery factor from J3 card (field 4) will be used for this control point.
		+	Capital recovery factor for this control point or reservoir to convert present worth cost (R$ or C$ cards) to an annual figure.
10	OMPER	0	No operation and maintenance costs.
		+	Proportion of capital cost, expressed as a percentage, that will be required for annual operation, maintenance and replacement of the facilities (reservoir or local protection works).

** ID Cards - Identification Card for Control Point

Field	Variable	Value	Description
1-4	CPT(M,1-10)	+	Title (alphanumeric) of control point in columns 3-32. Columns 3-32 will be printed in the summary.
5-8			Not used.
9	IPLOT	0	No hydrographs will be plotted for this control point, unless J3.10 is positive.
		1-8	IPLOT hydrographs will be plotted for this control point. (See J3.10 for priority of plots.)
10			Not used.

** RT Cards - Routing Card

Field	Variable	Value	Description
1	RTFR(M)	+	Control point number of upstream end of routing reach. Equal to MM of RL and CP card.
2	RTTO(M)	+	Control point number of downstream end of routing reach MM. Equal to MM of the RL and CP card for the next downstream control point. May be left blank for last control point in system.
3	RTMD(M)	+	Number of subreaches (to left of decimal) and ratios for method of routing for reach MM (.1 for straddle-stagger, .2 for Muskingum, .3 for Modified Puls and .4 for Working R&D). A 3.2 indicates three subreaches will be used in the Muskingum method.

**Required Card

RT Cards - Continued

Field	Variable	Value	Description
4	X(1)	+	Muskingum routing coefficient "X" for each subreach of reach MM. For the Muskingum and Working R&D methods, use the desired value of X between 0 and .5. Use 0 for Modified Puls. Enter the number of ordinates to be straddled and staggered (such as 3.1 for 3/1 straddle-stagger). For routing by the Tatum (successive Average-Lag) method, enter a 2.1 and make RTMD(RT.3) equal to $2K/\Delta t$.
5	K	0	For Modified Puls, R&D, and straddle-stagger. If no routing is desired use Muskingum with X = .5 and K = 0.
		+	Travel time (Muskingum K) in hours for Muskingum subreach. To avoid negative coefficients, K, for the subreach, should be approximately = Δt (IPER of J1.2); in no case should K be less than $\Delta t/[2\cdot(1-X)]$ or greater than $\Delta t/2X$.
6	LAG(1)	0	No lag in addition to routing.
		±	In addition to routing specified by Methods 1-4, lag outflow by the number of periods shown in this field (RT.6) (+ or -).
7-10			Not used.

(1) Do not use routing criteria that specifies that outflows are a function of future period inflows. (e.g., Straddle-Stagger of 3/0 or in some cases where a negative LAG is greater than or equal to the routing time.) The 3/0 straddle-stagger would have outflow for the present period equal to 1/3 the inflow for the previous, present, and future periods.

* DR Card - Diversion Data for Control Point

Dimension limit for number of diversions is KDIV (currently = 11).

Field	Variable	Value	Description
1	DRTFR(NDIV)	+	Control point identification number (same as MM on CP card) where diversion is made.
2	DRTTO(NDIV)	0,+	Control point number where diversion returns to system. Diversion flows will be routed from MM to DRTTO(NDIV). Can be zero if there is no return flow.
3	DRTMD(NDIV)	+	Routing method for diversion. See RTMD of RT card (field 3). Only linear methods are allowed.
4	DRTCOF(NDIV)	+	Routing coefficient "X" for diversion. See RTCOF of RT card (field 4).
5	DMUSK(NDIV)	+	Routing coefficient "K" for diversion. See XMUSK of RT card (field 5).
6	DCON(NDIV)	+	Percentage of flow (expressed as a ratio) diverted at MM which returns at DRTTO(NDIV). A .2 indicates 20% of diversion returns.
7	KDTY(NDIV)	0	Diversion flow is constant and equal to DFLOW(NDIV) on 8th field (QD card not needed).
		+	Each diversion flow from card QD is constant for KDTY periods and then the next flow on the QD card is used. For monthly operations, if KDTY = 1, 12 flow values on the QD card would provide monthly diversions that would cycle through for each years operation. The first diversion value must correspond to the starting time of the first flow value (IN card) unless ISTMO(J4.1) is used. For this option, diversions should not be made both from and to the same control point.

*Optional Card

DR Card - Continued

Field	Variable	Value	Description
		-1	Diversion quantity is a function of the inflows at control point MM according to the tables of CHQ (QS card) and FDQ (QD card).
		-2	Diversion quantity is a function of the reservoir storage for MM according to the tables of STOR (RS card) and FDQ (RD card).
8	DFLOW(NDIV)	0	Diversion flow is not constant.
		+	Diversion flow is constant and equal to DFLOW. Field 7 must be = 0.
9-10			Not used.

* QS Cards - River Discharges

Cards QS and SQ are read following RT cards when storage outflow data is required for Modified Puls or Working R&D routing (RTMD of RT card = .3 or .4).

Field	Variable	Value	Description
1	NPTSQ	+	Number of outflows on QS card and number of storages on SQ card. Maximum number = 18.
2-10	CHQ(M,N)	+	A table of river outflows in cfs or cubic meters per second at the downstream end of reach MM corresponding to the storages given on the SQ cards for use in non-linear flood routing from control point MM. NPTSQ values. Each value should be unique.

* SQ Card - Channel Storages

Field	Variable	Value	Description
1	NPTSQ	+	Number of outflows on QS card. Must correspond to the number of storages on SQ card.
2-10	CHSTG(M,N)	+	A table of channel storages in acre-feet or 1000 cubic meters corresponding to the outflows given on the QS cards. Storage represents total volume between control point MM and control point RTTO(M). NPTSQ Values.

---

*Optional Card

* QD Card - Diversion Flows

Field	Variable	Value	Description
1	X	+	Number of DQ(I,M) values on QD cards for control point.
2-10	FDQ(M,N)	+	When KDTY (field 7) of DR card = -1, fields 2-10 are the diversion flows corresponding to values of channel flow, CHQ(M,N), on the QS card. Maximum number = 18.
or			
2-10	DQ(I,M)	+	When KDTY (field 7) of DR card = 1 or more, DQ represents the diversion flow in cfs or cms for time periods composed of KDTY periods of IPER(J1.2 or BF.7). Maximum number = KPER.

*Optional Card

* EL Card - Elevation or stage for damage center at MM

Field	Variable	Value	Description
1	X	+	Number of outflows on QS card.
2-10	EL(M,N)	+	Elevation or stage in feet (or meters).

* C$ Card - Control point (local project) Cost Data

Field	Variable	Value	Description
1	DESQ	0	Damages for the modified channel are reflected in the second set of DC cards.
		+	Design discharge for the local project below which there are no damages. Damages described on the DC cards will be eliminated below this discharge if only one damage condition is provided. The channel capacity of field 2 of the CP card should be modified accordingly, but it can be different if desired.
2-19	COEF(N)	+	Capital (present worth) cost of the local project (channel modification, levee, floodwall, etc.) corresponding to the flows on the QS card. The design discharge (DESQ) will be used as the reference level for discharge in determining the cost of the project from the QS and C$ cards.

*Optional Card

* CC Card - Channel Capacities for Control Point

Optional card for varying the operational channel capacity with inflows at a control point. When this card is omitted, QMX (card CP.2) is used for the channel capacity.

Field	Variable	Value	Description
1	NK	+	Number of channel capacity values shown on this card up to 9 values (only 1 card can presently be read).
2-10	CHCAPT(K)	+	Channel capacity values at MM corresponding to the regulated flow (inflow) at MM on the QS cards. The table interpolation value of the channel capacity is used as the hydrograph progresses except that the channel capacity is never decreased from the previous period value. Thus, once the maximum channel capacity is reached, it is maintained throughout the remainder of the hydrograph.

* QM Card - Minimum desired flow which vary monthly(1)

Field	Variable	Value	Description
1	J	+	Number of minimum flows on QM cards for control point MM. Normally = 12. Maximum = 18.
2	FLDUR	+	Duration in days, for each minimum flow. Normally = 30.
3-14	COEF(I)	+	Minimum desired flow values for control point MM for J periods, each representing a duration of FLDUR. The first monthly value must be for the starting month of the flow data unless variable ISTMO(J4.1) is used.

---

*Optional Card

(1) QM Cards are assumed applicable to all floods. MR cards are not required for short interval flood periods if flows still vary monthly; but if they are used for any flood, they will override the monthly QM card data for that flood only.

*F. Damage Data (Cards DA-DC)

Evaluation can be made of the damages that would result from a single flood, a series of floods, or the expected value of annual damages (average annual damages). The evaluation is made for base conditions, modified conditions (regulated) and for conditions resulting from uncontrolled local flows below the reservoirs. Damages are assumed to be a unique function of peak flow rate and are computed at each damage center and for the basin as a whole. Total damage for a single flood or a series of floods can be evaluated by using only those floods. However, when computing the expected value of annual damages, at least 6 floods representing the full range of expected discharges should be processed. The J2 card controls the number of floods to be processed and the J3 card, field 7, provides the damage computation option. The DA, DF, DQ, and DC cards describe the flow frequency damage data required for each control point (nonreservoir).

If damages are not to be evaluated all cards DA-DC are omitted.

(1) DA Card - Damages (expected-annual) for base (normally natural) conditions.

Field	Variable	Value	Description
1	J	+	Number of damage categories to be read on this card. Must also equal the number of sets of DC cards to be read. Maximum of 9.
2-10	COEF(I)	0	Expected annual damages for base conditions are not given. The damages for base conditions will be computed from the input flow-damage-frequency functions and used in adjusting the integration procedure for the modified conditions as discussed below.
		+	Expected annual damage for base conditions for each of (J) damage categories.

---

*Optional Cards

(1) When DA card is read, all other damage cards (except DB) are required.

* DB Card - Base Damage Card for Existing System (card will follow the DA card if used)

The DB card may be used to input the expected annual damage for each damage category for an existing reservoir system. These expected damages are then substituted for natural (base) conditions expected damages so that the incremental reduction due to additions to the existing system can be displayed.

Field	Variable	Value	Description
1	J	+	Number of damage categories on the DA and DB cards.
2-10	COEF	+	Expected annual damages for each damage category in turn for this control point for existing reservoirs and other developments (base conditions) for which costs are not furnished.

(1) DF Card - Damage Frequencies

Field	Variable	Value	Description
1	K	+	Number of values of exceedence frequency on this DF card, of discharges on the DQ card and damages on each DC card. Maximum of 19 values.
2-10	COEF(I)	+	Exceedence frequencies, expressed as a ratio, read (in order of decreasing magnitude, i.e., .99, .95, etc.) from a frequency curve for each value of discharge on the DQ card. Values can be annual series or partial duration.

---

*Optional Card

(1) When DA card is read, all other damage cards (except DB) are required.

(1) DQ Card - Damage Discharge

Field	Variable	Value	Description
1	K	+	See field 1 of DF card.
2-10	COEF(I)	+	Discharges (K values) corresponding to the exceedence frequencies on the DF card. These discharges must be in increasing order of magnitude. Discharge values should be average values for the time interval used (IPER).

(1) DC Card

Base condition damages for each of J(DA.1) categories (one set for each damage category). (J sets of additional DC cards may be used if one represents base conditions and the second represents modified conditions from channel improvement or land purchase, etc.)

Field	Variable	Value	Description
1	N	+	Reserved for damage category identificaton (integer). Not used by program.
2-10	COEF(I)	+	Damage in dollars or multiples thereof corresponding to the same fields of the DF and DQ cards and for damage category N. All damages on these cards will be multiplied by ECFCT (field 2 of J3 card) to obtain the damages in dollars. (K(DQ.1) values on each set of cards. J(DA.1) sets of DC cards are used for base conditions and J additional sets may be used for modified conditions. Input for the J additional sets would follow the complete input for the base condition.

**Required Card

(1) When DA card is read, all other damage cards (except DB) are required.

G. End of Control Point Data

** ED Card - Required card at end of last set of RL-DC cards and just before IN card of first control point (or BF card).

Field	Variable	Value	Description
1	IDB	0	A BF card will not be read next.
		1	A BF card will be read next. All flow sets (IN cards, etc.) will start with a BF card and end with a EJ card.
2-10			Not used.

**Required Card

H. Flow Data [1]

* BF Card

Begin Flow Data Set (omit card unless field 1 of ED card is positive).

Field	Variable	Value	Description
1	FLOFMT	0	All flow data (Cards IN-EV) will be read using standard format of 10 fields per card. (First 2 fields of first card are used for identification and date.)
		1	All flow data (Cards IN-EV) will be read using control point identification (Columns 3-6), date (alphanumeric columns 7-8) and 12 flow fields per card (6 digits each - columns 9-14, 15-20, etc.). Same format as HEC-3.
		2	All flow data (Cards IN-EV) will be read using the standard format of 10 fields per card so that MM and DATE are read on the first card and the flows are read starting with the first field of the second card.

---

(1) Data after ED card represents flow data (except for BF and FC cards and monthly evaporation data). Data for each flood read (consult text for multiflood definition) is separated by an EJ card. For any set of flow data for a "flood" (could be NPER monthly periods) the set can be preceded by a single BF card and possibly by a single FC card (both are optional) followed by a set of IN cards (NPER values on each set) for each control point in the system (those omitted will be assumed as zero unless computed by a ratio of another station (see CP.3)), and followed, if desired, by sets of QA or NQ or MR or EV (NPER values on each set) for any or all of the control points or reservoirs, followed by an EJ card. The order of these cards is not important. Cards should be set up in order described above if convenient, however they could be set up in any order (NPER values of NQ for control point 5, NPER values of IN for control 10, etc.).

*Optional Card

BF Card - Continued

Field	Variable	Value	Description
2	NPER(1)	+	The number of periods of flow data on next set of cards (IN-EV). The value on J1 Card is ignored.
3	NPSTO	0	Reservoir storages are not transferred from one series of routings (called floods) to the next.
		+	The time period of the routing of the following flows, where the reservoir storages will be transferred to the subsequent routing. This is normally set equal to NPER less IFCAST(J2.3). When a monthly operation follows the current short interval flooding, NPSTO must equal NPER.
4	CNSTI(1)	+	Factor which is multiplied times all inflows and local flows on the next IN Cards. Value in first field of J2 card is ignored.
5	FLDAT(1)	+	Date corresponding to the first flow on the next IN Card. The data is an 8 digit number (2 digits each for year, month, day, hour) such as 54120223 for December 2, 1954 at 11 p.m. Date on J3.3 will not be used.
6	EPER(1)	+	Last computation period, if different from NPER. Field 6 of the J1 Card is ignored. Use (KPER -1) or less (49 on UNIVAC 1108).

(1) These values are not read unless greater than zero, thus the previous values of these variables are used from the BF or J1 or J2 Cards.

BF Card - Continued

Field	Variable	Value	Description
7	IPER(1)	+	Time interval (Δt) in hours between flows on next IN Cards. Field 2 of J1 Card will be ignored.
8	NDAYWK	0	Starting day will be assumed equal to Sunday.
		+	Day of week corresponds to the first flow on the next IN Cards.(1 = Sunday). Used in hydropower computations for power demand distributions less than or equal to a day.
9			Not used.
10	NFLCON(1)	+	Number of flood constants to be read on next card (FC Card must follow showing constants in field 1-9). CNSTI on BF card (4th field)is ignored. Maximum of 9.

* FC Card - Read only if NFLCON on BF card (BF.10) is positive.

Field	Variable	Value	Description
1-9	CNSTI	+	Ratios to multiply next set of flows read (IN cards) by to obtain additional system operations. NFLCON (BF.10) values are read.

---

(1) These values are not read unless greater than zero, thus the previous values of these variables are used from the J1 or J2 Cards or a previous BF card.

*Optional Card

** Card IN - Inflows or local flows for NPER(J1.1 or BF.2) periods. See BF.1 for card format for all flow data (IN, QA - PV).

Field	Variable	Value	Description
1	MM	+	Control point number. Equal to MM for RL and CP cards.
2	DATE	+	Starting date of flow in field 3 for identification only. Alphanumeric data such as: 6 June.
3	QII(I,M)	+	If ILOCAL(J1.8) is equal to 1, incremental local flows between M and the next upstream control points are read. If ILOCAL is equal to 10 or 15 observed gages are read and if = 20 or 25, natural flows are read.

Repeat IN cards for each control point in turn. IN cards for points not in system are ignored. Where IN cards are not read for a control point, flows are assumed = 0.

* QA Card - Specified reservoir releases for NPER(J1.1 or BF.2) periods for one or more reservoirs. Same format as IN cards.

Field	Variable	Value	Description
1	MM	+	Control point number.
2	DATE	+	Identification data (alphanumeric).
3+	QA(I,M)	0	Reservoir outflows for period I will be determined by computer.
		+	Reservoir outflows, in cfs or cubic meters per second for period I, specified by a positive number will be used instead of the computer-determined release. If a release of zero is desired, use .01. If specified release exceeds outlet capacity shown on RQ cards for corresponding storages on RS cards, release will be restricted to the appropriate maximum outlet capacity.

*Optional Card

**Required Card

* NQ Card - Base condition flows (normally natural flows but can be for an existing system) for NPER(J1.1 or BF.2) periods. Natural flows will be computed and printed, if these cards are omitted, and if FLONAT(J2.7) is set to -1.

Field	Variable	Value	Description
1	MM	+	Control point number.
2	DATE	+	Identification data (alphanumeric).
3-10	QPREP(I,M)	+	Base condition flows in cfs or cubic meters per second used for printout purposes and for expected annual damage base flows.

* MR Card - Minimum desired reservoir releases for NPER(J1.1 or BF.2) periods.

Field	Variable	Value	Description
1	MM	+	Control point number.
2	DATE	+	Identification data (alphanumeric).
3-10	QMIN(I,M)	+	Minimum desired reservoir release in cfs or cubic meters per second for reservoir MM, period I. Computer-determined releases will not be less than QMIN unless the reservoir is below level NLBUF(J1.7).

---

*Optional Card

* EV Card - Evaporation rates for reservoir MM only for NPER(J1.1 or BF.2) periods. Each rate will be multiplied by EVRTO(R2.3) if EVRTO is greater than zero.

Field	Variable	Value	Description
1	MM	+	Reservoir identification number.
2	DATE	+	Date of start of flood.
3-10	EVRATM(K,M)	+	Net evaporation minus precipitation rate in inches (or mm)/period over the reservoir area for each of NPER periods.

* PV Card - Power Requirements - By Period for Reservoir MM.

Field	Variable	Value	Description
1	MM	+	Reservoir identification number.
2	DATE	+	Identification date (alphanumeric)
3-10	POWR(I,M)	+	At-site power requirements in thousands kwh for each of NPER time periods. These values will override any values on PR, PD, or PH cards for this reservoir.

** EJ Card - Card read after last flow data.

Field	Variable	Value	Description
1-10			Not used.

I. Begin with T1 card for next job or use four blank cards after last job or if NFLRD(J2.5) is positive, enter next set of flow data, cards IN-EJ, (or BF-EJ card, if ED.1 is positive).

---

*Optional Card

**Required Card

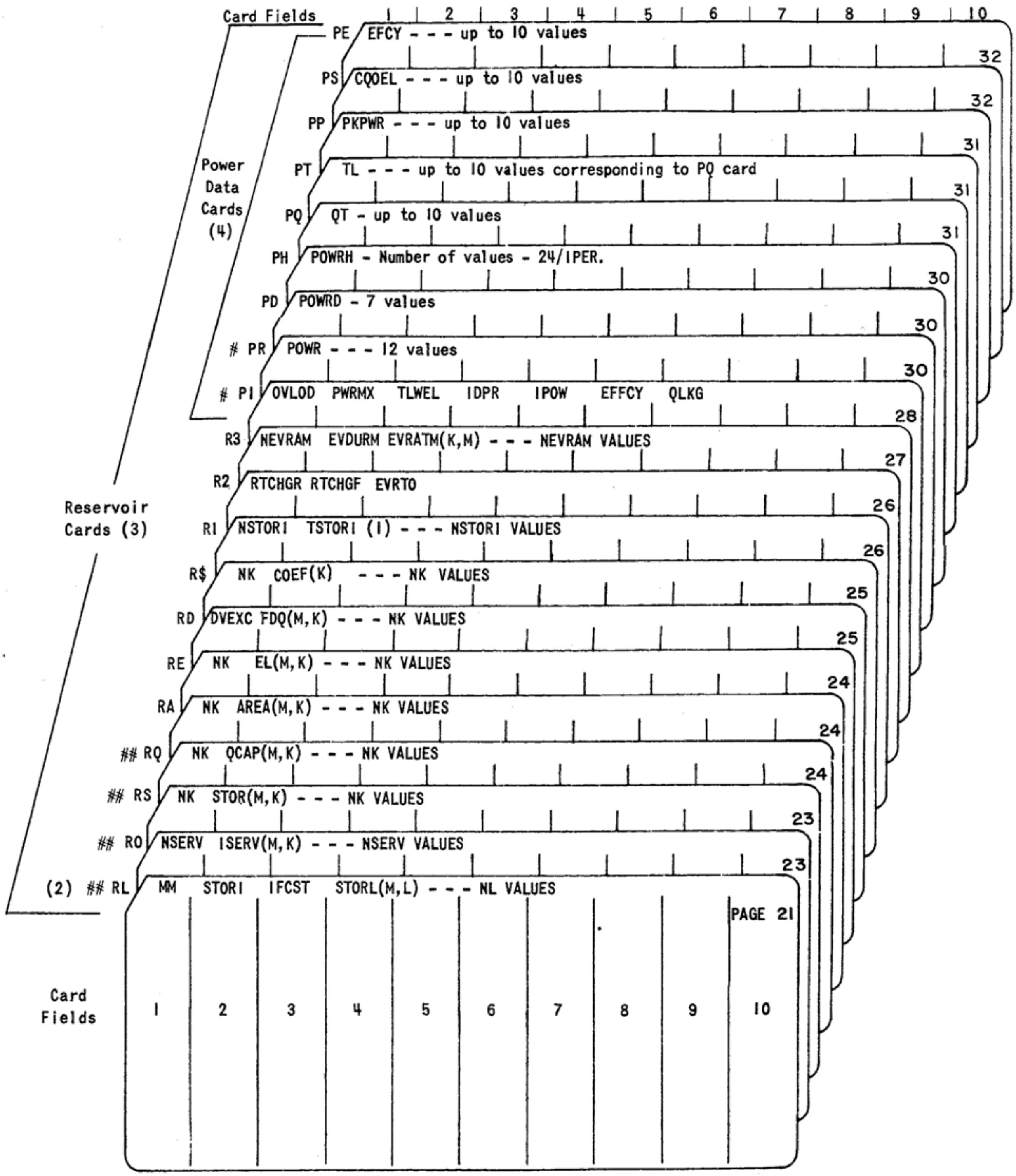
SUMMARY OF INPUT CARDS

Group	Card	1	2	3	4	5	6	7	8	9	10	PAGE*
Trace Cards	TP	NTRACE	ITRAP(1) - - - NTRACE VALUES									20
Trace Cards	TC	NTRAMX	MXTRA(1) - - - NTRAMX VALUES									20
Job Cards	J8	VPRT(1) up to 10 values per card. Maximum of 5 cards										19
Job Cards	J6	NEVAT	EVDUR	EVRAT(1) - - - 12 VALUES								18
Job Cards	J5	NRDEL	RESDEL(1) - - - NRDEL VALUES									18
Job Cards	J4	ISTMO										17
Job Cards	(1) J3	METRIC	ECFCT	FLDAT	BCRFAC	COSFAC	IPRECN	IDAMTP	ISCHED	IPRIO	IPLOT	13
Job Cards	** J2	CNSTI	CFLOD	IFCAST	RATCHG	NFLRD	IPRINT	FLONAT	NOROUT	NCPTR	TRACE	8
Job Cards	** J1	NPER	IPER	NL	NLI	NLM	EPER	NLBUF	ILOCAL	INFLOW	IOPMD	6
Title Cards	** T3											6
Title Cards	** T2											6
Title Cards	** T1	3 Output Title Cards										6

* Page number of Exhibit 7 where card is described

** Required Cards

(1) Cards without asterisk are optional



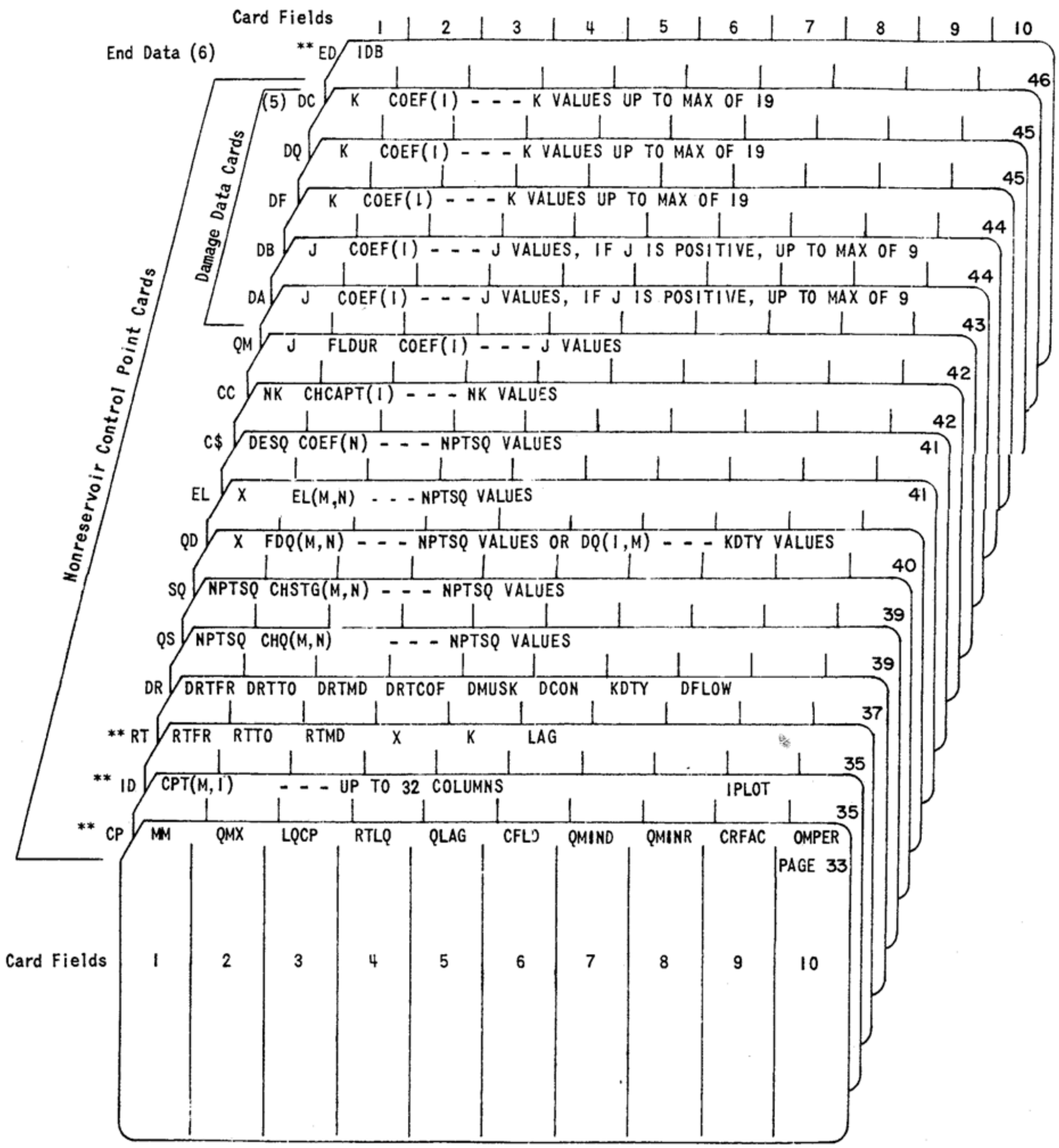
Required Cards for Reservoirs only

(2) Additional RL cards are used for any control point whose storage levels vary monthly

(3) Cards RL-DC are repeated for each control point in turn in downstream order. Cards RL-PE are omitted if control point is not a reservoir.

(4) Cards PI-PE are omitted if control point is not a power reservoir.

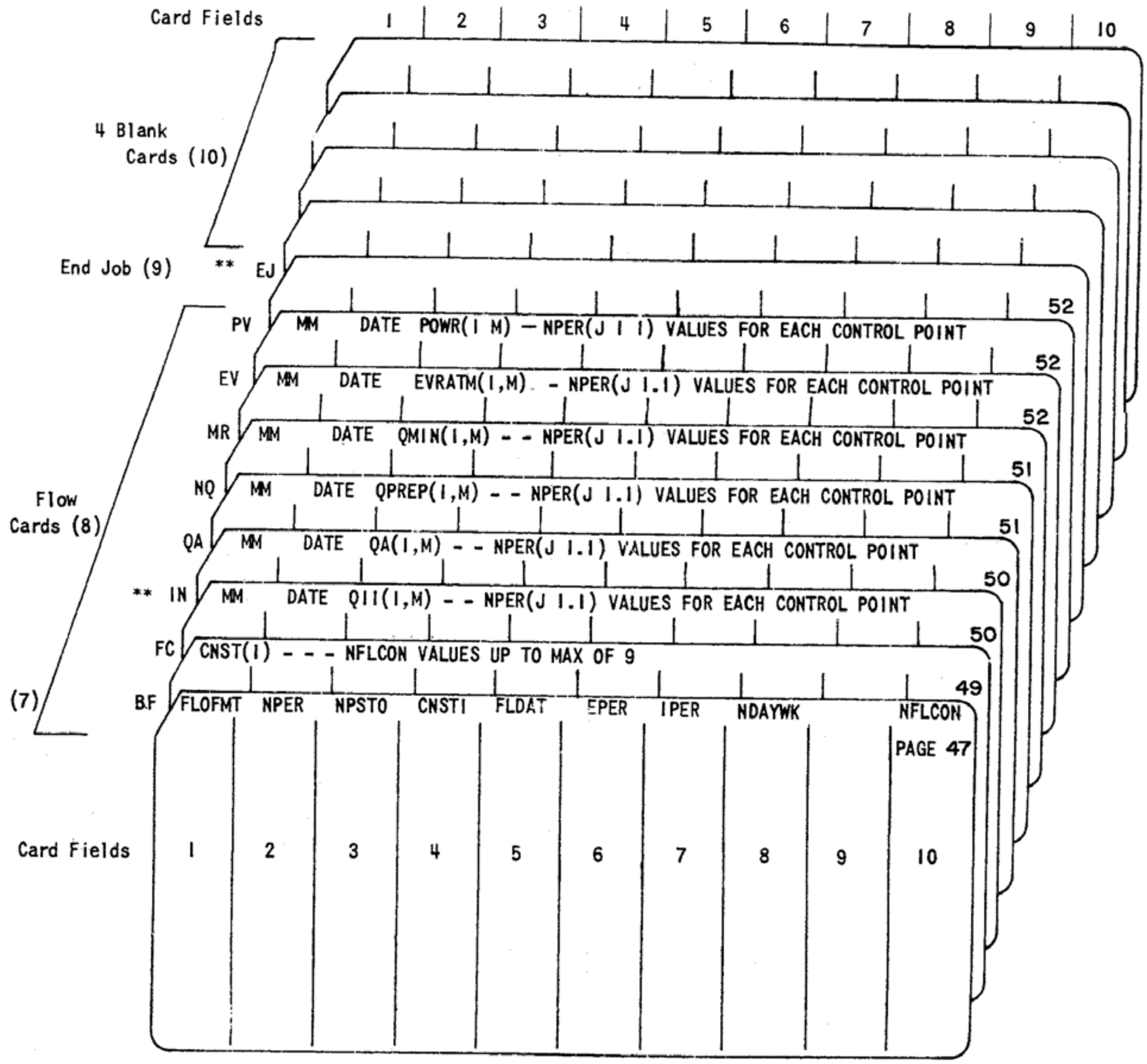
\# Cards PI and PR are required for power reservoirs.



** Required Cards

(5) Cards DA-DC (except DB) are required if damages are to evaluated.

(6) ED card follows last control point.



** Required Cards

(7) BF card is required when FC card is used or when IPER changes.

(8) NPER(J 1.1) items of flow data are read for each type of card (IN, QA, etc.) until all control points have been read, followed by NPER items for each control point for the next type of card.

(9) EJ card follows last flow data.

(10) The EJ card is followed by either

(a) 4 blank cards for last job

(b) TI - EJ for another separate job

(c) BF - EJ for multiple floods (NFLRD, J 2.5, is plus)

Appendix 2

Conduit Rating -
Partial Gate Openings

CONDUIT RATING - PARTIAL GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L224

JULY 1967

CORPS OF ENGINEERS, U. S. ARMY
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA

CONDUIT RATING - PARTIAL GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L224

CONTENTS

EXHIBITS

CONDUIT RATING - PARTIAL GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L224

1. ORIGIN OF PROGRAM

The original program was written in WIZ programming language for the Tulsa District's GE-225 computer by Mr. Warren L. Sharp. This version, in Fortran II, was prepared in the Hydrologic Engineering Center, Corps of Engineers, 650 Capitol Mall, Sacramento, California. Up-to-date information and copies of source statement cards for various types of computers can be obtained from the Center by Government and cooperating organizations.

2. PURPOSE OF PROGRAM

This program is designed to compute the discharge and hydraulic forces (upthrust and downthrust) for reservoir outlet structures with partial (vertical lift) gate openings. By varying gate openings and/or water levels for a given invert elevation, computations are made resulting in a convenient tabulation of conduit ratings.

3. DESCRIPTION OF EQUIPMENT

The program was prepared for use on the IBM 1620 computer with 40,000 digit, variable word length memory, card input and output, and is usable in the GE-225 and RCA-301 computers having comparable memory, providing that any required input and output statement changes are made.

4. METHOD OF COMPUTATION

The program uses the equation $Q = CG_oB\sqrt{2gH}$ as described in W.E.S. Hydraulic Design Criteria 320-1 to compute the discharge in cubic feet per second. Values of the discharge coefficient C may be furnished by the program user as desired or may be adopted from the above-mentioned criteria. The computation of upthrust and downthrust forces is also in accordance with W.E.S. criteria. Values of U_f/H and H_w/H from HDC 320-2/1 and 2/2 for Pine Flat Reservoir are included within the program, although other data may be used if desired.

5. INPUT

Input is summarized in Exhibits 5 and 6. All data are entered consecutively on each card, using 8 columns (digits, including decimal point, if used) per variable and 10 variables per card unless fewer are called for. The program is written for card input (required on the IBM 1620) which is satisfactory for high-speed computers, since there is so little input.

6. OUTPUT

Output consists of statements of basic input data, source of criteria and tabulation of discharge coefficients and hydraulic force data versus percent gate openings followed by blocks of computed data which include:

a. Gate opening above invert
b. Pool elevation, discharge and hydraulic forces
c. Computed and assigned constants

7. OPERATING INSTRUCTIONS

Standard FORTRAN II operating instructions are used. No sense switches are necessary.

8. DEFINITION OF TERMS

Terms used in this program are defined in Exhibit 3.

9. EXAMPLE

An example of program input and output is given in Exhibits 1 and 2.

10. PROPOSED FUTURE DEVELOPMENT

It is planned to modify the program output to produce a more convenient form of discharge-vs-elevation similar to the tables produced by HEC computer programs 23-J2-L233 and 22-J2-L225. Preference is given by reservoir regulation personnel for tables such as these over-plotted curves for reasons of accuracy and consistency. It is requested that any user of this program who finds desirable additions or modifications or inadequacies relating to the program, notify the Hydrologic Engineering Center.

SAMPLE INPUT

```
                TEST OF PROGRAM 22-J2-L224
USING HDC 320-1 CRITERIA AND GATE OPENING OF 1.0 FOOT
              TEST IS BEING RUN MAY 31, 1967
384     2   5.67     13     6.4    13.5
  1     1      5    465       0      42
```

EXHIBIT 1

SAMPLE OUTPUT

TEST OF PROGRAM 22-J2-L224
USING HDC 320-1 CRITERIA AND GATE OPENING OF 1.0 FOOT
TEST IS BEING RUN MAY 31, 1967
CONDUIT DISCHARGE RATING (PRESSURE FLOW)
PARTIAL GATE OPENINGS, 45 DEGREE GATELIP

NO. GATES	GATE WIDTH	GATE HEIGHT	INVERT ELEV.	TOP AREA	DRY WEIGHT
2	5.670	13.00	384.000	6.40	13.50

PERCENT GATE OPENING	DISCHARGE COEFFICIENT	UPTHRUST/ ENER HEAD	WELL HEAD/ ENER HEAD
0.00	.7290	1.0000	1.0000
5.00	.7293	.7600	.5500
10.00	.7297	.6800	.4750
15.00	.7300	.6300	.4650
20.00	.7310	.5800	.4700
25.00	.7330	.5400	.5000
30.00	.7355	.5200	.5300
35.00	.7390	.5000	.5300
40.00	.7425	.4900	.5000
45.00	.7470	.4850	.4600
50.00	.7530	.4850	.4250
55.00	.7590	.4900	.4000
60.00	.7665	.4950	.3700
65.00	.7746	.5050	.3500
70.00	.7825	.5200	.3200
75.00	.7920	.5250	.3000
80.00	.8030	.5200	.3150
82.00	.8075	.5100	.4150

(GATE OPENING - FEET ABOVE INVERT = .50)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
385.00	13.2	26.	.5	0.0	13.3
390.00	39.3	78.	4.5	0.0	12.5
395.00	54.1	108.	8.6	0.0	11.7
400.00	65.6	131.	12.7	0.0	10.9
405.00	75.3	150.	16.8	0.0	10.1
410.00	84.0	168.	20.9	3.2	9.9
415.00	91.8	183.	24.9	6.5	9.8
420.00	99.0	198.	29.0	9.8	9.6
425.00	105.7	211.	33.1	13.0	9.4
430.00	112.0	224.	37.2	16.3	9.3
435.00	118.0	236.	41.2	19.6	9.1
440.00	123.7	247.	45.3	22.8	9.0
445.00	129.1	258.	49.4	26.1	8.8
450.00	134.4	268.	53.5	29.4	8.6
455.00	139.4	278.	57.5	32.6	8.5
460.00	144.2	288.	61.6	35.9	8.3
465.00	148.9	297.	65.7	39.2	8.2

PERGO = 3.84, CVAL = .7292, COFIC = 16.590, UFH = .8153, HWH = .6538

(GATE OPENING - FEET ABOVE INVERT = 1.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
386.00	37.4	74.	.9	0.0	13.3
390.00	76.2	152.	3.7	0.0	12.7
395.00	106.3	212.	7.3	0.0	12.0
400.00	129.7	259.	10.9	0.0	11.3
405.00	149.4	298.	14.5	0.0	10.5
410.00	166.8	333.	18.1	0.0	9.8
415.00	182.6	365.	21.7	1.4	9.4
420.00	197.1	394.	25.2	3.9	9.2
425.00	210.6	421.	28.8	6.5	9.0
430.00	223.3	446.	32.4	9.0	8.8
435.00	235.3	470.	36.0	11.6	8.6
440.00	246.7	493.	39.6	14.1	8.4
445.00	257.7	515.	43.2	16.7	8.2
450.00	268.1	536.	46.7	19.2	8.0
455.00	278.2	556.	50.3	21.8	7.7
460.00	287.9	575.	53.9	24.3	7.5
465.00	297.3	594.	57.5	26.9	7.3

PERGO = 7.69, CVAL = .7295, COFIC = 33.194, UFH = .7169, HWH = .5096

EXHIBIT 2

(GATE OPENING - FEET ABOVE INVERT = 2.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
387.00	82.4	164.	.9	0.0	13.3
390.00	141.5	283.	2.8	0.0	12.9
395.00	205.2	410.	5.9	0.0	12.3
400.00	253.3	506.	9.1	0.0	11.6
405.00	293.6	587.	12.2	0.0	11.0
410.00	329.1	658.	15.3	0.0	10.4
415.00	361.1	722.	18.4	0.0	9.8
420.00	390.4	780.	21.6	1.0	9.3
425.00	417.7	835.	24.7	3.4	9.2
430.00	443.4	886.	27.8	5.7	9.0
435.00	467.6	935.	31.0	8.0	8.9
440.00	490.6	981.	34.1	10.3	8.7
445.00	512.6	1025.	37.2	12.7	8.5
450.00	533.7	1067.	40.4	15.0	8.4
455.00	554.0	1108.	43.5	17.3	8.2
460.00	573.6	1147.	46.6	19.6	8.1
465.00	592.5	1185.	49.8	22.0	7.9

PERGO = 15.38, CVAL = .7300, COFIC = 66.439, UFH = .6261, HWH = .4653

(GATE OPENING - FEET ABOVE INVERT = 3.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
388.00	134.2	268.	1.0	0.0	13.3
390.00	194.9	389.	2.1	0.0	13.0
395.00	296.5	593.	4.8	0.0	12.5
400.00	371.3	742.	7.6	0.0	11.9
405.00	433.4	866.	10.4	0.0	11.4
410.00	487.6	975.	13.2	0.0	10.8
415.00	536.4	1072.	15.9	0.0	10.3
420.00	581.1	1162.	18.7	.5	9.8
425.00	622.6	1245.	21.5	2.9	9.7
430.00	661.5	1323.	24.3	5.3	9.7
435.00	698.2	1396.	27.1	7.8	9.6
440.00	733.1	1466.	29.8	10.2	9.5
445.00	766.4	1532.	32.6	12.7	9.5
450.00	798.3	1596.	35.4	15.1	9.4
455.00	829.0	1658.	38.2	17.6	9.3
460.00	858.6	1717.	40.9	20.0	9.3
465.00	887.2	1774.	43.7	22.4	9.2

PERGO = 23.07, CVAL = .7322, COFIC = 99.953, UFH = .5553, HWH = .4884

EXHIBIT 2

(GATE OPENING - FEET ABOVE INVERT = 4.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
389.00	192.0	384.	1.0	0.0	13.2
390.00	234.1	468.	1.5	0.0	13.1
395.00	380.2	760.	4.1	0.0	12.6
400.00	484.0	968.	6.7	0.0	12.1
405.00	569.2	1138.	9.3	0.0	11.6
410.00	643.2	1286.	11.9	0.0	11.1
415.00	709.5	1419.	14.5	0.0	10.6
420.00	770.2	1540.	17.0	.5	10.1
425.00	826.4	1652.	19.6	3.1	10.2
430.00	879.0	1758.	22.2	5.8	10.2
435.00	928.6	1857.	24.8	8.4	10.2
440.00	975.7	1951.	27.4	11.1	10.2
445.00	1020.7	2041.	30.0	13.7	10.2
450.00	1063.7	2127.	32.5	16.4	10.2
455.00	1105.1	2210.	35.1	19.0	10.2
460.00	1145.0	2290.	37.7	21.7	10.2
465.00	1183.5	2367.	40.3	24.3	10.3

PERGO = 30.76, CVAL = .7360, COFIC = 133.964, UFH = .5169, HWH = .5300

(GATE OPENING - FEET ABOVE INVERT = 5.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
390.00	255.4	510.	1.1	0.0	13.2
395.00	455.5	911.	3.5	0.0	12.7
400.00	591.4	1182.	6.0	0.0	12.2
405.00	701.4	1402.	8.5	0.0	11.7
410.00	796.4	1592.	10.9	0.0	11.3
415.00	881.2	1762.	13.4	0.0	10.8
420.00	958.5	1917.	15.9	0.0	10.3
425.00	1030.0	2060.	18.3	.9	10.0
430.00	1096.9	2193.	20.8	3.5	10.0
435.00	1160.0	2320.	23.3	6.0	10.0
440.00	1219.7	2439.	25.7	8.6	10.0
445.00	1276.7	2553.	28.2	11.1	10.0
450.00	1331.3	2662.	30.7	13.7	10.1
455.00	1383.7	2767.	33.1	16.2	10.1
460.00	1434.2	2868.	35.6	18.8	10.1
465.00	1482.9	2965.	38.1	21.3	10.1

PERGO = 38.46, CVAL = .7414, COFIC = 168.680, UFH = .4930, HWH = .5092

EXHIBIT 2

(GATE OPENING - FEET ABOVE INVERT = 6.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
391.00	323.6	647.	1.2	0.0	13.2
395.00	521.2	1042.	3.1	0.0	12.8
400.00	693.1	1386.	5.5	0.0	12.3
405.00	830.1	1660.	8.0	0.0	11.9
410.00	947.5	1895.	10.4	0.0	11.4
415.00	1051.9	2103.	12.8	0.0	10.9
420.00	1146.9	2293.	15.2	0.0	10.4
425.00	1234.5	2469.	17.7	0.0	9.9
430.00	1316.3	2632.	20.1	0.0	9.4
435.00	1393.4	2786.	22.5	2.0	9.3
440.00	1466.3	2932.	24.9	4.2	9.3
445.00	1535.9	3071.	27.4	6.5	9.3
450.00	1602.4	3204.	29.8	8.7	9.2
455.00	1666.2	3332.	32.2	11.0	9.2
460.00	1727.7	3455.	34.6	13.3	9.2
465.00	1787.1	3574.	37.1	15.5	9.2

PERGO = 46.15, CVAL = .7483, COFIC = 204.316, UFH = .4850, HWH = .4519

(GATE OPENING - FEET ABOVE INVERT = 7.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
392.00	396.2	792.	1.3	0.0	13.2
395.00	575.9	1151.	2.7	0.0	12.9
400.00	789.2	1578.	5.2	0.0	12.4
405.00	956.0	1912.	7.6	0.0	11.9
410.00	1097.8	2195.	10.1	0.0	11.4
415.00	1223.2	2446.	12.5	0.0	10.9
420.00	1336.9	2673.	15.0	0.0	10.5
425.00	1441.7	2883.	17.4	0.0	10.0
430.00	1539.4	3078.	19.8	0.0	9.5
435.00	1631.2	3262.	22.3	0.0	9.0
440.00	1718.1	3436.	24.7	.5	8.6
445.00	1800.9	3601.	27.2	2.6	8.5
450.00	1879.9	3759.	29.6	4.6	8.4
455.00	1955.9	3911.	32.1	6.6	8.4
460.00	2028.9	4057.	34.5	8.6	8.3
465.00	2099.4	4198.	37.0	10.7	8.2

PERGO = 53.84, CVAL = .7576, COFIC = 241.309, UFH = .4888, HWH = .4057

(GATE OPENING - FEET ABOVE INVERT = 8.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
393.00	472.4	944.	1.4	0.0	13.2
395.00	616.3	1232.	2.4	0.0	13.0
400.00	878.4	1756.	4.9	0.0	12.5
405.00	1078.6	2157.	7.3	0.0	12.0
410.00	1247.0	2494.	9.8	0.0	11.5
415.00	1395.3	2790.	12.3	0.0	11.0
420.00	1529.3	3058.	14.8	0.0	10.5
425.00	1652.4	3304.	17.3	0.0	10.0
430.00	1767.0	3534.	19.8	0.0	9.5
435.00	1874.6	3749.	22.3	0.0	9.0
440.00	1976.3	3952.	24.8	0.0	8.5
445.00	2073.1	4146.	27.3	0.0	8.0
450.00	2165.5	4331.	29.8	.7	7.7
455.00	2254.1	4508.	32.2	2.5	7.5
460.00	2339.4	4678.	34.7	4.4	7.4
465.00	2421.7	4843.	37.2	6.2	7.3

PERGO = 61.53, CVAL = .7689, COFIC = 279.923, UFH = .4980, HWH = .3638

(GATE OPENING - FEET ABOVE INVERT = 9.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
394.00	551.2	1102.	1.5	0.0	13.1
395.00	637.3	1274.	2.0	0.0	13.0
400.00	958.1	1916.	4.6	0.0	12.5
405.00	1195.7	2391.	7.2	0.0	12.0
410.00	1393.4	2786.	9.8	0.0	11.5
415.00	1566.3	3132.	12.4	0.0	11.0
420.00	1722.0	3444.	14.9	0.0	10.5
425.00	1864.7	3729.	17.5	0.0	9.9
430.00	1997.2	3994.	20.1	0.0	9.4
435.00	2121.5	4243.	22.7	0.0	8.9
440.00	2238.9	4477.	25.3	0.0	8.4
445.00	2350.4	4700.	27.9	0.0	7.9
450.00	2456.9	4913.	30.5	0.0	7.4
455.00	2558.9	5117.	33.1	0.0	6.8
460.00	2657.0	5314.	35.7	.3	6.4
465.00	2751.7	5503.	38.2	2.0	6.2

PERGO = 69.23, CVAL = .7812, COFIC = 319.948, UFH = .5176, HWH = .3246

EXHIBIT 2

(GATE OPENING - FEET ABOVE INVERT = 10.00)

POOL ELEV	DISCHARGE ONE GATE	DISCHARGE ALL GATES	UPTHRUST (FT)	DOWNTHRUST (FT)	HOIST LOAD (TONS)
395.00	631.4	1262.	1.5	0.0	13.1
400.00	1027.1	2054.	4.2	0.0	12.6
405.00	1308.1	2616.	6.8	0.0	12.1
410.00	1538.7	3077.	9.4	0.0	11.6
415.00	1738.9	3477.	12.0	0.0	11.0
420.00	1918.3	3836.	14.6	0.0	10.5
425.00	2082.4	4164.	17.2	0.0	10.0
430.00	2234.4	4468.	19.8	0.0	9.5
435.00	2376.7	4753.	22.5	0.0	9.0
440.00	2511.0	5022.	25.1	0.0	8.4
445.00	2638.5	5277.	27.7	0.0	7.9
450.00	2760.0	5520.	30.3	0.0	7.4
455.00	2876.5	5753.	32.9	0.0	6.9
460.00	2988.4	5976.	35.5	0.0	6.3
465.00	3096.2	6192.	38.2	0.0	5.8

PERGO = 76.92, CVAL = .7962, COFIC = 362.298, UFH = .5230, HWH = .3057

EXHIBIT 2

DEFINITIONS - 22-J2-L224

A	- Top area of gate in ft^2 subjected to pressure due to water in the well head
B	- Width of gates in feet
C(N)	- Discharge coefficient (reference criteria)
COFIC	- Variable defined in equation Q = COFIC H
CVAL	- Computed value of discharge coefficient
DF	- Downthrust on top of gate in feet
EGEL	- Pool elevation in feet, m.s.l.
ELINV	- Invert elevation of intake water passage in feet, m.s.l.
ELMAX	- Maximum elevation desired for rating in feet, m.s.l.
GATES	- Number of intake water passages
GO	- Gate opening in feet
H	- Energy head in feet
HWH	- Head in gate well/Total energy head. See HDC 320-2/2
IND	- Test data indicator
KOUNT	- Counter for carriage control
KSLEW	- Indicator for number of blocks of output per page
KURVE	- Counter for incrementing gate openings
LPAGE	- Indicator for number of lines of output per page
OPEN	- Gate opening increments in feet
PERGO	- Computed gate opening in percent
PGO(N)	- Gate opening in percent (reference criteria)
Q1	- Discharge through one gate in c.f.s.
Q2	- Discharge through all gates in c.f.s.
SQRTF	- Library square root subroutine
STEP1	- First pool elevation =(ELINV + STEP1) in feet
STEP2	- Succeeding increments of pool elevations in feet
TITLE	- Array used to store title card information
UF	- Upthrust on bottom of gate in feet
UFH	- Upthrust/Head. See HDC 320-2/1
VI	- Velocity at the vena contracta in ft/sec.
W	- Dry weight of gate in tons
Y	- Height of gates in feet

SOURCE PROGRAM LISTING

```
*08054
C     PROGRAM 22-J2-L224, HYDROLOGIC ENGINEERING CENTER, JUNE 1966
C     FORTRAN 2           CONDUIT RATING - PARTIAL GATE OPENINGS
      DIMENSION PGO(18), C(18), TITLE(120),UFH(18),HWH(18)
C     READ THREE TITLE CARDS
  990 READ 995, (TITLE (I), I = 1,120)
      PUNCH 995, (TITLE(I), I=1,120)
  995 FORMAT (40A2)
  996 FORMAT (10F8.0)
      READ 996  ,ELINV,GATES,B,Y,A,W
      IF(GATES)1230,1230,1000
  998 FORMAT (4F8.0,6I8)
 1000 READ 998 ,OPEN,STEP1,STEP2,ELMAX,IND,LPAGE
      PUNCH 1002
 1002 FORMAT (20X, 40HCONDUIT DISCHARGE RATING (PRESSURE FLOW),20X)
      PUNCH 1003
 1003 FORMAT (20X, 40HPARTIAL GATE OPENINGS, 45 DEGREE GATELIP/)
      PUNCH 1004
 1004 FORMAT (1X,9HNO. GATES,4X,10HGATE WIDTH,3X,11HGATE HEIGHT,2X,12HIN
     1VERT ELEV.6X,8HTOP AREA,4X,10HDRY WEIGHT)
      IG=GATES
      PUNCH 1005, IG,B,Y,ELINV,A,W
 1005 FORMAT(I6,F15.3,F14.2,F14.3,F15.2,F13.2////)
C     CAN USE COEFFICIENTS FROM HDC 320-1 OR OTHER SOURCES
 1020 KURVE=1
      PAGE=LPAGE
      KSLEW = PAGE/((ELMAX - ELINV)/STEP2)
      KOUNT = 0
      IF (OPEN-1.) 1025,1030,1030
 1025 GO = OPEN
      GO TO 1044
 1030 GO=0.5
 1044 NCOEF=18
      PGO(1)=0.
      DO 1046 N=2,17
 1046 PGO(N)=PGO(N-1)+5.0
      PGO(18)=82.0
      C(1) =.729
      C(2) =.7293
      C(3) =.7297
      C(4) =.730
```

```
C(5) =.731
C(6) =.733
C(7) =.7355
C(8) =.739
C(9) =.7425
C(10) =.747
C(11) =.753
C(12) =.759
C(13) =.7665
C(14) =.7746
C(15) =.7825
C(16) =.792
C(17) =.803
C(18) =.8075
UFH(1) =1.0
UFH(2) =.76
UFH(3) =.68
UFH(4) =.63
UFH(5) =.58
UFH(6) =.54
UFH(7) =.52
UFH(8) =.50
UFH(9) =.49
UFH(10) =.485
UFH(11) =.485
UFH(12) =.49
UFH(13) =.495
UFH(14) =.505
UFH(15) =.52
UFH(16) =.525
UFH(17) =.52
UFH(18) =.51
HWH(1) =1.0
HWH(2) =.55
HWH(3) =.475
HWH(4) =.465
HWH(5) =.47
HWH(6) =.50
HWH(7) =.53
HWH(8) =.53
HWH(9) =.50
```

```
      HWH(10) =.46
      HWH(11) =.425
      HWH(12) =.40
      HWH(13) =.37
      HWH(14) =.35
      HWH(15) =.32
      HWH(16) =.30
      HWH(17) =.315
      HWH(18) =.415
      IF(IND-1) 1056,1050,1048
 1048 IF(IND-3) 1052,1050,1052
 1050 READ 996, (C(I),I=1,18)
 1052 IF(IND-2) 1056,1054,1054
 1054 READ 996,(UFH(I),I=1,18)
      READ 996,(HWH(I),I=1,18)
C     THE FOLLOWING DO-LOOP ROUNDS AND PRINTS PGO(N) AND C(N)
 1056 DO 1058 N=1,NCOEF
      PGO(N)=PGO(N)+.005
      C(N)=C(N)+.00005
      UFH(N)=UFH(N)+.00005
 1058 HWH(N)=HWH(N)+.00005
 1060 PUNCH 1061
 1061 FORMAT (18X, 23HPERCENT       DISCHARGE,7X,9HUPTHRUST/,5X,10HWELL
     1HEAD/)
 1062 PUNCH 1063, (PGO(N),C(N),UFH(N),HWH(N),N=1,NCOEF)
 1063 FORMAT (16X, 26HGATE OPENING   COEFFICIENT,6X,9HENER HEAD,6X,9HENE
     1R HEAD//(F24.2,3F15.4))
      DO 1064  N=1,NCOEF
      PGO(N)=PGO(N)-.005
      C(N)=C(N)-.00005
      UFH(N)=UFH(N)-.00005
 1064 HWH(N)=HWH(N)-.00005
C     SLEW TO NEXT PAGE
      PUNCH 1065
 1065 FORMAT (1H9)
 1070 IF (KURVE-1)1100, 1090, 1100
 1090 PERGO = (GO/Y)*100.
 1100 N = 2
 1110 IF (PGO(N)-PERGO)1111,1111,1120
 1111 N=N+1
      GO TO 1110
```

```
C     FOLLOWING STATEMENT INTERPOLATES FOR VALUES OF C
 1120 RTIO= (PERGO-PGO(N-1))/(PGO(N)-PGO(N-1))
      CVAL=RTIO*(C(N)-C(N-1))+C(N-1)
      UVAL=RTIO*(UFH(N)-UFH(N-1))+UFH(N-1)
      HVAL=RTIO*(HWH(N)-HWH(N-1))+HWH(N-1)
      EGEL=ELINV+STEP1
      J=1
 1130 PEGEL=EGEL
      IF (EGEL-(ELINV+GO))1140,1140,1141
 1140 EGEL=EGEL+1.0
      J=J+1
      GO TO 1130
 1141 PUNCH 1146, GO
 1146 FORMAT (7X, 36H(GATE OPENING - FEET ABOVE INVERT = , F7.2, 1H))
      PUNCH 1142
 1142 FORMAT (8X,61HPOOL  DISCHARGE  DISCHARGE   UPTHRUST  DOWNTHRUST  H
     1OIST LOAD)
     PUNCH 1143
 1143 FORMAT (8X, 59HELEV   ONE GATE  ALL GATES     (FT)       (FT)
     1  (TONS))
 1144 GO = GO + .005
 1147 GO = GO - .005
C     FOLLOWING STATEMENT IS FIRST OF MAIN LOOP FOR GIVEN GATE OPENING
 1150 H=EGEL-(ELINV+CVAL*GO)
 1160 Q1  =CVAL*GO*B*8.025*SQRTF(H)
      V1  =Q1/(CVAL*GO*B)
      Q2=GATES*Q1
      COFIC=CVAL*GO*B*8.025
      UF=UVAL*H
      HW=HVAL*H
      IF (HW-(Y+GO)) 1162,1164,1164
 1162 DF=0.0
      GO TO 1166
 1164 DF=HW-(Y+GO)
 1166 P=W+A*(DF-UF)*.0312
      EGEL=EGEL+.005
      PUNCH 1161,  EGEL, Q1, Q2,UF,DF,P
 1161 FORMAT (2X,F10.2,F10.1,F11.0,F10.1,F11.1,F13.1)
      EGEL=EGEL-.005
C     EGEL IS CHANGED BACK TO ELINV + STEP1 IN FOLLOWING
 1170 IF (J-1)1171,1180,1171
```

EXHIBIT 4

```
1171 EGEL=EGEL-1.0
     J=J-1
     GO TO 1170
1180 EGEL=EGEL+STEP2
     IF (EGEL-PEGEL)1180,1180,1181
1181 IF (ELMAX-EGEL)1182,1150,1150
1182 PUNCH 1183, PERGO, CVAL, COFIC, UVAL, HVAL
1183 FORMAT  (1X, 8HPERGO = , F6.2, 9H, CVAL = , F6.4, 10H, COFIC = , F
    19.3,8H, UFH = ,F6.4,8H, HWH = ,F6.4/)
     KURVE=KURVE+1
     IF (KURVE-2)1194,1194,1198
1194 IF (OPEN-1.)1198,1196,1196
1196 GO=GO+0.5
     GO TO 1210
1198 GO=GO+OPEN
1210 PERGO=(GO/Y)*100.
     IF (PERGO - PGO(NCOEF)) 1220,1220,990
1220 KOUNT = KOUNT + 1
     IF (KOUNT - KSLEW) 1070, 1223, 1070
1223 PUNCH 1065
     KOUNT = 0
     GO TO 1070
1230 CONTINUE
     END
```

INPUT DATA - 22-J2-L224

A. Three output title cards

B. Structural dimensions

1. ELINV - Invert elevation of water passage
2. GATES - Number of intake water passages
3. B - Width of gates
4. Y - Height of gates
5. A - Top area of one gate
6. W - Weight of one gate in tons

C. Job specification

1. OPEN - Gate opening increment
2. STEP1 - Vertical distance from invert to first pool elevation
3. STEP2 - Successive pool elevation increments
4. ELMAX - Maximum elevation desired for rating
5. IND - Indicate model (or prototype) test data being furnished.

IND	DATA BEING FURNISHED
0	None (program will use W.E.S. data)
1	Discharge coefficients
2	Hydraulic force data
3	Discharge coefficients and hydraulic force data

6. LPAGE - Lines of output desired per page.

All remaining data are versus 5% gate opening increments. The first and last values being for zero and 85% openings, respectively.

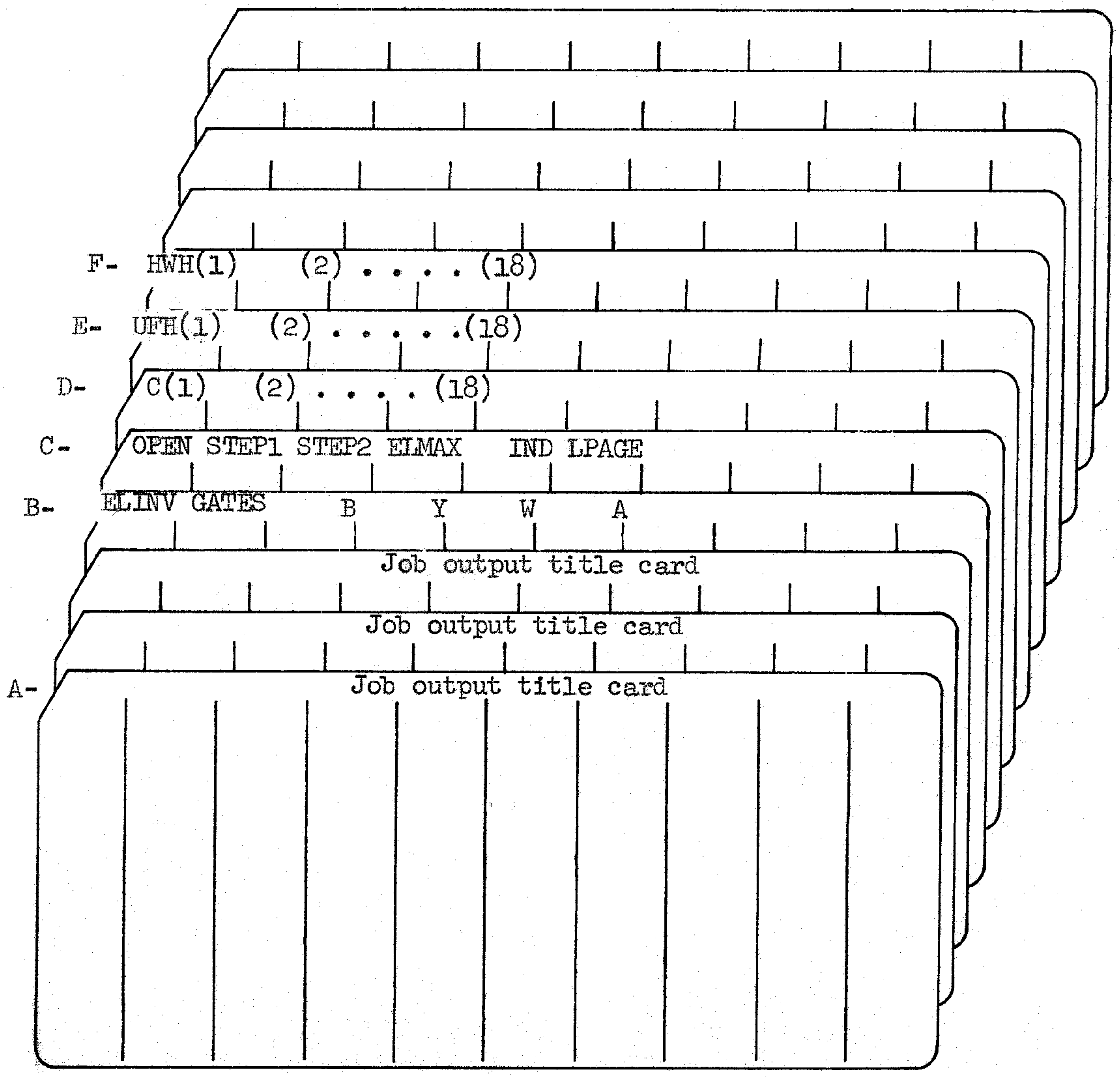
D. C(1) thru C(18) - Discharge coefficients

E. UFH(1) thru (18) - Values of Upthrust/Head

F. HWH(1) thru (18) - Values of gate well head/total energy head

EXHIBIT 5

SUMMARY OF REQUIRED CARDS



Notes:

1. Furnish D when IND equals 1 or 3.
2. Furnish E and F when IND equals 2 or 3.
3. Multiple runs may be performed. (Include title cards for each successive run).
4. Furnish <u>four</u> blank cards at end of data for normal exit.

Appendix 3

Spillway Rating - Partial Tainter Gate Openings

SPILLWAY RATING
PARTIAL TAINTER GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L225

JULY 1966

U. S. ARMY ENGINEER DISTRICT
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA

SPILLWAY RATING
PARTIAL TAINTER GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L225

CONTENTS

EXHIBITS

SPILLWAY RATING
PARTIAL TAINTER GATE OPENINGS

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L225

1. ORIGIN OR PROGRAM

This program was originally developed in the Tulsa District (No. 22-G1-G517) in WIZ language for the GE 225 by Warren L. Sharp. Conversion to Fortran has been performed at the Hydrologic Engineering Center, Corps of Engineers, 650 Capitol Mall, Sacramento, California, by the same author. Up-to-date information and copies of source statement cards for various types of Computers can be obtained from the Center upon request by Government and Cooperating organizations.

2. PURPOSE OF PROGRAM

This program was developed to compute the discharge for ogee-type weirs with partial tainter gate openings. Precise ratings can be obtained in a convenient table form for use in reservoir regulation sections or a limited volume of output can be obtained that is useful during the planning and design stages of a project. In either case, the accuracy of the input (discharge coefficients) prescribes the accuracy of the output. Partial gate opening ratings can be determined for any planned or existing ogee-spillway having radial-type gates. See paragraph 5 for special cases.

3. DESCRIPTION OF EQUIPMENT

This program was prepared for use in the IBM 1620 (FORTRAN II) and IBM 7090 (FORTRAN IV) classes. Due to memory limitations of the IBM 1620 (40,000 digit, variable word length, card input and output) the convenient table form is only obtainable using the Fortran IV version.

4. METHODS

In general, the computational procedure shown on W.E.S. Hydraulic Design Charts 311-1 to 311-5 is followed with the primary difference being in the determination of G_o (effective gate opening). The method used in computing G_o is shown on exhibit 3.1. This method eliminates the need for HDC-311-3 and is not limited to vertical face weirs, but also applies to overflow spillway crests with sloping upstream faces (Ref. HDC 111-7 to 111-10). Most project specifications require each gate opening to be the straight line distance (cord length) from the gate seat to the downstream side of the gate lip. Consequently, the determination of the gate seat coordinates (X_s, Y_s) is necessarily included in the program. The top of gate elevation for each gate opening and the ogee equation of the weir crest are also computed.

5. INPUT

The program is designed to simplify the most common usage although ratings for special cases may be performed with a limited amount of data preparation. The top of gate elevation is supplied for each gate opening in the output format, therefore the program may be used to assist in the determination of induced surcharge and/or gate regulation rating curves. In order to shorten run time, choose a large elevation increment (STEP 2). The job specification variables allow certain flexibilities in computation, thus broadening the application of the program. Gate opening increments of 1/2 foot or 1-foot are optional by means of "OPEN". In either case, the first two gate openings are 1/2 foot and 1 foot. The geometric quantities pertaining to each gate opening will be supplied (as output) when a positive value is given "LIST".

SPECIAL CASE 1

Provision is made to compute partial gate opening ratings for weir crests whose ogee equations follow the general form $Y = kX^p$, but are not included in the Hydraulic Design Criteria. For this condition, "k" (denoted as CAY for the computer) and "P" must be entered in accordance with the input format described on exhibits 5 and 6.

SPECIAL CASE 2

Discharge coefficient criteria shown on HDC 311-1 (for X_s/H_d = .1 to .3) is included in the program. If it is desired to use other coefficient data, such as would be obtained by measurement, then an array of "BETA" versus "C" can be supplied on input cards. With "NCOEF" positive, this data is read and used, otherwise the above mentioned Hydraulic Design Criteria is used. (Note that the maximum value of "BETA" must be 110 degrees.) Moreover, a tabulation of the discharge coefficient in terms of a parameter other than Beta, such as G_O, Cord or Y_L, can also be utilized. "BETA" is obtained as a function of the independent parameter by making an initial computer run with "LIST" positive (preferably with a large pool increment) and recording the respective geometrical quantities ("BETA" and either "GO", the gate opening, or Y_L). Elimination of the independent parameter allows the discharge coefficient "C" to be tabulated as an explicit function of "BETA". (This graphical procedure is shown on exhibit 3.3.) The program, supplied with the above array of "BETA" versus "C" (NCOEF positive), and the desired pool elevation interval, is again executed in order to compute the correct discharge curve.

SPECIAL CASE 3

Provision is made to determine ratings when the gate dial is calibrated in terms of some dimension other than the cord length, such as

G_O or Y_L. To accomplish this, an additional computer run can be made to obtain an array of the desired dial settings versus the corresponding cord lengths. Therefore the immediate objective of the first run is to obtain the "geometrical quantity" output ("LIST" positive) for each gate opening. It is advisable to supply a large increment for the pool elevation (STEP 2) to limit the run time. The ratings for this first run are based on whole numbered cord lengths and therefore are not the desired ratings. From the geometrical quantity output, plot a curve of the desired dial settings, say "GO", as absissa versus the quantity "CORD" as ordinate as shown on exhibit 3.4. Construct an array from this curve based on whole numbered GO values using a recommended interval of one foot. Supply this array (NDIAL positive) for a second computer run to obtain the desired ratings using the desired pool elevation interval.

6. OUTPUT

An example of the output format using an IBM 1620 is shown on exhibit 2. The convenient display shown on exhibit 2.2 will be obtained when using the Fortran IV version on a larger computer for pool elevation increments (STEP 2) of 1, .1 or .01 foot, otherwise the output will be in the form of exhibit 2. The values of the geometrical variables will be printed when a positive value is furnished "LIST".

7. OPERATING INSTRUCTIONS

Standard operating instructions for both the Fortran II and Fortran IV programs. No sense switches are used in either program.

8. DEFINITION OF TERMS

The nomenclature of the geometrical quantities is synoymous to that in the Hydraulics Design Criteria when similar dimensions are used. Other dimensions and angles used are shown on exhibit 3.2. The values of the nomenclature are NOT in terms of the design head as they are in HDC. The angle "BETA" is in degrees, all other angles are in radians and all linear dimensions are in feet.

9. EXAMPLES

Examples of the Fortran II and Fortran IV programs are shown in exhibits 1 and 2, respectively.

10. PROPOSED FUTURE DEVELOPMENT

It is anticipated that additions to or revisions of this program may be desirable from time to time. It is requested that any user who finds an inadequacy, desirable addition or modification notify the Hydrologic Engineering Center.

SAMPLE INPUT

```
JOHN DOE RESERVOIR
BLUE RIVER
TEST OUTPUT
  45  2757.5     6    40    30    30  29.89    10   1.0    0
   1     2.5     5                                1
```

EXHIBIT 1

SAMPLE OUTPUT (IBM 1620)

JOHN DOE RESERVOIR
BLUE RIVER
TEST OUTPUT

SPILLWAY RATING
PARTIAL TAINTER GATE OPENINGS

(HYDRAULIC DESIGN CHARTS 311-1 TO 311-5)

NOTE GATE DIAL SETTINGS ARE CALIBRATED IN TERMS OF THE
(CIRCLE CORRECT TERM)
EFFECTIVE OPENING (GO), CORD LENGTH, ARC LENGTH,

VERTICAL OPENING (YL), NONE OF THESE-(EXPLAIN)

PERTINENT DATA

CREST ELEV.	NO. GATES	GATE WIDTH	GATE HEIGHT
2757.50	6	40.00	30.00

OGEE DESIGN HEAD	TAINTER GATE RADIUS	TRUNNION COORDINATES X	TRUNNION COORDINATES Y
45.00	30.00	29.89	10.00

SLOPE OF WEIR FACE X	SLOPE OF WEIR FACE Y	GATE SEAT COORDINATES X	GATE SEAT COORDINATES Y
0.00	1.00	1.622803	-.048164

OGEE EQUATION Y=KX,WITH X RAISED TO THE POWER P.

K	P
.019667	1.850

EXHIBIT 2

GATE DIAL SETTING	TOP OF GATE ELEVATION	NUMBER OF GATES	EFFECTIVE OPENING
.50	2787.87	6	.46

POOL ELEVATION	DISCHARGE ONE GATE	DISCHARGE ALL GATES
2757.50	0.0	0.0
2760.00	152.9	917.8
2765.00	272.2	1633.3
2770.00	353.3	2119.8
2775.00	418.9	2513.8
2780.00	475.6	2853.9
2785.00	526.2	3157.6
2787.87	553.2	3319.3
2790.00	572.4	3434.5
2795.00	615.1	3690.7
2800.00	655.0	3930.3

```
.1459266E+01 $ XL      .4243341E-00 $ YL                   3 $ JTRIAL
.1459266E+01 $ CXL     .1436360E+01 $ XC     .3843057E-01 $ YC
.4633312E-00 $ GO      .2290562E-01 $ GX     .4627647E-00 $ GY
.3415403E-00 $ A1      .1562462E+01 $ A2     .1237589E+01 $ A3
.1666685E-01 $ A4      .1229256E+01 $ A5     .7297276E-00 $ A6
.7463945E-00 $ A7     -.4945734E-01 $ AMC   -.3248734E-00 $ ALFA
.6855242E+02 $ BETA    .6771314E-00 $ C      .2757692E+04 $ YPEL
.5000000E-00 $ CORD    .5000056E-00 $ ARC
```

GATE DIAL SETTING	TOP OF GATE ELEVATION	NUMBER OF GATES	EFFECTIVE OPENING
1.00	2788.23	6	.93

POOL ELEVATION	DISCHARGE ONE GATE	DISCHARGE ALL GATES
2758.50	152.2	913.6
2760.00	291.0	1746.3
2765.00	538.3	3229.9
2770.00	703.4	4220.7
2775.00	836.6	5019.7
2780.00	951.3	5707.9
2785.00	1053.6	6321.6
2788.23	1114.7	6688.6
2790.00	1146.8	6880.8
2795.00	1232.9	7397.8
2800.00	1313.5	7881.0

```
.1303615E+01 $ XL      .8995263E-00 $ YL                   3 $ JTRIAL
.1303615E+01 $ CXL     .1262376E+01 $ XC     .3026488E-01 $ YC
.9307052E-00 $ GO      .4123887E-01 $ GX     .9297911E-00 $ GY
.3415403E-00 $ A1      .1554128E+01 $ A2     .1245923E+01 $ A3
.3333487E-01 $ A4      .1229256E+01 $ A5     .7297276E-00 $ A6
.7630625E-00 $ A7     -.4432382E-01 $ AMC   -.3082054E-00 $ ALFA
.6980156E+02 $ BETA    .6778809E-00 $ C      .2757934E+04 $ YPEL
.1000000E+01 $ CORD    .1000046E+01 $ ARC
```

EXHIBIT 2

GATE DIAL SETTING	TOP OF GATE ELEVATION	NUMBER OF GATES	EFFECTIVE OPENING
2.00	2788.95	6	1.87

POOL ELEVATION	DISCHARGE ONE GATE	DISCHARGE ALL GATES
2759.50	425.7	2554.6
2760.00	514.9	3089.9
2765.00	1050.9	6305.4
2770.00	1394.1	8364.7
2775.00	1668.1	10008.9
2780.00	1903.1	11418.8
2785.00	2112.1	12672.8
2788.95	2263.4	13580.8
2790.00	2302.2	13813.4
2795.00	2477.8	14866.8
2800.00	2641.7	15850.3

.1016114E+01 $ XL	.1857596E+01 $ YL	4 $ JTRIAL
.1016114E+01 $ CXL	.9507436E-00 $ XC	.1791252E-01 $ YC
.1876648E+01 $ GO	.6537084E-01 $ GX	.1875509E+01 $ GY
.3415403E-00 $ A1	.1537456E+01 $ A2	.1262595E+01 $ A3
.6667901E-01 $ A4	.1229256E+01 $ A5	.7297276E-00 $ A6
.7964066E-00 $ A7	-.3484088E-01 $ AMC	-.2748613E-00 $ ALFA
.7225537E+02 $ BETA	.6800749E-00 $ C	.2758419E+04 $ YPEL
.2000000E+01 $ PCORD	.2000370E+01 $ ARC	

GATE DIAL SETTING	TOP OF GATE ELEVATION	NUMBER OF GATES	EFFECTIVE OPENING
3.00	2789.63	6	2.83

POOL ELEVATION	DISCHARGE ONE GATE	DISCHARGE ALL GATES
2760.50	783.7	4702.5
2765.00	1533.0	9198.5
2770.00	2068.6	12411.9
2775.00	2491.6	14949.8
2780.00	2852.5	17115.5
2785.00	3172.7	19036.4
2789.63	3442.9	20657.5
2790.00	3463.4	20780.4
2795.00	3731.5	22389.0
2800.00	3981.6	23889.6

.7605801E-00 $ XL	.2825259E+01 $ YL	4 $ JTRIAL
.7605801E-00 $ CXL	.6857286E-00 $ XC	.9786357E-02 $ YC
.2836034E+01 $ GO	.7485153E-01 $ GX	.2835046E+01 $ GY
.3415403E-00 $ A1	.1520775E+01 $ A2	.1279276E+01 $ A3
.1000417E-00 $ A4	.1229256E+01 $ A5	.7297276E-00 $ A6
.8297693E-00 $ A7	-.2639609E-01 $ AMC	-.2414986E-00 $ ALFA
.7465076E+02 $ BETA	.6822787E-00 $ C	.2758907E+04 $ YPEL
.3000000E+01 $ PCORD	.3001251E+01 $ ARC	

EXHIBIT 2

SAMPLE OUTPUT (7090 CLASS)

BLUE RIVER
TEST OUTPUT

SPILLWAY RATING
PARTIAL TAINTER GATE OPENINGS

(HYDRAULIC DESIGN CHARTS 311-1 TO 311-5)

NOTE GATE DIAL SETTINGS ARE CALIBRATED IN TERMS OF THE
(CIRCLE CORRECT TERM)
EFFECTIVE OPENING (GO), CORD LENGTH, ARC LENGTH,

VERTICAL OPENING (YL), NONE OF THESE-(EXPLAIN)

PERTINENT DATA

CREST ELEV.	NO. GATES	GATE WIDTH	GATE HEIGHT
2757.50	6	40.00	30.00

OGEE DESIGN HEAD	TAINTER GATE RADIUS	TRUNNION COORDINATES X	TRUNNION COORDINATES Y
45.00	30.00	29.89	10.00

SLOPE OF WEIR FACE X	SLOPE OF WEIR FACE Y	GATE SEAT COORDINATES X	GATE SEAT COORDINATES Y
0.	1.00	1.622804	-.048155

OGEE EQUATION Y=KX,WITH X RAISED TO THE POWER P.

K	P
.019668	1.850

EXHIBIT 2

EXHIBIT 2

GATE DIAL SETTING = .50 TOP GATE ELEV = 2787.37 NO OF GATES = 6 EFFECT. GATE OPENING = .46

POOL DISCHARGE IN CFS ONE GATE - ALL GATES

POOL ELEV	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
2758	56	64	72	79	85	91	96	101	106	111
	335	386	431	471	508	543	576	607	636	664
2759	115	120	124	128	132	135	139	143	146	150
	691	717	742	766	790	813	835	856	877	898
2760	153	156	159	163	166	169	172	175	178	180
	918	938	957	976	994	1013	1030	1048	1066	1082
2761	183	186	189	191	194	197	199	202	204	207
	1099	1116	1132	1148	1164	1179	1195	1210	1225	1240
2762	209	211	214	216	219	221	223	225	228	230
	1254	1269	1283	1297	1311	1325	1339	1352	1366	1379
2763	232	234	236	238	241	243	245	247	249	251
	1392	1405	1418	1431	1444	1456	1469	1481	1493	1506
2764	253	255	257	259	261	263	265	267	269	270
	1518	1530	1542	1553	1565	1577	1588	1600	1611	1622
2765	272	274	276	278	280	281	283	285	287	289
	1634	1645	1656	1667	1678	1688	1699	1710	1721	1731

5

JOHN DOE RESERVOIR

GATE DIAL SETTING = .50 TOP GATE ELEV = 2787.87 NO OF GATES = 6 EFFECT. GATE OPENING = .46

DISCHARGE IN CFS ONE GATE - ALL GATES

POOL ELEV	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
2766	290 1742	292 1752	294 1763	295 1773	297 1783	299 1793	301 1803	302 1814	304 1824	306 1834
2767	307 1844	309 1853	311 1863	312 1873	314 1883	315 1892	317 1902	319 1912	320 1921	322 1931
2768	323 1940	325 1949	325 1959	328 1968	330 1977	331 1987	333 1995	334 2005	336 2014	337 2023
2769	339 2032	340 2041	342 2050	343 2059	345 2068	346 2076	348 2085	349 2094	350 2103	352 2111
2770	353 2120	355 2128	356 2137	358 2145	359 2154	360 2153	362 2171	363 2179	365 2188	366 2196
2771	357 2204	369 2213	370 2221	372 2229	373 2237	374 2245	376 2253	377 2262	378 2270	380 2278
2772	381 2286	382 2294	384 2302	385 2309	386 2317	388 2325	389 2333	390 2341	391 2349	393 2356
2773	394 2354	395 2372	397 2380	398 2387	399 2395	400 2402	402 2410	403 2418	404 2425	405 2433
2774	407 2440	408 2448	409 2455	410 2463	412 2470	413 2477	414 2485	415 2492	417 2499	418 2507
2775	419 2514	420 2521	421 2523	423 2535	424 2543	425 2550	426 2557	427 2564	429 2571	430 2578

9

EXHIBIT 2

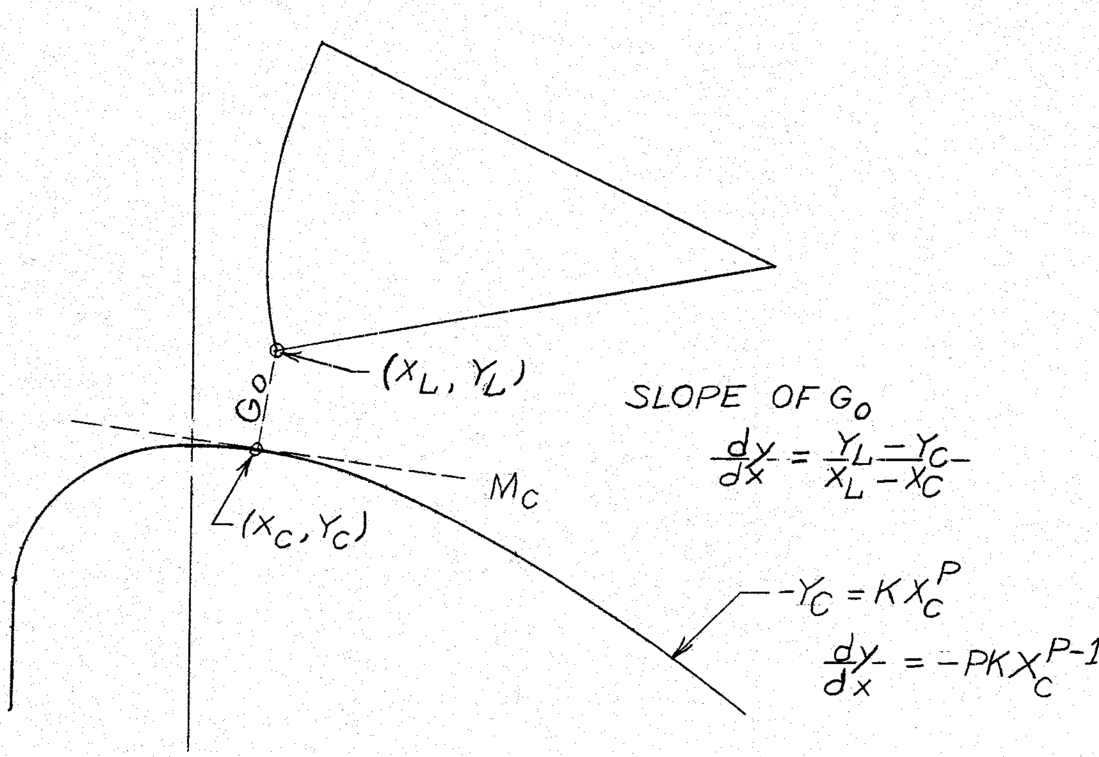
DEFINITIONS 23-J2-L225

Computer Designation	Description	Analytical Symbol	Units
A1	See exhibit 3.2		rad.
A2	See exhibit 3.2		rad.
A3	See exhibit 3.2		rad.
A4	See exhibit 3.2		rad.
A5	See exhibit 3.2		rad.
A6	An angle used in determining the top of gate elev.		rad.
A7	An angle used in determining the top of gate elev.		rad.
ALFA	See HDC 311-2		rad.
AMC	Angle the tangent line makes with horizontal	AMC	rad.
ANGLE	Same as BETA		
ARC	Arc subtended by A4: ARC = R*A4		
B	Width of tainter gates		
BETA	See HDC 311-2	β	
C	Discharge coefficient	C	
CAY	Constant in ogee equation, $Y = kX^p$	k	
CORD	Straight line distance from gate seat to downstream side of gate lip. (Cord length)		ft.
CREL	Elevation of spillway crest		ft. (msl)
CXL	Computed X_L		
DIAL	Gate opening corresponding to gate dial setting		
DX	Small horizontal component of S		

Computer Designation	Description	Analytical Symbol	Units
DY	Small vertical component of S		
EL	Pool elevation		
GATES	Number of tainter gates		
GO	Shortest distance from gate lip to ogee		
GX	Horizontal component of G_o		
GY	Vertical component of G_o		
H	Head, H = EL-YPEL	H	ft.
HD	Ogee Design head	H_d	ft.
HT	Height of tainter gates		ft.
IPAGE	Page number for each gate opening		
J	Counter		
JD	Index for DIAL, CORD		
JTRIAL	Number of trials required to compute X_c		
LINE	Counter used to slew page		
LIST	Indicator for printing geometrical values for each gate opening.		
M	Counter used to slew page		
N	Counter used in determining BETA		
NCOEF	Number of points defining B-VS-C curve		
NDIAL	Number of points defining DIAL-VS-CORD curve		
OPEN	Gate opening increment		
P	The power of X in ogee equation	P	
PCORD	Previous CORD		
PEL	Previous elevation		
PI	3.14159265		

Computer Designation	Description	Analytical Symbol	Units
PXC	Previous X_c		
PXL	Previous X_L		
Q1	Discharge through one tainter gate	Q	c.f.s.
Q2	Discharge through all tainter gates	Q	c.f.s.
R	Radius of tainter gates		
S	Slope of upstream face of weir		
SMC	Slope of tangent line to ogee at intersection G_o	MC	
LIST	Value of 1 causes printout of the geometrical quantities. If LIST = 0, that portion of the printout is suppressed.		
STEP1	Vertical distance from weir crest to first pool elev.		ft.
STEP2	Pool elevation intervals		ft.
TGEL	Top of gate elevation		
TXC	Temporary X_c		ft.
V	Velocity through each gate	V	
X	Horizontal component of CORD		ft.
XC	Horizontal distance from weir crest to intersection of G_o with the ogee	X_c	ft.
XC1	X_c for the previous gate opening		ft.
XC2	X_c for the time-before-last gate opening		ft.
XCORD	See CORD		
XDIAL	See DIAL		

Computer Designation	Description	Analytical Symbol	Units
XL	Horizontal distance from weir crest to bottom of gate	X_L	ft.
XT	Horizontal distance from weir crest to gate trunnion	Y_T	ft.
XS	Horizontal distance from weir crest to gate seat	X_s	ft.
Y	Vertical component of CORD		ft.
YC	Vertical distance from weir crest to intersection of G_o with the ogee	Y_c	ft.
YCEL	Elevation of Y_C	ELEV Y_C	ft. (msl)
YGT	Height of closed gate minus Y_T		ft.
YGTO	Vertical distance from trunnion to top of gate		
YL	Vertical distance from weir crest to bottom of gate	Y_L	ft.
YLEL	Elevation of Y_L	ELEV Y_L	ft. (msl)
YPEL	(ELEV Y_L + ELEV Y_C)/2	ELEV Y_P	ft. (msl)
YS	Vertical distance from weir crest to gate seat	Y_S	ft.
YT	Vertical distance from weir crest to gate trunnion	Y_T	ft.
Z	Used as decimal transfer in computing X_s		
ZERO	See exhibit 3.1		



GIVEN: X_L, Y_L, P & K.

SLOPE OF M_C $= -\frac{X_L - X_C}{Y_L - Y_C} = -PKX_C^{P-1}$

SUBSTITUTING: $\frac{X_L - X_C}{Y_L + KX_C^P} = PKX_C^{P-1}$

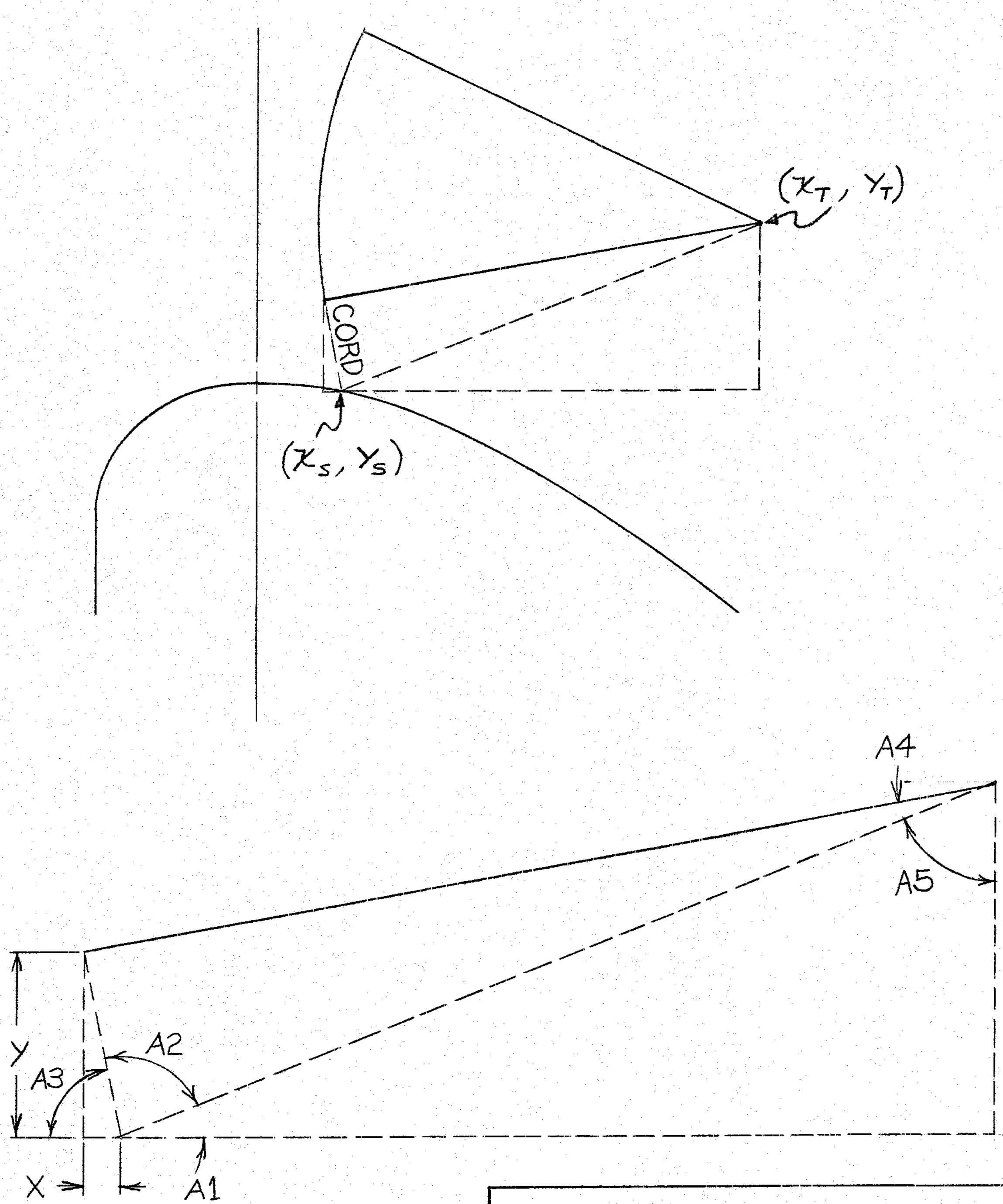
SOLVING: $\boxed{X_L = PKX_C^{P-1} Y_L + PKX_C^{P-1} \cdot KX_C^P + X_C}$

ASSUME VALUES OF X_C TO SATISFY A KNOWN X_L !

$$\boxed{G_o = \sqrt{(X_L - X_C)^2 + (Y_L - Y_C)^2}}$$

PARTIAL GATE OPENING
METHOD USED IN PROGRAM
FOR
DETERMINATION OF G_o

22-J 2-L225 Exhibit 3.1

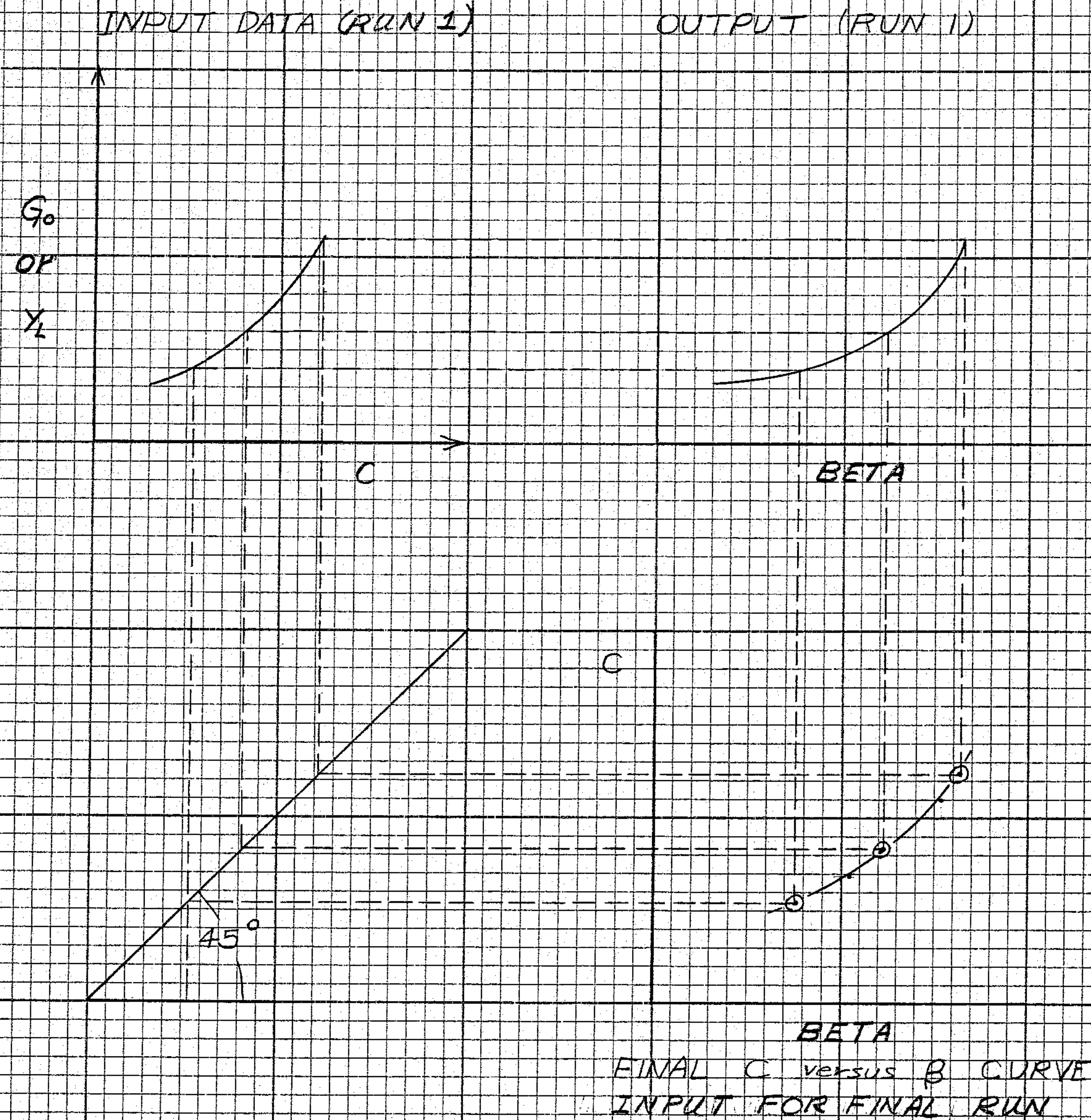


PARTIAL GATE OPENING VARIABLES

NOT SHOWN ON

HYDRAULIC DESIGN CHART 311-2

22-J2-L225 Exhibit 3.2



DETERMINATION OF DISCHARGE COEFFICIENTS "C" IN TERMS OF BETA WHEN NOT USING COEFF'S. SHOWN ON W.E.S.-HDC 311-1.

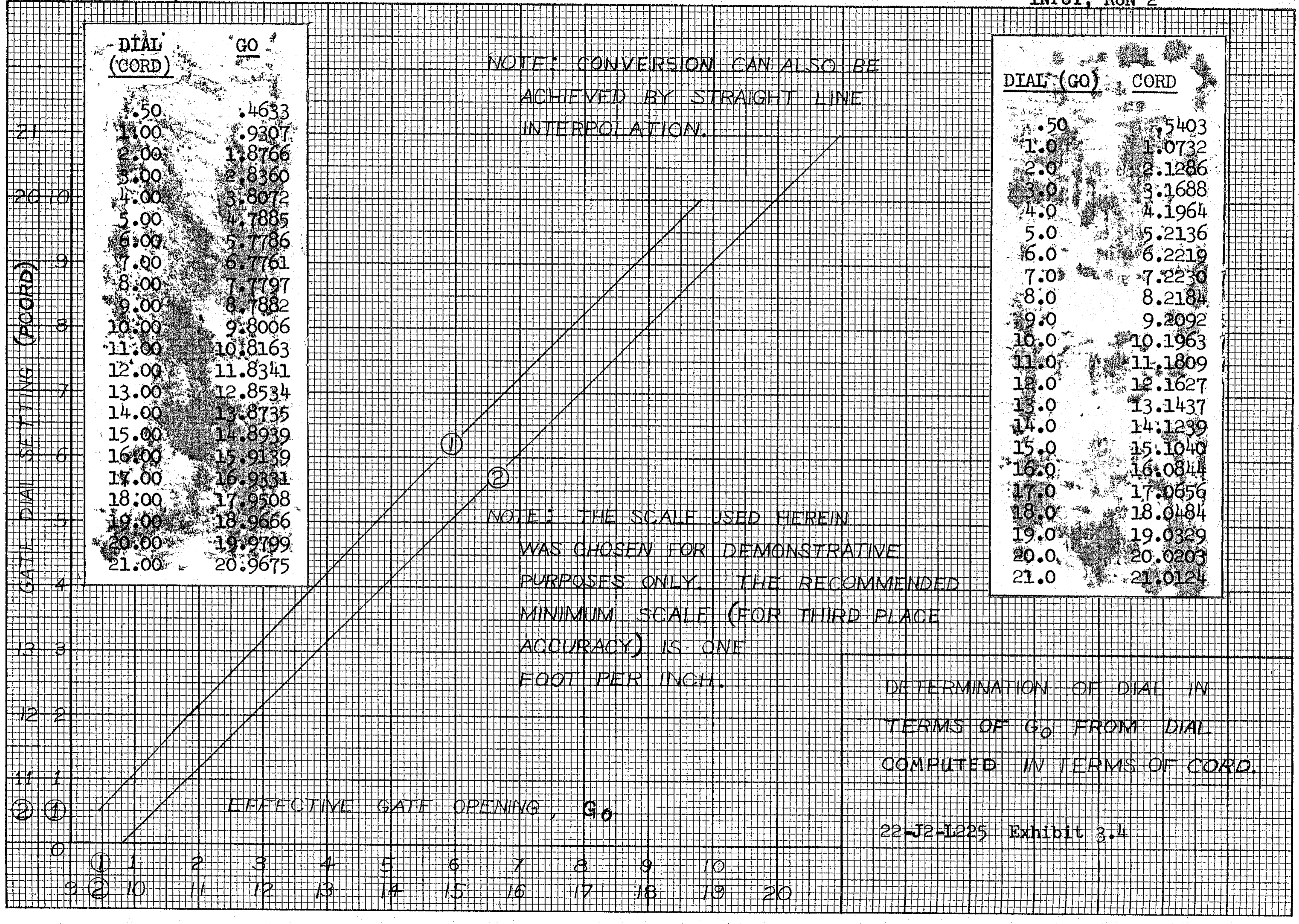
22-J2-L225 Exhibit 3.3

OUTPUT, RUN 1

DIAL (CORD)	GO
.50	.4633
1.00	.9307
2.00	1.8766
3.00	2.8360
4.00	3.8072
5.00	4.7885
6.00	5.7786
7.00	6.7761
8.00	7.7797
9.00	8.7882
10.00	9.8006
11.00	10.8163
12.00	11.8341
13.00	12.8534
14.00	13.8735
15.00	14.8939
16.00	15.9139
17.00	16.9331
18.00	17.9508
19.00	18.9666
20.00	19.9799
21.00	20.9675

INPUT, RUN 2

DIAL (GO)	CORD
.50	.5403
1.0	1.0732
2.0	2.1286
3.0	3.1688
4.0	4.1964
5.0	5.2136
6.0	6.2219
7.0	7.2230
8.0	8.2184
9.0	9.2092
10.0	10.1963
11.0	11.1809
12.0	12.1627
13.0	13.1437
14.0	14.1239
15.0	15.1040
16.0	16.0844
17.0	17.0656
18.0	18.0484
19.0	19.0329
20.0	20.0203
21.0	21.0124



NOTE: CONVERSION CAN ALSO BE ACHIEVED BY STRAIGHT LINE INTERPOLATION.

NOTE: THE SCALE USED HEREIN WAS CHOSEN FOR DEMONSTRATIVE PURPOSES ONLY. THE RECOMMENDED MINIMUM SCALE (FOR THIRD PLACE ACCURACY) IS ONE FOOT PER INCH.

DETERMINATION OF DIAL IN TERMS OF G_0 FROM DIAL COMPUTED IN TERMS OF CORD.

22-J2-L225 Exhibit 3.4

SOURCE PROGRAM LISTING (IBM 1620)

```
*10084
C       SPILLWAY RATING - PARTIAL TAINTER GATE OPENINGS
C       U.S. ARMY CORPS OF ENGINEERS - HYDROLOGIC ENGINEERING CENTER
C       PROGRAM NO. 22-J2-L225    FOR IBM 1620        W.L.SHARP (AUTHOR)
        DIMENSION BETA(14),C(14),DIAL(50),CORD(50)
     60 FORMAT (40A2)
     65 DO 70 J=1,3
        READ 60, (DIAL(I), I=1,40)
     70 PUNCH 60, (DIAL(I), I=1,40)
        IPAGE=2
        READ 390, HD,CREL,GATES,B,HT,R,XT,YT,DY,DX
        IF (HD) 1270,85,85
     85 READ 90, OPEN,STEP1,STEP2,CAY,P,NCOEF,NDIAL,LIST
     90 FORMAT (5F8.0,5I8)
        IF (NCOEF) 100,100,120
    100 BETA(1)=0.
        BETA(2)=50.
        DO 110 J=3,14
    110 BETA(J)=BETA(J-1)+5.
        C(1)=.66
        C(2)=.6685
        C(3)=.67
        C(4)=.672
        C(5)=.675
        C(6)=.678
        C(7)=.6826
        C(8)=.688
        C(9)=.695
        C(10)=.705
        C(11)=.716
        C(12)=.7285
        C(13)=.742
        C(14)=.755
    120 PI=3.14159265
        MS=28
        IF (R) 150,150,160
    150 R=HT
        XT=HT
        YT=HT/3.
    160 IF (CAY) 170,170,310
    170 IF (DX) 180,220,180
```

EXHIBIT 4

```
  180 S=DY/DX
      IF(S-10.) 230,220,220
  220 CAY=1./(2.*HD**.85)
      P=1.85
C     VERTICAL FACE
      GO TO 310
  230 IF(S-3.) 250,240,250
  240 CAY=1./(1.936*HD**.836)
      P=1.836
C     3 ON 1 FACE
      GO TO 310
  250 IF (S-1.5) 270,260,270
  260 CAY=1./(1.939*HD**.81)
      P=1.81
C     3 ON 2 FACE
      GO TO 310
  270 IF (S-1.) 290,280,290
  280 K=1./(1.873*HD**.776)
      P=1.776
C     1 ON FACE
      GO TO 310
  290 PUNCH 300
  300 FORMAT (76HOGEE EQUATION NOT GIVEN IN HYDRAULIC DESIGN CRITERIA FO
     1R SPECIFIED SLOPE OF /13HUPSTREAM FACE)
      GO TO 1250
  310 J=0
      Z=10.
      XS=(XT-R)+.01
      IF (XS) 320,320,330
  320 XS=.01
  330 ZERO=SQRTF(R*R -((XT-XS)*(XT-XS)))-YT-CAY*XS**P
      IF (ZERO) 340,370,350
  340 XS=XS+(Z*.1)
      GO TO 330
  350 IF (J-7) 360,370,360
  360 J=J+1
      Z=Z*.1
      XS=XS-Z
      GO TO 330
  370 YS=-CAY*XS**P
      IF (NCOEF) 415,415,380
```

```
380 READ 390,(BETA(N), N=1,NCOEF)
390 FORMAT (10F8.0)
    READ 390, (C(N), N=1,NCOEF)
415 A1=ATANF(SQRTF(R*R-((XT-XS)*(XT-XS)))/(XT-XS))
    PUNCH 420
420 FORMAT (/////27X15HSPILLWAY RATING/19X29HPARTIAL TAINTER GATE OPEN
   1INGS//13X41H(HYDRAULIC DESIGN CHARTS  311-1 TO 311-5)//6X55HNOTE
   1GATE DIAL SETTINGS ARE CALIBRATED IN TERMS OF THE/26X21H(CIRCLE CO
   1RRECT TERM)/12X48HEFFECTIVE OPENING (GO), CORD LENGTH, ARC LENGTH,
   1)
    PUNCH 430, CREL,GATES,B,HT
430 FORMAT (/12X46HVERTICAL OPENING (YL), NONE OF THESE-(EXPLAIN)////2
   16X14HPERTINENT DATA///6X11HCREST ELEV.,5X9HNO. GATES,5X10HGATE WID
   1TH,6X11HGATE HEIGHT/6XF8.2,10XI5,7XF8.2,7XF8.2//)
    PUNCH 440,HD,R,XT,YT
440 FORMAT (9X4HOGEE,10X7HTAINTER,8X20HTRUNNION COORDINATES/5X11HDESIG
   1N HEAD,5X11HGATE RADIUS,9X1HX,14X1HY/6XF8.2,7XF8.2,7XF8.2,7XF8.2/)
    PUNCH 450,DX,DY,XS,YS
450 FORMAT (10X18HSLOPE OF WEIR FACE,10X21HGATE SEAT COORDINATES/11X1H
   1X,14X1HY,14X1HX,14X1HY/6XF8.2,7XF8.2,5XF10.6,5XF10.6)
    YS=-YS
    M=1
    P=P+.00001
    JD=1
    CAY=CAY+.0000005
    PUNCH 460, CAY,P
460 FORMAT (//6X48HOGEE EQUATION Y=KX,WITH X RAISED TO THE POWER P./4X
   11HK,14X1HP/F10.6,7XF8.3/79X1H9)
    CAY=CAY-.0000005
    P=P-.00001
    IF (NDIAL) 470,470,480
470 XCORD=.5
    GO TO 520
480 READ 390, (DIAL(JD), JD=1,NDIAL)
    READ 390, (CORD(JD), JD=1,NDIAL)
    JD=1
    XDIAL=DIAL(JD)
    XCORD=CORD(JD)
520 A2=ATANF(SQRTF(R*R-((XCORD/2.)*(XCORD/2.)))/(XCORD/2.))
    LINE=0
    JU=0
```


EXHIBIT 4

```
      IF(A1+A2-PI/2.) 530,540,550
  530 A3=(PI/2.)-(A1+A2)
      Y=XCORD*COSF(A3)
      X=(XCORD*SINF(A3))*(-1.)
      GO TO 560
  540 Y=XCORD
      X=XS
      GO TO 560
  550 A3=PI-(A1+A2)
      Y=XCORD*SINF(A3)
      X=XCORD*COSF(A3)
  560 YL=Y-YS
      XL=XS-X
      A4=PI-2.*A2
      A5=PI/2.-A1
      ALFA=A4+A5-PI/2.
      YGT=HT-YT
      ARC=R*A4
      A6=ATANF(YGT/SQRTF(R*R-YGT*YGT))
      A7=A6+A4
      YGTO=R*SINF(A7)
      TGEL=CREL+YT+YGTO
      IF (XL)570,570,580
  570 GO=YL
      GY=YL
C     BOT OF GATE AT(OR UPSTREAM OF)AXIS
      JTRIAL=0
      SMC=0.
      AMC=0.
      YC=0.
      XC=0.
      CXL=0.
      GX=0.
      GO TO 790
  580 JTRIAL=0
      IF (JD-1) 590,590,600
  590 XC=XS-.2
C     FOR FIRST GATE OPENING
      GO TO 650
  600 IF (JD-2) 605,605,610
  605 XC=2.*XC1-XS-.0005
```

4

```
C       FOR SECOND GATE OPENING
        GO TO 650
  610 IF(YT-YL) 640,620,630
C       FOR SUCCEEDING GATE OPENINGS
  620 XC=XC1
        GO TO 650
  630 XC=2.*XC1-XC2+.0005
C       BOT GATE BELOW TRUN
        IF(XC) 620,650,650
  640 XC=2.*XC1-XC2-.0005
C       BOT GATE ABOVE TRUN
        IF (XC) 620,650,650
  650 CXL=P*CAY*XC**(P-1.)*(YL+CAY*XC**P)+XC
        JTRIAL=JTRIAL+1
        IF (XL-CXL)660,760,670
  660 IF (XL-CXL+.00001) 680,760,760
  670 IF (XL-CXL-.00001) 760,760,680
  680 IF (JTRIAL-1) 690,690,730
  690 PXC=XC
        PXL=CXL
        IF (CXL-XL) 700,700,720
  700 XC=XC+.005
        IF (XC) 710,710,650
  710 XC=.0005
        GO TO 650
  720 XC=XC-.005
        IF ( XC) 710,730,650
  730 TXC=XC
        XC=((PXC-TXC)*(XL-CXL)/(PXL-CXL))+TXC
        IF (XC) 740,740,750
  740 XC=TXC/2.
  750 PXC=TXC
        PXL=CXL
        GO TO 650
  760 IF(JD-1) 770,780,770
  770 XC2=XC1
  780 XC1=XC
        YC=CAY*XC**P
        GX=XL-XC
        GY=YL+YC
        GO=SQRTF(GX*GX+GY*GY)
```

```
      SMC=-P*CAY*XC**(P-1.)                                             2290
      AMC=ATANF(SMC)                                                    2300
  790 ANGLE=PI/2.+AMC+ALFA                                              2310
C     RADIANS                                                           2320
      ANGLE=ANGLE*57.29578                                              2330
C     DEGREES                                                           2340
      IF (ANGLE-110.) 800,800,1250                                      2350
  800 IF (NDIAL) 810,810,820
  810 XDIAL=XCORD                                                       2370
  820 TGEL=TGEL+.005                                                    2375
      PUNCH 830,XDIAL,TGEL,GATES,GO
  830 FORMAT (5X9HGATE DIAL,7X11HTOP OF GATE,6X6HNUMBER,7X9HEFFECTIVE/6X 2390
     17HSETTING,9X9HELEVATION,6X8HOF GATES,7X7HOPENING/6XF8.2,7XF8.2,10X 2400
     1I4,7XF8.2/)                                                       2410
      TGEL=TGEL-.005                                                    2413
      IF (NUM-1) 840,840,850                                            2415
  840 PUNCH 845                                                         2420
  845 FORMAT (9X4HPOOL,9X9HDISCHARGE/6X9HELEVATION,7X8HONE GATE)        2425
      GO TO 857                                                         2427
  850 PUNCH 855                                                         2430
  855 FORMAT (9X4HPOOL,9X9HDISCHARGE,10X9HDISCHARGE/6X9HELEVATION,7X8HON 2435
     1E GATE,11X9HALL GATES)                                            2440
  857 IF (LINE-MS) 865,865,860                                          2450
  860 LINE=1                                                            2460
      IPAGE=IPAGE+1                                                     2470
      GO TO 960                                                         2480
  865 N=1                                                               2490
  870 IF (BETA(N)-ANGLE) 880,880,890                                    2500
  880 N=N+1                                                             2510
      GO TO 870                                                         2520
  890 CV=((ANGLE-BETA(N-1))/(BETA(N)-BETA(N-1))*(C(N)-C(N-1)))+C(N-1)   2530
      YLEL=CREL+YL                                                      2540
      YCEL=CREL-YC                                                      2550
      YPEL=(YLEL+YCEL)/2.                                               2560
      J=1                                                               2570
      EL=CREL+STEP1                                                     2580
      ELS1=EL                                                           2590
      PEL=EL                                                            2600
      IF (YL) 910,900,900                                               2620
  900 INT=1.25*YL                                                       2630
      FP=INT                                                            2640
```

```
      EL=CREL+FP
      PEL=EL
      J=J+1
  910 H=EL-YPEL
      IF (H) 920,930,930
  920 H=0.
  930 Q1=CV*GO*B*SQRTF(H)*8.025
      V=Q1/(CV*GO*B)
      Q2 = GATES*Q1
      LINE=LINE+1
  937 IF (LINE-MS) 960,960,940
  940 PUNCH 1190
      PUNCH 950,IPAGE
  950 FORMAT (23X4HPAGE/21XI4/79X1H9)
      GO TO 800
  960 IJEL=100.*(EL+.005)
      EL=IJEL
      EL=EL/100.
      IF (NUM-1) 962,962,964
  962 PUNCH 963, EL,Q1
  963 FORMAT (6XF8.2,7XF8.1)
      GO TO 978
  964 PUNCH 965, EL,Q1,Q2
  965 FORMAT (6XF8.2,7XF8.1,12XF9.1)
  978 IF (J-1) 990,1000,990
  990 EL=ELS1-STEP2
      J=J-1
      GO TO 978
 1000 EL=EL+STEP2
      IF (EL-PEL) 1000,1000,1010
 1010 IF (EL-TGEL) 910,1015,1015
 1015 IF (JU) 1020,1020,1030
 1020 JU=1
      TEL=EL
      EL=TGEL
      GO TO 910
 1030 IF(JU-1) 1040,1040,1050
 1040 JU=2
      EL=TEL
      GO TO 910
 1050 IF (STEP2-1.) 1070,1060,1060
```


EXHIBIT 4

8

```
1060 IF (EL-(CREL+YT+R+STEP2)) 910,910,1070                          3020
1070 JD=JD+1                                                           3040
     PCORD=XCORD                                                       3050
     IF (NDIAL) 1080,1080,1090
1080 IF (OPEN-1.) 1120,1100,1100
1090 XDIAL=DIAL(JD)                                                    3090
     XCORD=CORD(JD)                                                    3100
     GO TO 1130                                                        3110
1100 IF (XCORD-.5) 1110,1120,1110                                      3120
1110 XCORD=XCORD+1.                                                    3130
     GO TO 1130                                                        3140
1120 XCORD=XCORD+.5                                                    3150
1130 IF (LIST ) 1140,1140,1220
1140 IF (STEP2-4.) 1150,1150,1170                                      3170
1150 PUNCH 1190                                                        3174
     PUNCH 950,IPAGE                                                   3175
     GO TO 520                                                         3210
1170 IF (M-2) 1180,1200,1200                                           3230
1180 M=M+1                                                             3240
     PUNCH 1190                                                        3250
1190 FORMAT (//)                                                       3260
     GO TO 520                                                         3270
1200 M=M-1                                                             3280
     PUNCH 1190                                                        3285
     PUNCH 950,IPAGE                                                   3286
     IPAGE=IPAGE+1                                                     3188
     GO TO 520                                                         3310
1220 PUNCH 1230,XL,YL,JTRIAL,CXL,XC,YC,GO,GX,GY                        3320
1230 FORMAT (/E13.7,5H $ XL,4XE13.7,5H $ YL,12XI3,9H $ JTRIAL/E13.7,6H 3330
    1$ CXL,3XE13.7,5H $ XC,2XE13.7,5H $ YC/E13.7,5H $ GO,4XE13.7,5H $ G 3340
    1X,2XE13.7,5H $ GY)                                                3350
     PUNCH 1240,A1,A2,A3,A4,A5,A6,A7,AMC,ALFA,ANGLE,CV,YPEL,PCORD,ARC  3360
1240 FORMAT (E13.7,5H $ A1,4XE13.7,5H $ A2,2XE13.7, 5H $ A3/E13.7,5H $ 3370
    1A4,4XE13.7,5H $ A5,2XE13.7,5H $ A6/E13.7,5H $ A7,4XE13.7,6H $ AMC, 3380
    11XE13.7,7H $ ALFA/E13.7,8H $ BETA ,1XE13.7,5H $ C ,2XE13.7,7H $ YP 3390
    1EL/E13.7,7H $ CORD,2XE13.7,6H $ ARC)                              3400
     IF (STEP2-5.) 1150,1170,1170                                      3410
1250 TYPE 1260                                                         3420
1260 FORMAT (36X14HEND OF PROGRAM)                                     3430
     PUNCH 1190                                                        3435
     PUNCH 950, IPAGE                                                  3437
```

```
      PAUSE                                                             3440
      GO TO 65
 1270 STOP
      END                                                               3460
```

INPUT DATA - 22-J2-L225

A. Three output title cards

B. Structural Dimensions

1. HD - Design head of ogee weir
2. CREL - Crest elevation of ogee weir
3. GATES - Number of tainter gates
4. B - Width of gates
5. HT - Height of gates
*6. R - Radius of gates
*7. XT - Horizontal distance from weir crest to trunnion.
*8. YT - Vertical distance from weir crest to trunnion.
9. DY - Vertical component of slope of upstream face of weir.
10. DX - Horizontal component of slope of upstream face of weir. Zero for vertical face weir.

C. Job Specification

1. OPEN - Gate opening increment. Limited to 0.5'or 1.0'for reasons of accuracy.
2. STEP1 - Vertical distance from weir crest to first pool elevation.
3. STEP2 - Subsequent pool elevation intervals.
4. CAY - Constant "k" in the ogee equation $Y = kX^p$. Omit when W.E.S. criteria is pertinent.
5. P - Power of the above "X" value. Omit when W.E.S. criteria is pertinent.
6. NCOEF - Number of discharge coefficients-vs-percent gate opening values to be read. Omit when W.E.S. criteria is pertinent.
7. NDIAL - Number of gate dial-vs-cord values to be read. Omission permits discharge computations in terms of whole numbered cord lengths.
8. LIST - Positive to print geometrical values for each gate opening.

SPECIAL CASE 2
(omit when NCOEF is zero)

D. BETA(1) thru BETA (NCOEF) - Angle β shown on W.E.S. - HDC 311-2.

E. C (1) thru C (NCOEF) - Discharge coefficients corresponding to BETA values selected in D.

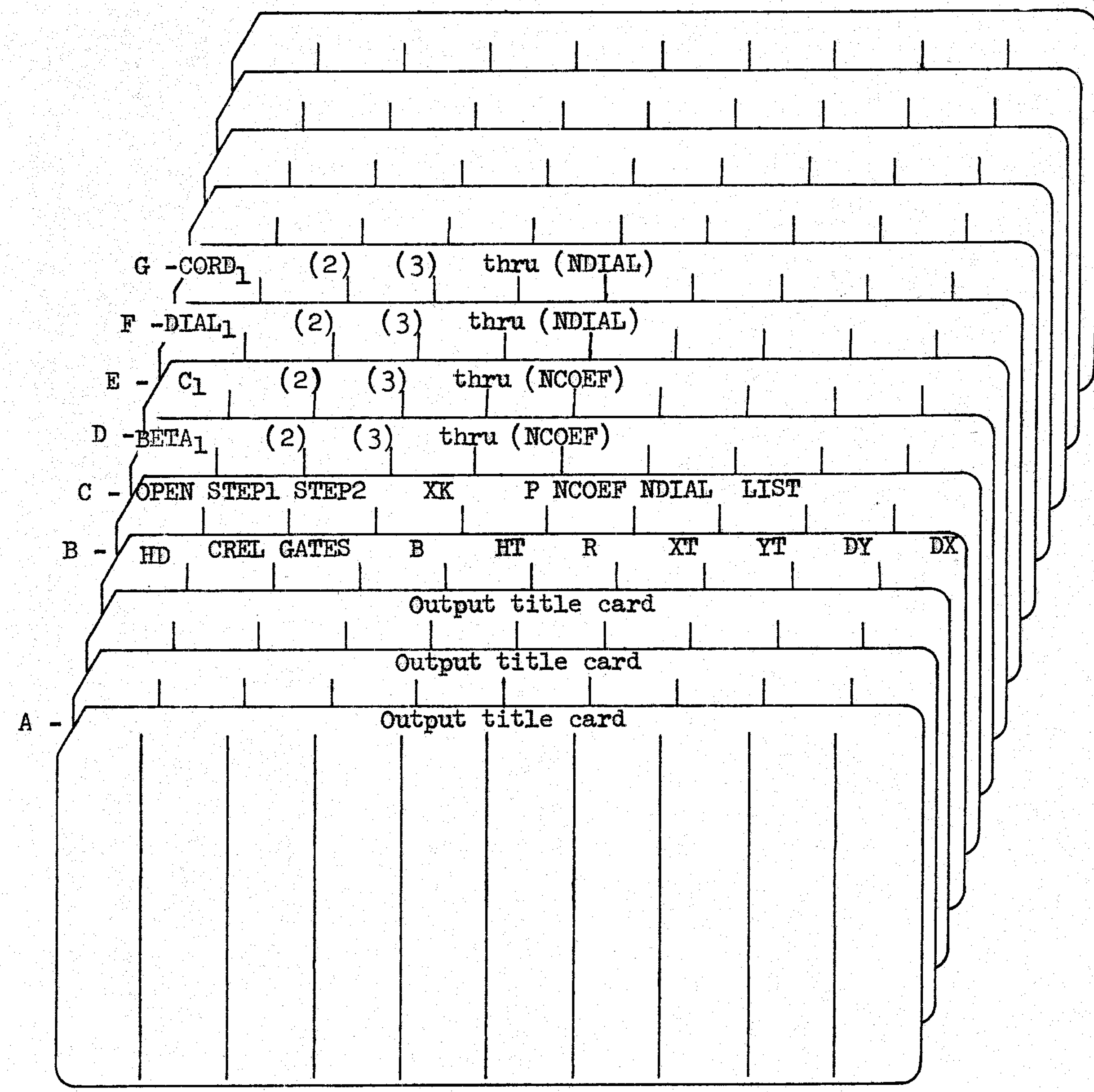
*If trunnion position is unknown, an approximation of position will be made when "zero" is furnished R, XT and YT.

SPECIAL CASE 3
(omit when NDIAL is zero)

F. DIAL (1) thru DIAL (NDIAL) - Whole numbered gate openings such as G_o or Y_L

G. CORD (1) thru CORD (NDIAL) - Cord lengths corresponding to DIAL values selected in F.

SUMMARY OF REQUIRED CARDS



Notes:

1. Omit D and E when NCOEF is zero.
2. Omit F and G when NDIAL is zero.
3. Multiple runs can be performed. (Include title cards for each successive run).
4. Furnish <u>four</u> blank cards at end of data for normal exit.

EXHIBIT 6

Appendix 4

Spillway Rating and Flood Routing

SPILLWAY RATING AND FLOOD ROUTING

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L210

OCTOBER 1966

U. S. ARMY ENGINEER DISTRICT
650 CAPITOL MALL
SACRAMENTO, CALIFORNIA

SPILLWAY RATING AND FLOOD ROUTING

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L210

CONTENTS

TABLES

EXHIBITS

SPILLWAY RATING AND FLOOD ROUTING

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 22-J2-L210

1. ORIGIN OF PROGRAM

a. This program is a modification and translation of Tulsa District program 22-G1-G512. It was translated in the Hydrologic Engineering Center Corps of Engineers, 650 Capitol Mall, Sacramento, California, by Bill S. Eichert, original author of the program, from Fortran II for the General Electric 225 computer to a Fortran II common to IBM, RCA and GE. The major changes made in the Center were the addition of a routine to make an induced surcharge operation of the flood control conduit for a project with an uncontrolled spillway, and the substitution of the faster Modified Puls routine instead of the trial and error routine of assuming and computing the water surface elevation (so called arithmetic method). A source deck for a two-part program for the 40K, IBM 1620 is available for computers with limited memory. The version for the larger computers, GE 225-8K, is shown as Exhibit 6.

b. Up-to-date information and copies of source statement cards for various types of computers can be obtained from the Center upon request by Government and cooperating organizations.

2. PURPOSE OF PROGRAM

The main purpose of this program is to compute a spillway rating curve for a concrete ogee spillway with vertical walls for an assumed design head, then make a flood routing of the spillway design flood to determine the maximum water surface. The spillway rating computation is performed according to the Hydrologic Design Charts of the Waterways Experiment Station. The rating can also be for a broad-crested weir and can also include the discharge from a conduit or sluice. The routing can be for a gated or uncontrolled spillway. The gated routing uses the emergency release diagram discussed in EM 1110-2-3600.

3. DESCRIPTION OF PROGRAM

a. This general description is for the one-part program. The two-part program is for computers with memory equivalent to the IBM 1620 with 40,000 digits of storage. Computers equivalent to the GE 225,8K can take the whole program in one part and can make a trial and error solution to get the proper design head "DESHD" in the spillway rating. Separate runs must be made on the 2 Part program for different design heads.

b. A tailwater curve must be read into the computer. This tailwater rating curve will be used to compute the submergence (caused by the conduit and spillway discharge) of the conduit or sluice if variable "ISPCTW" is equal to zero. If ISPCTW = 10, the conduit discharge only will be considered in computing submergence. The tailwater for the spillway can be the tailwater curve read in or, if the tailwater is not dependent upon downstream conditions but on the spillway apron elevation (such as a high level saddle spillway), the tailwater can be computed by the specific energy equation assuming a 10 percent loss of energy going over the weir. With variable "ISPITW" = 0, the spillway tailwater is the table that was read in, but if the variable = 10 the tailwater is based on the specific energy equation.

c. The abutment contraction coefficients (for various value of HE/HD) are read into the computer along with other values which are stored in table form. The coefficients normally used are for adjacent earthen embankment sections as shown in the Waterways Experiment Charts 111-3/2; however, adjacent concrete section coefficients using ZKA = 0.1 at HE/HD = 1.0 based on WES 111-3/1 can be used by setting IABCOA equal to ten.

d. This program will also compute a spillway rating curve for a trapezoidal (or rectangular) spillway based on critical depth control at the weir. This rating would be applicable to a spillway with a minimum control section where the approach depth was less than 10 percent of the design head, where the spillway apron elevation was only a foot or two below the spillway crest elevation and where the exit channel was sloped at a grade greater than the critical slope. The critical depth rating at the weir can be adjusted due to approach losses by the same routine as the ogee rating. (See paragraph 4, step 3).

e. The flood routing portion of this program uses either a storage indication routing for uncontrolled spillways or for projects with no induced surcharge, or it uses a routing based on gate schedule curves.

f. The storage indication routing procedure for uncontrolled spillways only makes releases equal to the freeflow discharge when the elevation is greater than the top of the induced surcharge pool "ELTSUR", (ICASE=1). When the pool elevation is below the spillway crest a release equal to "QMIN1" is made (ICASE=14) and when the pool is above the crest elevation but below the elevation of "ELSURO" a release of QMIN2 is made (ICASE=15). When the pool is between "ELSURO and ELTSUR" (ICASE=13) a release is made which includes the freeflow discharge of the spillway if any, plus a conduit release which is interpolated between the freeflow discharge at elevation "ELTSUR" and the desired conduit release at "ELSURO". These cases are summarized in Table 2, and are shown graphically on Exhibit 3.

TABLE 1

PROGRAM OPTIONS

Option NO.	Variables	Variable = 10	Variable = 0
1	ITYSP	(For controlled spillways)	(For uncontrolled spillways)
			Following variables may be 0.0: ELTFC, STFC, CHCAP, QSURO, and TS
		Routing by gate regulation curves	Making outflow equal to spillway Q plus regulated conduit Q until elevation exceeds "ELTSUR", then use storage indication routing
2	INDCON	Conduit or sluice used in rating and routing	No conduit or sluice used
3	ISPITW	Spillway tailwater by specific energy, conduit tailwater by table look up	Spillway and conduit tailwater by table look up
4	IABCOA	Abutment contraction coefficients based on adjacent concrete non-overflow section	Abutment contraction coefficients based on adjacent earthen non-overflow
5	ISPILN	Effective length spillway may exceed net	Effective length spillway may not exceed net
6	ISRCD	To compute spillway rating for trapezoidal channels based on critical depth (variable ITYSP should be = 0.)	Compute rating for "ogee" spillway (variable "ss" on card E.1 can be 0.0)
		Variable "ss" will be used as side slope of channel - Following variables may be "0.0": NGATES, APEL, APWID, PDPTH	

TABLE 1 continued

PROGRAM OPTIONS

Option No.	Variables	Variable = 10	Variable = 0
7	ISPCTW	Use conduit discharge only in computing conduit submergence	Use spillway and conduit discharge in computing conduit submergence
8	ITABLE	Start program over again reading in only heading cards, Card A, and cards F, G and H. The tables of ELEV-CAP, TWEL-TWQ, and inflows used for the previous runs are the same for current run and do not need to be repeated.	Read in all cards as described in Exhibit 8.

g. The releases below "ELTSUR" using QMIN1, QMIN2, etc., are determined during the spillway rating portion of the program and are printed out as "assumed Q" for various elevations in the table preceding the routing. The routing then is made using the Modified Puls Method with a linear interpolation for the discharge between various elevations. If this interpolation is not satisfactory more elevations may be used to define the curve.

h. The flood routing by regulated gates is appropriate for all gated spillways with or without induced surcharge. The induced surcharge envelope curve will normally be estimated by the computer using the values of the curve shown on Exhibit 2 for the values in the tables "IPERDQ" and "IPERSR". If a more detailed analysis requires the use of another envelope curve, this curve can be read into the computer by changing the value in the input data for either or both of the tables "IPERDQ" and "IPERSR". The standard values in the input data must be replaced after the special run is made. The program will route both the antecedent flood and the spillway design flood if desired. The starting elevation for the antecedent flood is usually at the bottom of flood pool. The outflows are normally based on gate schedule curves when the pool is rising. A minimum release is used if the gate schedule release is smaller than the minimum desired ("QMIN1"). When the pool elevation of the antecedent flood peaks, the maximum gate opening is maintained until the pool drops to the top of flood control pool. Below the top of flood control pool the outflow is based on the average of the current inflow and the previous release with a minimum release of "CHCAP". The spillway design flood is routed in the same manner as the antecedent flood except that the spillway design flood causes all gates to be fully opened requiring a storage indication routing from that point until the pool drops to "ELTSUR" when the gate regulation routing routine takes over again. The criteria for determining the release for each period of the routing is printed out on the computer sheets in code form under the title, "Case" (except for the storage indication type routing). Table 2 shows what each case represents.

TABLE 2

CASE	RELEASE CRITERIA
	a. Gate Schedule Curve Routing
0	Starting conditions
1	Release based on storage indication routing
2	Minimum release. - A release of "QMIN1" would not cause pool to get to elevation of bottom of surcharge
3	Release = Discharge at top of induced surcharge pool since Q to satisfy "Case 5" is greater than "QTOPSR"
4	Outflow = inflow
5	Gate regulation release (equation 3 of EM 1110-2-3600)
6	Release = QMIN1. - Gate regulation release would be less than "QMIN1".
7	Release. - Based on discharge resulting from maintaining maximum gate opening until top of flood control pool is reached (partial gate opening).
8	Release equals average of previous period's release and current inflow since pool elevation is below top flood pool and is falling.
9	Release = "CHCAP" since pool elevation is below top of flood pool and inflow is less than "CHCAP"
10	Release based on bringing pool elevation down to top of Induced Surcharge Pool exactly at the end of a period.
11	Release based on freeflow discharge (all gates fully open) since gate regulation release (Case 5) is greater than freeflow discharge
12	Release based on not exceeding "Q1" (The average inflow for the last one hour based on estimated rate of rise of reservoir).
	b. Modified Puls Method (cases not printed out)
1	Release based on storage indication routing (Modified Puls)

CASE	RELEASE CRITERIA (cont'd)
13	Release equals spillway discharge, plus a conduit release which is interpolated between the freeflow discharge at elevation "ELTSUR"and the desired conduit release at "ELSURC"
14	Release = QMIN1 since the elevation is equal to or less than the spillway crest elevation
15	Release = greater of QMIN2 or spillway discharge (QSPI) plus minimum conduit release (CONMIN) since the elevation is between the spillway crest elevation and the bottom of the induced surcharge pool. This case exists only when "ELSPI" is below "ELSURO".

4. METHODS OF CUMPUTATION

Step 1 - The input data consist of a description of the spillway, a description of the flood routing, the elevation-capacity table, the tailwater rating curve in the river channel, and the inflows of the spillway design flood.

Step 2 - The maximum elevation ("ELTOP") for which a discharge will be computed is determined by the minimum of either (a) the maximum elevation of the elevation-capacity table or (b) one hundred and fifty percent of the design head assumed ("DESHD").

Step 3 - The energy head over the weir is next computed for the current elevation in the elevation table. This energy head ("HE") is equal to the current elevation (ELEV(I)) minus the spillway crest elevation (ELSPI) minus the spillway approach loss at this elevation. This approach loss is simply a ratio of the current energy head to the design head times the approach loss at the design head which was read in. (APLOSS * HE/DESHD).

Step 4 - If variable "ISRCD" is 10, a critical depth rating for the spillway will be made as described in step 5, if it is "0" a rating for the "OGEE" spillway will be made as follows": The general method of computing the rating is described in the Corps of Engineers Engineering Manual on Hydraulic Design of Spillways (EM 1110-2-1603). The general equation of the rating is:

$$Q = C(L' - 2(NxKp + KA)\ HE)\ HE^{3/2}$$

The coefficient of discharge (C) is determined from WES Hydraulic Design Chart 122-1, Revised 1-64, by the use of the following equation: COFQ = XCC * $XPHD^{XEC}$, where XPHD = the P/HD calculated from the approach depth and design head, and XCC and XEC represent variables dependent on the value of HE/HD. The values of XCC and XEC for various values of HE/HD are shown on Table 3. The "KP" is from Plate 11 of EM 1110-2-1603 and is determined by table look up of the values shown in Table 3. The "KA" is determined from WES Hydraulic Design Chart 111-3/1 (See Table 3) or 111-3/2 (Revised 1-64). The freeflow discharge for the "OGEE" spillway is then calculated by the general equation shown at the first of this step. The freeflow discharge is then checked for submergence by calculating HD/HE and (HD + D)/HE and reducing the freeflow discharge according to the Hydraulic Design Chart 111-4. Two hundred and fifty-two (252) values of submergence dependent on HD/HE and (HD + D)/HE are used for this computation (see Table 4). This reduction in discharge is a trial and error solution since the tailwater is dependent upon the discharge which is dependent on the submergence. The tailwater is determined either by the specific energy equation (variable "ISPITW" = 10) as shown on Page 17 of EM 1110-2-1603 or by a table lookup. Step No. 6 is next for the "OGEE" spillway.

Step 5 - The discharge for the trapezoidal spillway based on critical depth is determined from the basic equation:

$\frac{V^2}{2g} = \frac{A}{2T}$ where V = average velocity, A = area, T = top width

By a trial and error solution a depth of flow ("D") can be determined which will satisfy the above equation and provide an energy head which is equal to "HE" from Step 3. This solution is accomplished as follows: First, a velocity head ("HV") of 30 percent of "HE" is assumed. Then the depth (HE minus HV), the top width, the area, the computed velocity head, and the computed energy head are determined. The actual and computed energy heads are then compared and if not within one tenth of a percent of the energy head the velocity head is assumed again as halfway between the assumed and computed velocity heads; if they are within the allowable error the tailwater elevation ("APEL" + "D") and discharge (Q = AV) are computed.

Step 6 - If variable "INDCON" = 0, proceed to Step 7. If equal to 10, the next step is to compute the discharge from the conduit or sluice. This is accomplished by first calculating the free flow discharge by $Q = C\sqrt{H}$ where C = the coefficient of discharge (read in), H is the head causing discharge which for freeflow discharge is equal to the current elevation ("ELEV(I)") minus the centerline of pressure ("CLINEP"-read in). The submergence is then calculated (by trial and error) by the same equation except the head is the difference between the "ELEV(I)" and the tailwater. The tailwater is calculated by table look using the conduit discharge only or both the spillway and conduit discharge (as determined by variable "ISPCTW"). The total discharge is then calculated by adding the spillway and conduit discharges.

Step 7 - The above procedure (Steps 3 - 6) is repeated for each elevation in the ELEV(I) table up to "ELTOP" (see Step No. 2) unless a tailwater table look up of the spillway discharge limits the spillway discharge rating to an elevation below "ELTOP".

Step 8 - When the spillway rating has been completed, the computer starts the flood routing of the spillway design flood. This routing is described starting with Step 9 if variable "ITYSP" = 10. If the variable = 0, the flood routing will be made as described in paragraph 3. Basically, the assumed outflow will be determined according to the pool elevation assumed. Then the reservoir pool elevation will be computed using a trial and error method by computing charge for the assumed reservoir elevation, the reservoir capacity based on the assumed release, and the computed pool elevation. A new reservoir pool elevation is assumed until the assumed and computed pool elevations are within .005 of a foot. This routing is made for each inflow until the last inflow is completed. With variable "ITYSP" = 0, the next step is No. 10.

TABLE 3

ARRAYS FOR SPILLWAY RATING

(N)	HDHE(N)	HEHD(N)	CC(N)	EC(N)	ZKP(N)	ZKA(N) (1)	ZKA(N) (2)
1	0	0	3.100	0	.123	-.008	.005
2	.05	.1	3.205	.0059	.101	.023	.030
3	.1	.2	3.320	.0090	.082	.045	.053
4	.15	.3	3.415	.0114	.063	.062	.074
5	.2	.4	3.520	.0135	.046	.074	.092
6	.25	.5	3.617	.0155	.034	.081	.112
7	.3	.6	3.710	.0174	.026	.089	.123
8	.4	.7	3.800	.0191	.017	.093	.137
9	.5	.8	3.880	.0208	.009	.097	.150
10	.6	.9	3.943	.0224	.003	.099	.162
11	.7	1	4.000	.0241	0	.100	.174
12	.8	1.1	4.045	.0260	-.006	.100	.182
13	.85	1.2	4.070	.0281	-.012	.100	.189
14	.9	1.3	4.090	.0307	-.013	.100	.194

(1) Abutment contraction coefficients for adjacent concrete non overflow section using W.E.S. Hydraulic Design Chart III - 3/1 dated August 1960 and making KA = .1 at HE/HD = 1.0.

(2) Abutment contraction coefficients for adjacent embankment non overflow section from W.E.S. Hydraulic Design Chart III - 3/2 Rev. January 1964.

14

TABLE 4

SUBMERGED COEFFICIENTS

(HD + D)/HE: 1.07	1.10	1.15	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.25	2.50	3.00	3.50	4.00	4.50	HD/HE
PERCENT OF SUBMERGENCE																		
100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	.00
55.0	54.0	52.0	49.0	45.0	42.0	40.0	39.0	38.0	38.0	37.5	39.0	40.5	43.0	53.0	58.0	60.0	60.0	.05
36.5	35.0	33.0	31.0	27.0	23.5	21.0	19.0	18.5	18.0	18.785	18.88	19.52	21.15	26.25	29.0	31.0	32.0	.10
27.5	25.0	22.0	19.5	17.5	15.5	14.0	13.5	13.0	12.5	12.45	12.21	12.63	13.44	15.0	17.0	18.3	21.0	.15
21.0	18.0	17.0	15.0	13.0	11.3	9.8	9.0	8.5	8.2	8.0	8.0	8.19	8.56	9.41	11.2	12.0	13.0	.20
18.0	15.5	13.5	12.0	10.0	8.4	7.2	6.0	5.4	5.0	4.9	4.914	5.375	5.888	7.0	7.85	8.5	9.0	.25
16.0	13.5	12.0	10.5	8.0	6.1	4.3	3.7	3.3	3.1	3.00	3.02	3.333	3.82	5.123	6.08	6.66	7.0	.30
15.0	13.0	10.0	8.0	5.5	3.6	2.5	1.8	1.7	1.5	1.450	1.438	1.625	1.888	2.717	3.73	4.19	4.5	.40
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.2	.96	.87	.857	.842	.853	.933	1.62	2.24	2.70	2.9	.50
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.90	.75	.525	.515	.562	.600	.860	1.27	1.65	1.8	.60
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.80	.50	.475	.450	.390	.385	.470	.69	0.93	1.0	.70
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.450	.415	.323	.250	.110	.20	0.34	0.3	.80
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.445	.410	.310	.220	.030	0.0	0.0	0.0	.85
15.0	13.0	10.0	8.0	5.5	3.3	2.0	1.1	.70	.49	.445	.400	.300	.200	0.0	0.0	0:0	0.0	.90

Step 9 - With variable "ITYSP" = 10, the flood routing is accomplished by making flood releases from the controlled spillway by adjusting the gate openings for the desired release as generally described in the Reservoir Regulation Engineering Manual (EM 1110-2-3600). The flood routing is started with the first inflow that is greater than "QSURO". The starting conditions are printed out for the previous period's inflow. A discharge of "QMIN1" is released until "QMIN1" is exceeded by the computed reservoir released based on the gate regulation schedule computed from equation No. 3, Page 15 of EM 1110-2-3600, using the induced surcharge envelope curve computed from the tables "IPERDQ" and "IPERSR". The gate schedule release is then made as long as the computed gate regulation release is greater than the previous release. When the computed gate regulation release is less than the previous release, the maximum gate opening made is retained until the pool elevation falls below the top of flood pool (as described on Page 15, 16 of EM 1110-2-3600. The discharge from this partial gate opening is computed by first computing the vertical gate opening (XD) required to furnish the desired discharge for the previous period (assuming all gates open equally):

$$PQAV = A \sqrt{2gH/k} \qquad \text{where k is assumed = 1}$$

$$\text{or } XD = PQAV /(((64.4 * HEAD) * * .5) * SPWID)$$

A gate opening of 4 feet is assumed first and the corresponding head is computed. This head is measured from the center of the gate opening to the pool elevation. Using this head a new gate opening is computed and then a new head and so on until 5 trials have been made. Each trial the gate opening becomes closer to the correct answer and at the end of the 5 trials the answer is real close. The discharge for this period's gate setting is based on the following equation:

$$QCAVE = \frac{(H)^{\frac{1}{2}}}{(HEAD)^{\frac{1}{2}}} \times \frac{A \sqrt{2g/k}}{A \sqrt{2g/k}}$$

$$\text{or simply } QCAVE = PQAV * ((H/HDAD) * * .5)$$

Although the computation process appears to change the gate setting for each period on the partial gate opening routine, the actual gate opening change is negligible. This computation process is simpler to program than to calculate the maximum gate opening for the last release (based on gate regulation) and vary this discharge based on pool elevation change alone.

When the pool elevation falls below the top of the flood control pool a release is made which is halfway between the current period's inflow and the previous period's release, but not less than "CHCAP". If the calculated release exceeds the freeflow discharge of the spillway and conduit, the gates are fully opened and the routing is made in a manner similar to that described in Step No. 8. The releases shown in Table 2 show the criteria used for each "case" in the printout.

Step 10 - After the spillway rating and flood routing have been completed, a new "run" is made if desired.

5. INPUT

a. Since this program has been written in Fortran the input data must be in certain columns on specific cards. All the data are read using ten numbers per card and eight spaces on the card are reserved for each number except that column 1 on all cards is reserved for the alphanumeric character (A-H) showing the type of card. The arrangment of the variable on various cards is described in Exhibit 8 and is shown on Exhibit 9.

b. Table cards. Standard table cards are required just before the first 5 heading cards for only the first run. The table cards are used to initialize array values. The values of "HDHE, HEHD, CC, EC, ZKP, HDDHE, IS, and ZKA" (both concrete and earth arrays) requiring 39 cards are required for the Part I (Spillway Rating). The value of "IPERSR" and "IPERDQ" requiring 2 cards must be used for the Part II (Flood Routing). For the 1 large program all 41 cards are used before the five heading cards. Exhibit 4 shows these standard cards.

6. OUTPUT

a. The output for the test runs is shown in Exhibit 5 and discussed in paragraph 9.

b. Most of the input to the program is punched out for a permanent record of the assumptions used in the program such as the 5 heading cards and the cards describing the rating and the routing. A table is punched out snowing elevation versus capacity, spillway freeflow, spillway tailwater, submerged spillway discharge, conduit discharge freeflow, conduit tailwater, submerged conduit discharge, total discharge spillway and conduit and assumed discharge for Modified Puls routing.

c. The routing for the gate schedule curve operation is described by punching out time, Inflow, Outflow, storage on induced surcharge envelope curve, storage available assumed and computed, Reservoir capacity in acre feet, pool elevation and the criteria for making the release ("ICASE").

d. For the Modified Puls Method the following values are punched out: Time, Inflow, Outflow (average and end of period), S+ Q/2 value, and the reservoir capacity and pool elevation.

7. OPERATING INSTRUCTIONS

a. Standard Fortran II instructions are used. No sense switches are required. Make sure the 41 standard table cards are entered after the object deck and before the first output title card.

b. Built-in Program Checks

(1) Print "EXTEND THE TAILWATER OR CAPACITY CURVES".

(2) Print "ERROR 730" - Elev. assumed is less than ELEV (1) - ELEV-Cap. table doesn't go low enough.

(3) Print "ERROR 11717" - ELAS is greater than ELTOP - Extend ELEV-Capacity table, increase design head assumption, or extend tailwater table.

(4) Print "ERROR 17177" - CUMSTG is less than ELEV-CAPACITY table - Elevations aren't low enough in table.

(5) Type "1170" - (HD+D)/HE is less than 1.07 - (Hasn't happened yet).

(6) Type "1174" - Trial exceeds 100 tries on spillway submergence (Hasn't happened yet).

(7) Type "1175" - Approach depth is less than 10 percent of design head.

(8) Type "1177" - General stop command - numerous items can cause this error.

c. Common Mistakes in Data Preparation

(1) ELEV (1) not below starting elevation in routing.

(2) Elevation-capacity points don't extend from minimum elevation in routing to maximum elevation in routing.

(3) Design head assumed was too low. The maximum elevation the computer will compute a discharge for is the lesser of (a) ELSPI + 1.5 x DESHD (b) ELMAX in the elev-capacity table or (c) the highest elevation having a discharge less than "QMAX".

(4) Tailwater rating not high enough. When the spillway discharge freeflow for an ogee spillway exceeds "QMAX" the computer will stop the rating (with last "Q(N)" less than "QMAX") and start the flood routing. If variable "INDCON" = 10, and the conduit discharge exceeds "QMAX" the tailwater needs to be extended.

(5) Inflows are erroneously in 1,000's c.f.s. instead of in c.f.s. as they must be.

(6) ELMAX or QMAX on Card "A" is not in table.

(7) Numbers on input cards are not proper fields, Col. 2-8, 9-16, 17-24, etc.

(8) Too many points in elev-cap table (max of 30 points on 6 cards), tailwater table (max of 30 points on 6 cards), or too many inflows (maximum of 80 inflows). If variable "ITYSP" = 0 (storage indication routing), inflows less than conduit and spillway discharge at starting elevation are not needed. Likewise too many inflows past the peak elevation of the routing are unnecessary (regardless of variable "ITYSP") for all but the final routing (to draw hydrographs) and just take more computer time.

(9) Design head assumption cannot be "0".

(10) Reversing value at side slope. Inserting .5 instead of 2 for side slope of two horizontal to one vertical.

(11) Omission of five heading cards (immediately in front of the data for a new run).

8. DEFINITION OF TERMS - See Exhibits 6 and 8

9. EXAMPLES

a. Several test runs are inclosed in order to better show the performance of the computer program. In addition to the computer print-outs, shown as Exhibit 5, a print-out of the data cards is also shown as Exhibit 4. The print-out of the data cards show the order the cards must be read into the computer.

b. Test 1. - The first of this test shows a description of the project (accomplished by the heading cards), the variables used by the computer to make the run, and the abutment contraction coefficients used in the spillway rating. For the run the tailwater table did not affect the rating since the spillway tailwater was computed by the specific energy equation, and the spillway discharge did not cause conduit submergence. The spillway rating and conduit rating as well as the reservoir elevation capacity table are shown as well as the tailwater for the conduit and spillway and the total discharge. The flood routing is shown next, which in this case is based on an emergency gate regulation operation using five feet of induced surcharge. When this operation forces the gates fully open a storage indication routing is made. The last column of this sheet shows the criteria (see Table 2) used in making the release.

c. Run No. 2. - This run shows the operation of the spillway for both the antecedent and the spillway design floods. It makes a spillway and conduit rating and then performs a flood routing. Releases from the reservoir are made according to the gate regulation curve until this release becomes less than the previous period's release. When this occurs the maximum gate opening obtained is maintained until the pool elevation drops below the top of flood control pool. The releases during this period are based on the discharge from the partially open gates. When the pool drops below the top of flood control pool releases are made which are equal to the average of the previous release and the current inflow; but in no case to be less than the operational channel capacity (CHCAP). When the pool starts rising again releases are again based on gate regulation curves until the gates are fully open. At this time a storage indication type routing is made. When the pool drops below "BLTSUR" the routing type again changes.

d. Test Run No. 4. - This test shows a valley spillway plan where the spillway and conduit tailwater are both in the valley. The tailwater shown for the two should be the same but as you can see there is a slight difference because the conduit discharge was not used in computing the spillway tailwater (note that the tailwater has practically no effect on the spillway discharge). Both the spillway and conduit discharges were used in computing the conduit tailwater (conduit tailwater is the correct figure). This apparent error could easily be corrected in the program but it would slow down the operation and would not improve the accuracy much. Note that the tailwater rating curve's maximum discharge of 318,000 c.f.s. prevented the rating curve from going any higher. The flood routing is about the same as Run No. 1 except only three feet of induced surcharge was used.

e. Run No. 5. - This run unlike the others is based on a trapezoidal spillway using a critical depth rating. The spillway does not cause submergence on the conduit as shown by use of variable "ISPCTW". The tailwater rating in this case is fictitious and causes no submergence on the conduit and is not used for the spillway. This tailwater curve was used because a good tailwater rating was not available and would not affect the overall answer. Note the high approach loss of 2.0 from spillway weir crest to the main reservoir. This loss was based on backwater studies and was reduced in the computer program for lower discharges by a ratio of the heads (HE/DESHD). The routing was made using a storage indication routing.

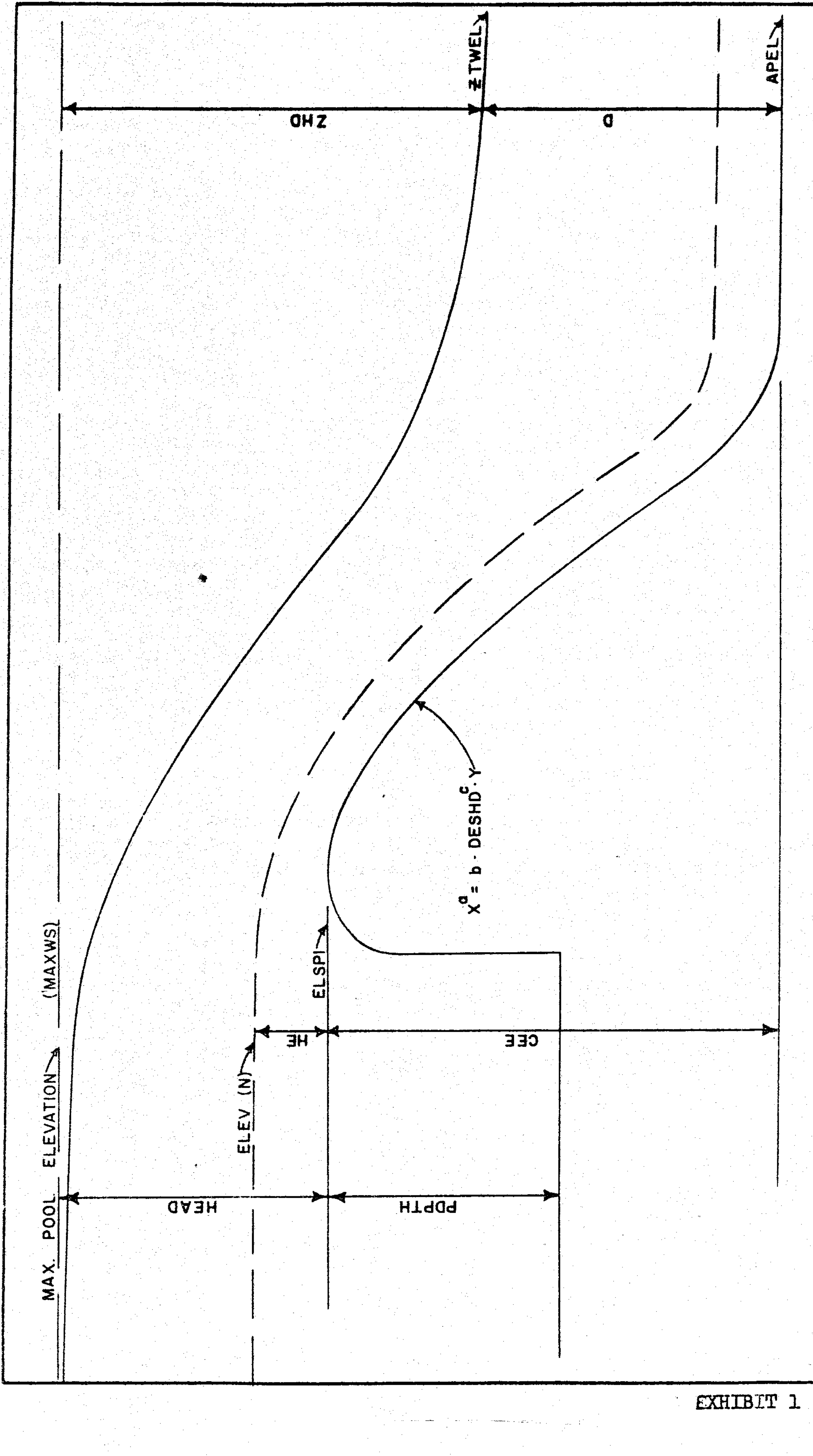
f. Run No. 10. - Exhibit 3 shows the outflow assumed for the Modified Puls routing using an induced surcharge operation of the flood control conduit. On Exhibit 3 discharge rating curves are shown for the conduit only (curve 1), for the spillway only (curve 2), for the spillway plus conduit (curve 3), and for the assumed discharge for the Modified Puls routing. Note that above the top of the induced surcharge pool (ELTSUR) the assumed discharge is equal to the total discharge of spillway and conduit (ICASE = 1). Between the elevation of the bottom of induced surcharge (ELSURO) and "ELTSUR" the conduit is opened so its discharge is increased uniformly until fully open. The assumed discharge between the spillway crest elevation and "ELSURO" is controlled by "ICASE" 15 which uses a minimum discharge of "QMIN2" or 900 c.f.s., but not less than the spillway discharge only. Using this criteria the assumed discharge for elevation 464 was 900 c.f.s., for elevation 466 the spillway discharge alone gives 1900 c.f.s. During the routing the computer will use a linear interpolation between the elevation-discharge points. If this straight line interpolation is not satisfactory between elevations 464 and 466 another elevation can be read in at 464.4 to correctly define the criteria. The actual Modified Puls routing is self-explanatory. Notice the design head assumed is 11.0 feet while the computed head was 22.52 feet. This indicates a new rating for a higher head (close to 23 feet) should be made as well as a new routing.

10. PROPOSED FUTURE DEVELOPMENT

It is anticipated that additions to this program will be made from time to time. It is requested that any user of this program who finds an inadequacy or desirable addition or modification notify the Hydrologic Engineering Center.

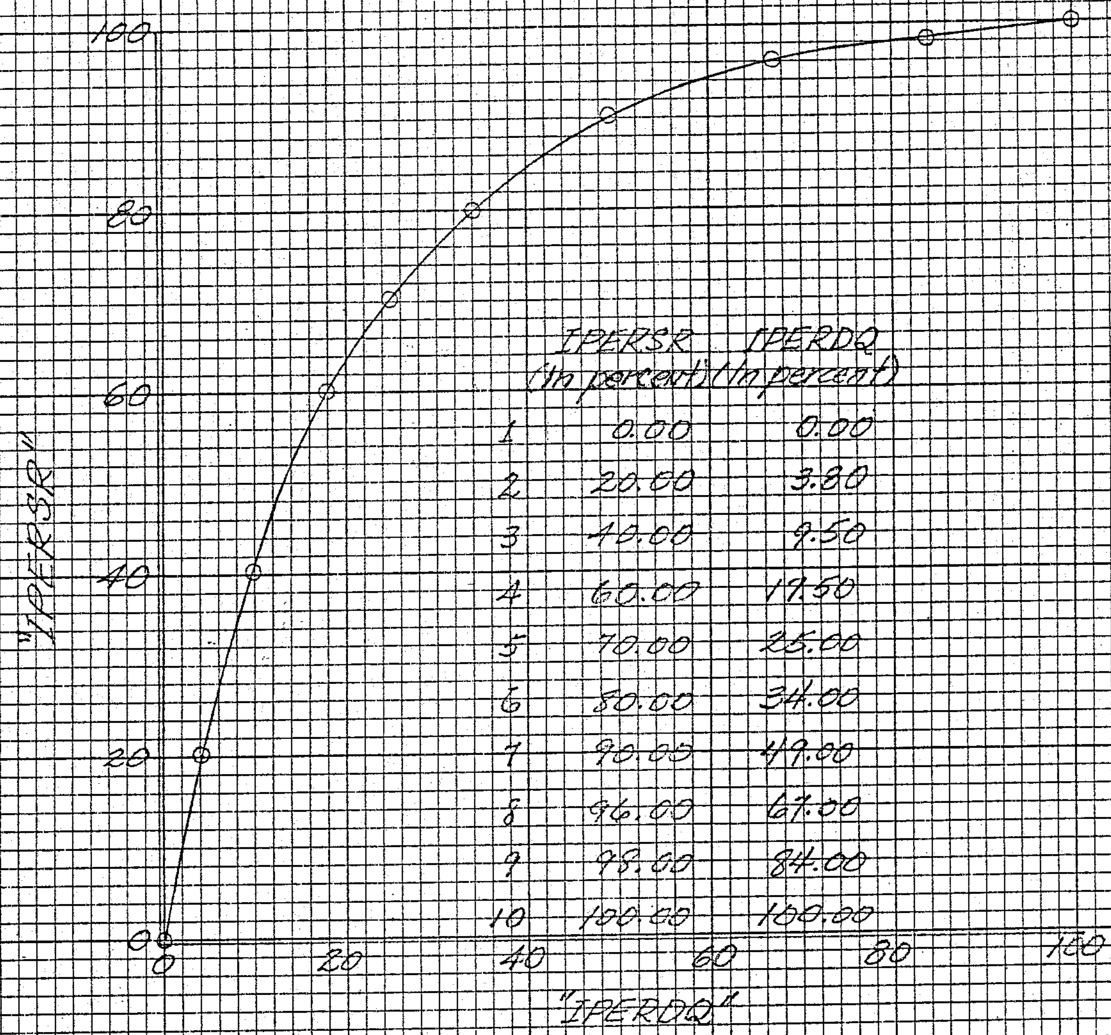
11. RELATED PROGRAMS

Separate computer programs are available for computing the spillway rating only (22-J2-L211) and for making the flood routing (23-J2-L210). The primary advantage in their use instead of this program is that sometimes different engineers perform the ratings and the routings. The input data for these programs is also easier to prepare.



SKETCH SHOWING FORTRAN SYMBOLS USED IN SPILLWAY RATING PROGRAM

EXHIBIT 1



	IPERSR (in percent)	IPERDQ (in percent)
1	0.00	0.00
2	20.00	3.80
3	40.00	9.50
4	60.00	17.50
5	70.00	25.00
6	80.00	34.00
7	90.00	49.00
8	96.00	67.00
9	98.00	84.00
10	100.00	100.00

STANDARD INDUCED
SURCHARGE ENVELOPE CURVE

EXHIBIT 2

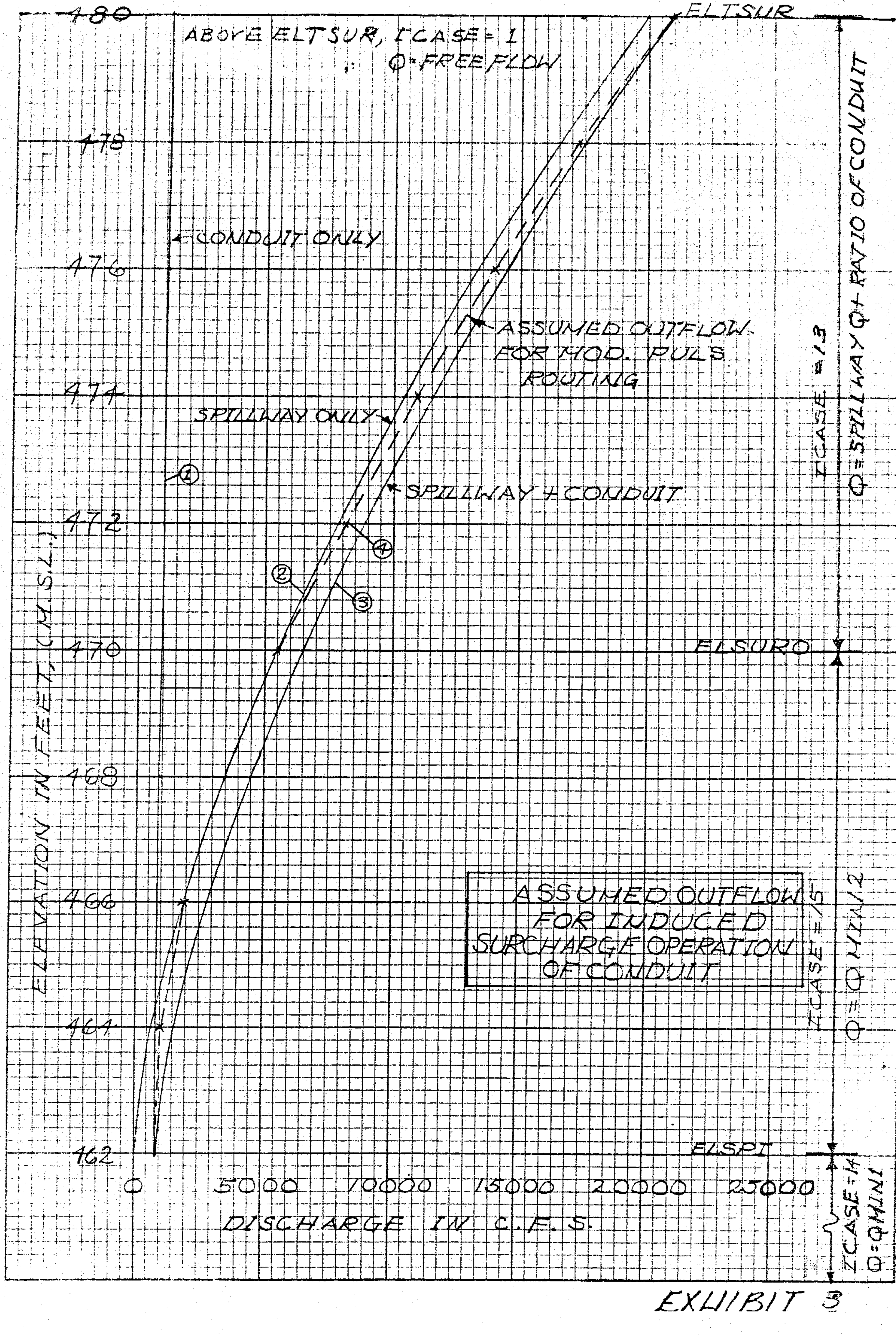

ELTSUR
ABOVE ELTSUR, ICASE = 1
∴ Q = FREE FLOW
480
478
476
474
472
470
468
466
464
462
← CONDUIT ONLY
ASSUMED OUTFLOW FOR MOD. PULS ROUTING
SPILLWAY ONLY
SPILLWAY + CONDUIT
①
②
③
④
ELSURO
ELSPI
ASSUMED OUTFLOW FOR INDUCED SURCHARGE OPERATION OF CONDUIT
ELEVATION IN FEET, (M.S.L.)
0
5000
10000
15000
20000
25000
DISCHARGE IN C.F.S.
ICASE = 13
Q = SPILLWAY Q + RATIO OF CONDUIT
ICASE = 15
Q = QMIN2
ICASE = 14
Q = QMIN1

EXHIBIT 3

0	0	3.1	0	.123	.05	.1	3.205	.0059	.101
.1	.2	3.32	.0090	.082	.15	.3	3.415	.0114	.063
.2	.4	3.52	.0135	.046	.25	.5	3.617	.0155	.034
.3	.6	3.71	.0174	.026	.4	.7	3.8	.0191	.017
.5	.8	3.88	.0208	.009	.6	.9	3.943	.0224	.003
.7	1.0	4.00	.0241	0	.8	1.1	4.045	.0260	-.006
.85	1.2	4.07	.0281	-.012	.9	1.3	4.09	.0307	-.013
1.07	1.1	1.15	1.2	1.3	1.4	1.5	1.6	1.7	1.8
1.9	2.0	2.25	2.5	3.0	3.5	4.0	4.5		
100000	55000	36500	27500	27000	18000	16000	15000	15000	15000
15000	15000	15000	15000	100000	54000	35000	25000	18000	15500
13500	13000	13000	13000	13000	13000	13000	13000	100000	52000
33000	22000	17000	13500	12000	10000	10000	10000	10000	10000
10000	10000	100000	49000	31000	19500	15000	12000	10500	8000
8000	8000	8000	8000	8000	8000	100000	45000	27000	17500
13000	10000	8000	5500	5500	5500	5500	5500	5500	5500
100000	42000	23500	15500	11300	8400	6100	3600	3300	3300
3300	3300	3300	3300	100000	40000	21000	14000	9800	7200
4300	2500	2000	2000	2000	2000	2000	2000	100000	39000
19000	13500	9000	6000	3700	1800	1200	1100	1100	1100
1100	1100	100000	38000	18500	13000	8500	5400	3300	1700
960	900	800	700	700	700	100000	38000	18000	12500
8200	5000	3100	1500	870	750	500	490	490	490
100000	37500	18785	12450	8000	4900	3000	1450	857	525
475	450	445	445	100000	39000	18880	12210	8000	4914
3020	1438	842	515	450	415	410	400	100000	40500
19520	12630	8190	5375	3333	1625	853	562	390	323
310	300	100000	43000	21150	13440	8560	5888	3820	1888
933	600	385	250	220	200	100000	53000	26250	15000
9410	7000	5230	2717	1620	860	470	110	30	0
100000	58000	29000	17000	11200	7850	6080	3730	2240	1270
691	200	0	0	100000	60000	31000	18300	12000	8500
6660	4190	2700	1650	930	340	0	0	100000	60000
32000	21000	13000	9000	7000	4500	2900	1800	1000	300
0	0								
.005	.030	.053	.074	.092	.112	.123	.137	.150	.162
.174	.182	.189	.194						
-.008	.023	.045	.062	.074	.081	.089	.093	.097	.099
.100	.100	.100	.100						
0	2000	4000	6000	7000	8000	9000	9600	9800	10000
0	380	950	1750	2500	3400	4900	6700	8400	10000

EXHIBIT 4

EXHIBIT 4

2

TEST RUN NO. 1

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

SPILLWAY RATING AND FLOOD ROUTING

SADDLE SPILLWAY WITH 5-40X40 GATES AND 10 FOOT DIAMETER CONDUIT

USING 5 FEET OF INDUCED SURCHARGE

A	10	10	10				10			
B	30	13	33	0	3000	0	517			
C	516	55730	517	57610	524	71900	540	113000	550	145100
C	552	152100	554	159400	556	166900	558	174600	560	184650
C	562	190800	564	199300	566	208100	568	217200	570	226500
C	572	236200	574	246100	576	256400	578	266900	580	277800
C	582	289000	584	300500	586	312300	588	324500	590	337000
C	592	349800	594	363000	596	376500	598	390300	610	480600
D	432	0	442.5	18000	445	22000	450	36000	455	52000
D	460	72000	465	95000	470	122000	475	153000	480	188000
D	485	228000	490	271000	495	318000				
E	1300	1300	1300	1600	3100	5600	8400	11400	14600	17700
E	20500	23200	26000	29100	29100	32300	37200	46700	59500	90300
E	164200	272500	372200	376400	300200	193500	127000	95900	80000	68200
E	59000	51400	45000							
F	0	564	199300	564	2	132	3000	0		
G	569	564	3310	11	426.7	437	100	.5		
H	5	200	56.5	524	515	232	.3	6		

TEST RUN NO. 2

SPILLWAY RATING AND FLOOD ROUTING

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

SADDLE SPILLWAY USING 6-50X20 FOOT GATES AND 13 FOOT DIAMETER CONDUIT

USING 5 FEET OF INDUCED SURCHARGE IN ANTECEDENT AND SPILLWAY DESIGN FLOOD

A	10	10	10				10			
B	30	13	37	0	4000	0	442			
C	440	72340	442	83040	446	94840	448	107800	450	122000
C	454	172690	456	192370	458	213460	460	235970	462	259920
C	464	285340	466	312250	468	340680	470	370650	472	402170
C	474	435250	476	469890	478	506090	480	543850	482	583190
C	484	624130	486	666670	488	710820	490	756600	492	804000
C	494	853000	496	903600	498	955850	500	1009830	502	1065530
D	380	0	385	12000	390	24000	395	39000	400	57000
D	405	81000	410	112000	415	152000	420	205000	425	270000
D	427.5	300000	428	340000	429	435000				
E	1800	2900	7400	20100	43200	158500	284300	212300	128200	76600
E	42000	22900	13400	8700	6200	4700	3500	2900	2700	2400

E	2300	2200	2900	6700	20600	42400	65500	104900	307000	527100
E	398600	250500	160700	100300	57600	32600	19500			
F	0	475	384400	441	6	0	4000	0		
G	480	475	0	11	557.2	386.5	100	.5		
H	6	300	39	455	440.5	340	.3	5		

TEST RUN NO. 4

SPILLWAY RATING AND ROUTING

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

VALLEY SPILLWAY WITH 5-40X40 GATES AND 10 FOOT DIAMETER CONDUIT

USING 3 FEET OF INDUCED SURCHARGE

A	10	10								
B	30	13	33	0	3000	0	517			
C	516	55730	517	57610	524	71900	540	113000	550	145100
C	552	152100	554	159400	556	166900	558	174600	560	184650
C	562	190800	564	199300	566	208100	568	217200	570	226500
C	572	236200	574	246100	576	256400	578	266900	580	277800
C	582	289000	584	300500	586	312300	588	324500	590	337000
C	592	349800	594	363000	596	376500	598	390300	610	480600
D	432	0	442.5	18000	445	22000	450	36000	455	52000
D	460	72000	465	95000	470	122000	475	153000	480	188000
D	485	228000	490	271000	495	318000				
E	1300	1300	1300	1600	3100	5600	8400	11400	14600	17700
E	20500	23200	26000	29100	29100	32300	37200	46700	59500	90300
E	164200	272500	372200	376400	300200	193500	127000	95900	80000	68200
E	59000	51400	45000							
F	0	564	199300	564	2	132	3000	0		
G	567	564	3300	11	426.7	437	100	.5		
H	5	200	56.5	524	430	232	0.0	94		

TEST RUN NO. 5

SPILLWAY RATING AND FLOOD ROUTING

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

LIMITED SERVICE TRAPEZOIDAL SPILLWAY   BOTTOM WIDTH IS 100 FEET

OUTLET WORKS IS MORNING GLORY DROP INLET WITH 5.5 DIAMETER THROAT

A		10				10	10			
B	25	5	46	400	900	0	454			
C	450	118600	452	130600	454	143200	456	156500	458	170600
C	460	185300	462	200900	464	217500	466	235100	468	253800
C	470	273500	472	294500	474	316700	476	340300	478	365400
C	480	391800	482	419700	484	448800	486	479100	488	510800
C	490	543900	492	578500	494	614900	496	653300	498	693700
D	395	0	400	1000	405	100000	410	200000	415	300000

EXHIBIT 4

EXHIBIT 4

E	1300	1300	1300	1700	2900	3900	5100	6600	7900	9400
E	10800	12000	17400	24000	30300	77300	136600	193900	207500	203100
E	192800	169500	140400	110100	83900	63300	48100	37100	29200	23400
E	18300	14300	10900	8700	6600	5000	3900	3100	2300	2000
E	1800	1700	1600	1400	1400	1300				
F	2	462	200900	462	2	0	800	0		
G	480	470	0	0	181.7	442	100	.5		
H	0	100	11	477	440	100	2	3	2	

TEST RUN NO. 10

SPILLWAY RATING AND FLOOD ROUTING

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

LIMITED SERVICE TRAPEZOIDAL SPILLWAY   BOTTOM WIDTH IS 100 FEET

OUTLET WORKS IS MORNING GLORY DROP INLET WITH 5.5 DIAMETER THROAT

A		10				10	10			
B	25	5	46	400	900	0				
C	450	118600	452	130600	454	143200	456	156500	458	170600
C	460	185300	462	200900	464	217500	466	235100	468	253800
C	470	273500	472	294500	474	316700	476	340300	478	365400
C	480	391800	482	419700	484	448800	486	479100	488	510800
C	490	543900	492	578500	494	614900	496	653300	498	693700
D	395	0	400	1000	405	100000	410	200000	415	300000
E	1300	1300	1300	1700	2900	3900	5100	6600	7900	9400
E	10800	12000	17400	24000	30300	77300	136600	193900	207500	203100
E	192800	169500	140400	110100	83900	63300	48100	37100	29200	23400
E	18300	14300	10900	8700	6600	5000	3900	3100	2300	2000
E	1800	1700	1600	1400	1400	1300				
F	2	462	200900	462	2	0	800	0		
G	480	470	0	0	181.7	442	100	.5		
H	0	100	11	462	440	100	2	3	2	

4

TEST RUN NO. 1

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

SPILLWAY RATING AND FLOOD ROUTING

SADDLE SPILLWAY WITH 5-40X40 GATES AND 10 FOOT DIAMETER CONDUIT

USING 5 FEET OF INDUCED SURCHARGE

ITYSP	INDCON	ISPITW	IABCOA	ISPILN	ISRCD	ISPCTW	ITABLE
10	10	10	-0	-0	-0	10	-0

ABUTMENT CONTRACTION COEFFICIENT

KA	0.005	0.030	0.053	0.074	0.092	0.112	0.123
KA	0.137	0.150	0.162	0.174	0.182	0.189	0.194

SS	ELTFC	STFC	ELST	PER	TIME	CHCAP	QMIN1	PERHD
0.00	564.00	199300	564.00	2.00	132.00	3000	0	100

ELTSUR	ELSURO	QSURO	TS	C	CLINEP	CONMIN	QMIN2	ERRHD
569.00	564.00	3310	11.00	426.70	437.00	0.00	3000.00	0.50

NGATES	SPWID	DESHD	ELSPI	APEL	APWID	APLOSS	PDPTH
5.0	200.00	56.50	524.00	515.00	232.00	0.300	6.0

EXHIBIT 5

DESIGN HEAD = 56.50

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
516.00	55730	0	0.0	0	3793	0.0	3793	3793	3793
517.00	57610	0	0.0	0	3817	0.0	3817	3817	3817
524.00	71900	0	0.0	0	3980	0.0	3980	3980	3980
540.00	113000	39844	520.1	39282	4331	434.5	4331	43613	43613
550.00	145100	84906	524.3	81132	4536	434.6	4536	85668	85668
552.00	152100	95395	525.1	90634	4576	434.7	4576	95210	95210
554.00	159400	106303	526.0	100493	4615	434.7	4615	105109	105109
556.00	166900	117670	526.9	110691	4655	434.7	4655	115346	115346
558.00	174600	129521	527.9	121301	4694	434.7	4694	125994	125994
560.00	184650	141862	528.8	132334	4732	434.8	4732	137066	137066
562.00	190800	154700	529.8	143797	4771	434.8	4771	148568	148568
564.00	199300	168015	530.8	155674	4809	434.8	4809	160483	160483
566.00	208100	181616	531.7	167787	4846	434.8	4846	172633	172633
568.00	217200	195696	532.8	180316	4884	434.8	4884	185200	185200
570.00	226500	210107	533.8	193021	4921	434.9	4921	197942	197942
572.00	236200	224544	534.7	205547	4958	434.9	4958	210505	210505
574.00	246100	239383	535.7	218409	4994	434.9	4994	223404	223404
576.00	256400	254293	536.6	231305	5031	434.9	5031	236335	236335
578.00	266900	269080	537.5	244062	5067	435.0	5067	249128	249128
580.00	277800	284130	538.4	257032	5103	435.0	5103	262135	262135
582.00	289000	299867	539.3	270600	5138	435.0	5138	275738	275738
584.00	300500	316271	540.3	284745	5173	435.0	5173	289918	289918
586.00	312300	333094	541.3	298972	5209	435.0	5209	304181	304181
588.00	324500	349909	542.2	313107	5243	435.1	5243	318351	318351
590.00	337000	366982	543.2	327442	5278	435.1	5278	332720	332720
592.00	349800	384458	544.1	342104	5312	435.1	5312	347416	347416
594.00	363000	400240	544.8	355235	5347	435.1	5347	360582	360582
596.00	376500	415961	545.5	368292	5380	435.1	5380	373672	373672
598.00	390300	431806	546.2	381441	5414	435.2	5414	386856	386856

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
140	3100	0	0	0	0	199300	564.00	0
142	5600	3340	199319	19	19	199674	564.08	5
144	8400	4392	199966	292	294	200336	564.24	5
146	11400	5943	200920	584	584	201238	564.44	5
148	14600	7804	202064	826	826	202361	564.70	5
150	17700	9923	203367	1006	1006	203647	564.99	5
152	20500	12608	204579	933	933	204951	565.28	5
154	23200	15427	205735	784	784	206236	565.58	5
156	26000	18253	206894	658	661	207516	565.87	5
158	29100	21170	208090	574	575	208827	566.16	5
160	29100	24669	209150	322	324	209559	566.32	5
162	32300	26597	209732	172	172	210502	566.53	5
164	37200	29795	210698	196	196	211726	566.80	5
166	46700	34303	212060	334	334	213775	567.25	5
168	59500	44777	214023	248	248	216209	567.78	5
170	90300	61572	216428	220	221	220957	568.81	5
172	164200	158799	0	0	0	221850	569.00	10

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
174	272500	199553	207536	1518907	233907	571.53
176	372200	223233	238930	1683571	258530	576.41
178	376400	251380	263829	1821041	279194	580.25
180	300200	269679	275530	1857412	288828	581.97
182	193500	265567	255605	1775383	272327	579.00
184	127000	243845	232085	1646778	253014	575.34
186	95900	219006	205928	1510594	232666	571.27

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
188	80000	192415	0	0	0	214085	567.32	11
190	68200	130308	0	0	0	203819	565.03	8
192	59000	94654	0	0	0	197926	563.68	8
194	51400	73027	0	0	0	194351	562.84	8
196	45000	59013	0	0	0	192035	562.29	8

ASSUMED ENERGY HEAD = 56.50

COMPUTED ENERGY HEAD = 57.97

EXHIBIT 5

DESIGN HEAD = 57.97

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
516.00	55730	0	0.0	0	3793	0.0	3793	3793	3793
517.00	57610	0	0.0	0	3817	0.0	3817	3817	3817
524.00	71900	0	0.0	0	3980	0.0	3980	3980	3980
540.00	113000	39751	520.1	39190	4331	434.5	4331	43521	43521
550.00	145100	84593	524.2	80833	4536	434.6	4536	85369	85369
552.00	152100	95012	525.1	90269	4576	434.7	4576	94845	94845
554.00	159400	105883	526.0	100096	4615	434.7	4615	104712	104712
556.00	166900	117171	526.9	110220	4655	434.7	4655	114875	114875
558.00	174600	128932	527.8	120748	4694	434.7	4694	125442	125442
560.00	184650	141172	528.7	131689	4732	434.8	4732	136421	136421
562.00	190800	153898	529.7	143051	4771	434.8	4771	147822	147822
564.00	199300	167118	530.6	154842	4809	434.8	4809	159650	159650
566.00	208100	180690	531.6	166930	4846	434.8	4846	171776	171776
568.00	217200	194640	532.6	179342	4884	434.8	4884	184226	184226
570.00	226500	209067	533.6	192064	4921	434.9	4921	196984	196984
572.00	236200	223565	534.6	204649	4958	434.9	4958	209607	209607
574.00	246100	238287	535.5	217407	4994	434.9	4994	222402	222402
576.00	256400	253407	536.5	230496	5031	434.9	5031	235527	235527
578.00	266900	268293	537.4	243345	5067	435.0	5067	248412	248412
580.00	277800	283273	538.3	256254	5103	435.0	5103	261357	261357
582.00	289000	298506	539.2	269369	5138	435.0	5138	274507	274507
584.00	300500	314656	540.1	283289	5173	435.0	5173	288462	288462
586.00	312300	331308	541.1	297366	5209	435.0	5209	302574	302574
588.00	324500	348377	542.0	311732	5243	435.1	5243	316976	316976
590.00	337000	365316	543.0	325951	5278	435.1	5278	331229	331229
592.00	349800	382618	543.9	340463	5312	435.1	5312	345776	345776
594.00	363000	400237	544.8	355228	5347	435.1	5347	360575	360575
596.00	376500	415958	545.5	368285	5380	435.1	5380	373666	373666
598.00	390300	431784	546.2	381417	5414	435.2	5414	386832	386832
610.00	480600	530429	550.2	463127	5612	435.3	5612	468740	468740

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
140	3100	0	0	0	0	199300	564.00	0
142	5600	3340	199319	19	19	199674	564.08	5
144	8400	4389	199967	293	295	200337	564.24	5
146	11400	5936	200923	587	587	201240	564.44	5
148	14600	7792	202071	831	831	202365	564.70	5
150	17700	9906	203378	1013	1013	203653	564.99	5
152	20500	12591	204592	939	939	204961	565.29	5
154	23200	15404	205751	791	791	206249	565.58	5
156	26000	18225	206914	665	668	207534	565.87	5
158	29100	21148	208114	579	580	208849	566.16	5
160	29100	24643	209175	326	327	209585	566.33	5
162	32300	26571	209760	175	175	210532	566.53	5
164	37200	29767	210731	199	199	211761	566.80	5
166	46700	34271	212099	338	339	213815	567.26	5
168	59500	44798	214061	246	246	216245	567.79	5
170	90300	61554	216466	221	222	220997	568.82	5
172	164200	159038	0	0	0	221850	569.00	10

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
174	272500	198706	206806	1519390	234047	571.56
176	372200	222621	238437	1684784	258771	576.45
178	376400	250903	263370	1822747	279514	580.31
180	300200	268848	274325	1859577	288845	581.97
182	193500	264926	255527	1778752	272891	579.10
184	127000	243740	231952	1650225	253595	575.46
186	95900	218873	205793	1514173	233269	571.40

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
188	80000	192050	0	0	0	214748	567.46	11
190	68200	130125	0	0	0	204513	565.18	8
192	59000	94562	0	0	0	198635	563.84	8
194	51400	72981	0	0	0	195068	563.00	8
196	45000	58991	0	0	0	192755	562.46	8

ASSUMED ENERGY HEAD = 57.97

COMPUTED ENERGY HEAD = 57.97

DESIGN HEAD O.K.

EXHIBIT 5

TEST RUN NO. 2
SPILLWAY RATING AND FLOOD ROUTING
TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)
SADDLE SPILLWAY USING 6-50X20 FOOT GATES AND 13 FOOT DIAMETER CONDUIT
SING 5 FEET OF INDUCED SURCHARGE IN ANTECEDENT AND SPILLWAY DESIGN FLOOD

ITYSP	INDCON	ISPITW	IABCOA	ISPILN	ISRCD	ISPCTW	ITABLE
10	10	10	-0	-0	-0	10	-0

ABUTMENT CONTRACTION COEFFICIENT

KA	0.005	0.030	0.053	0.074	0.092	0.112	0.123
KA	0.137	0.150	0.162	0.174	0.182	0.189	0.194

SS	ELTFC	STFC	ELST	PER	TIME	CHCAP	QMIN1	PERHD
0.00	475.00	384400	441.00	6.00	0.00	4000	0	100

ELTSUR	ELSURO	QSURO	TS	C	CLINEP	CONMIN	QMIN2	ERRHD
480.00	475.00	0	11.00	557.20	386.50	0.00	4000.00	0.50

NGATES	SPWID	DESHD	ELSPI	APEL	APWID	APLOSS	PDPTH
6.0	300.00	39.00	455.00	440.50	340.00	0.300	5.0

DESIGN HEAD = 39.00

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
440.00	72340	0	0.0	0	4076	0.0	4076	4076	4076
442.00	83040	0	0.0	0	4151	0.0	4151	4151	4151
446.00	94840	0	0.0	0	4298	0.0	4298	4298	4298
448.00	107800	0	0.0	0	4370	0.0	4370	4370	4370
450.00	122000	0	0.0	0	4440	0.0	4440	4440	4440
454.00	172690	0	0.0	0	4578	0.0	4578	4578	4578
455.00	182530	0	0.0	0	4612	0.0	4612	4612	4612
456.00	192370	921	440.6	921	4645	381.9	4645	5566	5566
458.00	213460	4802	441.0	4802	4712	382.0	4712	9513	9513
460.00	235970	10402	441.4	10402	4777	382.0	4777	15179	15179
462.00	259920	17394	442.0	17394	4842	382.0	4842	22236	22236
464.00	285340	25584	442.7	25545	4905	382.0	4905	30450	30450
466.00	312250	34869	443.4	34775	4968	382.1	4968	39743	39743
468.00	340680	45265	444.1	45106	5030	382.1	5030	50136	50136
470.00	370650	56759	444.9	56526	5092	382.1	5092	61617	61617
472.00	402170	69215	445.8	68894	5152	382.1	5152	74047	74047
474.00	435250	82614	446.7	82156	5212	382.2	5212	87368	87368
476.00	469890	96927	447.7	96232	5271	382.2	5271	101503	101503
478.00	506090	112157	448.6	111082	5330	382.2	5330	116412	116412
480.00	543850	128341	449.6	126750	5388	382.2	5388	132138	132138
482.00	583190	145492	450.7	143122	5445	382.3	5445	148567	148567
484.00	624130	163416	451.6	160204	5502	382.3	5502	165706	165706
486.00	666670	182207	452.7	177885	5558	382.3	5558	183443	183443
488.00	710820	201452	453.8	195925	5614	382.3	5614	201539	201539
490.00	756600	221392	454.9	214590	5669	382.4	5669	220259	220259
492.00	804000	241604	456.0	233362	5723	382.4	5723	239085	239085
494.00	853000	262370	457.0	252250	5777	382.4	5777	258027	258027
496.00	903600	284039	458.1	271941	5831	382.4	5831	277772	277772
498.00	955850	306526	459.2	292353	5884	382.5	5884	298236	298236
500.00	1009830	329067	460.3	312758	5936	382.5	5936	318695	318695
502.00	1065530	352224	461.4	333697	5988	382.5	5988	339685	339685

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
-6	0	0	0	0	0	77690	441.00	0
0	1800	0	0	0	0	78583	441.17	2
6	2900	0	0	0	0	80021	441.44	2
12	7400	0	0	0	0	83690	442.22	2
18	20100	0	0	0	0	93657	445.60	2
24	43200	0	0	0	0	115078	449.03	2
30	158500	0	0	0	0	193673	456.12	2
36	284300	0	0	0	0	334649	467.58	2
42	212300	20147	500992	166343	166432	429931	473.68	5
48	128200	31062	513651	83720	83726	478099	476.45	5
54	76600	32016	0	0	0	500207	477.67	7
60	42000	32221	0	0	0	505055	477.94	7
66	22900	32030	0	0	0	500528	477.69	7
72	13400	31643	0	0	0	491483	477.19	7
78	8700	31160	0	0	0	480346	476.58	7
84	6200	30622	0	0	0	468235	475.90	7
90	4700	30033	0	0	0	455674	475.18	7
96	3500	16766	0	0	0	449095	474.80	8
102	2900	9833	0	0	0	445657	474.60	8
108	2700	6267	0	0	0	443889	474.50	8
114	2400	4333	0	0	0	442930	474.44	8
120	2300	4000	0	0	0	442087	474.39	9
126	2200	4000	0	0	0	441195	474.34	9
132	2900	4000	0	0	0	440649	474.31	9
138	6700	4000	0	0	0	441988	474.39	9
144	20600	4000	0	0	0	450219	474.86	9
150	42400	4000	0	0	0	469261	475.96	9
156	65500	12863	488521	19261	19261	495362	477.41	5
162	104900	31338	513914	18552	18607	531839	479.36	5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
168	307000	144019	160903	1315973	612656	483.44
174	527100	194725	228548	1682171	777470	490.88
180	398600	243551	258555	1852223	854353	494.05
186	250500	257848	257142	1844168	850709	493.91
192	160700	248707	240272	1747726	807070	492.13
198	100300	227671	215070	1607755	743911	489.45
204	57600	200558	186047	1450285	673022	486.29
210	32600	171675	157304	1296838	604059	483.02

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
216	19500	145239	0	0	0	541709	479.89	11

ASSUMED ENERGY HEAD = 39.00

COMPUTED ENERGY HEAD = 39.05

DESIGN HEAD O.K.

EXHIBIT 5

TEST RUN NO. 4
SPILLWAY RATING AND ROUTING
TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)
VALLEY SPILLWAY WITH 5-40X40 GATES AND 10 FOOT DIAMETER CONDUIT
USING 3 FEET OF INDUCED SURCHARGE

ITYSP	INDCON	ISPITW	IABCOA	ISPILN	ISRCD	ISPCTW	ITABLE
10	10	-0	-0	-0	-0	-0	-0

ABUTMENT CONTRACTION COEFFICIENT

KA	0.005	0.030	0.053	0.074	0.092	0.112	0.123
KA	0.137	0.150	0.162	0.174	0.182	0.189	0.194

SS	ELTFC	STFC	ELST	PER	TIME	CHCAP	QMIN1	PERHD
0.00	564.00	199300	564.00	2.00	132.00	3000	0	100

ELTSUR	ELSURO	QSURO	TS	C	CLINEP	CONMIN	QMIN2	ERRHD
567.00	564.00	3300	11.00	426.70	437.00	0.00	3000.00	0.50

NGATES	SPWID	DESHD	ELSPI	APEL	APWID	APLOSS	PDPTH
5.0	200.00	56.50	524.00	430.00	232.00	0.000	94.0

DESIGN HEAD = 56.50

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
516.00	55730	0	0.0	0	3793	0.0	3793	3793	3793
517.00	57610	0	0.0	0	3817	0.0	3817	3817	3817
524.00	71900	0	0.0	0	3980	0.0	3980	3980	3980
540.00	113000	41303	451.7	41303	4331	452.9	3982	45285	45285
550.00	145100	88859	463.7	88859	4536	464.5	3945	92804	92804
552.00	152100	100021	465.9	100021	4576	466.7	3942	103963	103963
554.00	159400	111644	468.1	111644	4615	468.8	3938	115582	115582
556.00	166900	123799	470.3	123799	4655	470.9	3936	127735	127735
558.00	174600	136504	472.3	136504	4694	473.0	3935	140439	140439
560.00	184650	149746	474.5	149746	4732	475.1	3932	153677	153677
562.00	190800	163554	476.5	163554	4771	477.1	3932	167487	167487
564.00	199300	177886	478.6	177886	4809	479.1	3931	181818	181818
566.00	208100	192589	480.6	192589	4846	481.1	3932	196521	196521
568.00	217200	207847	482.5	207847	4884	483.0	3935	211782	211782
570.00	226500	223422	484.4	223422	4921	484.9	3936	227358	227358
572.00	236200	239124	486.3	239084	4958	486.7	3940	243024	243024
574.00	246100	255301	488.2	255178	4994	488.6	3943	259121	259121
576.00	256400	271498	490.1	271289	5031	490.5	3947	275236	275236
578.00	266900	287722	491.8	287423	5067	492.2	3953	291377	291377
580.00	277800	304275	493.5	303884	5103	493.9	3959	307843	307843

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
140	3100	0	0	0	0	199300	564.00	0
142	5600	3351	199318	18	18	199672	564.08	5
144	8400	4851	199836	165	165	200258	564.22	5
146	11400	6880	200538	280	280	201005	564.39	5
148	14600	9252	201359	353	353	201889	564.59	5
150	17700	12149	202221	331	332	202807	564.80	5
152	20500	15586	203013	206	206	203619	564.98	5
154	23200	18770	203747	128	129	204351	565.15	5
156	26000	21773	204440	89	89	205050	565.31	5
158	29100	25426	205080	30	31	205657	565.44	5
160	29100	28937	205657	0	0	205684	565.45	5
162	32300	29153	205693	9	9	206204	565.57	5
164	37200	32374	206222	18	18	207002	565.75	5
166	46700	37444	207055	53	53	208532	566.09	5
168	59500	49900	0	0	0	210119	566.44	12
170	90300	74985	0	0	0	212650	567.00	10
172	164200	164200	0	0	0	212650	567.00	10

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
174	272500	212466	220781	1456957	222573	569.16
176	372200	238756	256731	1608376	244630	573.70
178	376400	270403	284075	1728045	262150	577.10
180	300200	287651	291227	1744170	266803	577.98
182	193500	278378	265528	1646443	250195	574.80
184	127000	249259	232989	1507915	229987	570.72

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
186	95900	207676	0	0	0	211512	566.75	11
188	80000	143838	0	0	0	200960	564.38	8
190	68200	106019	0	0	0	194709	562.92	8
192	59000	82509	0	0	0	190823	562.01	8
194	51400	66955	0	0	0	188252	561.17	8
196	45000	55977	0	0	0	186437	560.58	8

ASSUMED ENERGY HEAD = 56.50

COMPUTED ENERGY HEAD = 53.98

EXHIBIT 5

34

DESIGN HEAD = 53.98

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
516.00	55730	0	0.0	0	3793	0.0	3793	3793	3793
517.00	57610	0	0.0	0	3817	0.0	3817	3817	3817
524.00	71900	0	0.0	0	3980	0.0	3980	3980	3980
540.00	113000	41510	451.7	41510	4331	453.0	3981	45491	45491
550.00	145100	89537	463.8	89537	4536	464.7	3942	93479	93479
552.00	152100	100790	466.1	100790	4576	466.8	3939	104729	104729
554.00	159400	112554	468.3	112554	4615	469.0	3934	116488	116488
556.00	166900	124883	470.5	124883	4655	471.1	3932	128815	128815
558.00	174600	137765	472.5	137765	4694	473.2	3930	141695	141695
560.00	184650	151223	474.7	151223	4732	475.3	3927	155150	155150
562.00	190800	165248	476.7	165248	4771	477.3	3927	169175	169175
564.00	199300	179639	478.8	179639	4809	479.4	3925	183565	183565
566.00	208100	194600	480.8	194600	4846	481.3	3927	198527	198527
568.00	217200	209896	482.7	209896	4884	483.2	3929	213825	213825
570.00	226500	225351	484.7	225351	4921	485.1	3931	229282	229282
572.00	236200	241295	486.5	241255	4958	487.0	3934	245189	245189
574.00	246100	257191	488.4	257068	4994	488.8	3938	261006	261006
576.00	256400	273235	490.2	273025	5031	490.6	3942	276968	276968
578.00	266900	289631	492.0	289330	5067	492.4	3949	293279	293279
580.00	277800	307152	493.8	306757	5103	494.2	3952	310709	310709

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
140	3100	0	0	0	0	199300	564.00	0
142	5600	3351	199317	17	18	199672	564.08	5
144	8400	4860	199834	162	163	200257	564.22	5
146	11400	6898	200532	275	275	201001	564.39	5
148	14600	9279	201348	347	347	201880	564.59	5
150	17700	12175	202206	326	326	202794	564.79	5
152	20500	15626	202994	200	200	203599	564.98	5
154	23200	18817	203723	123	124	204324	565.14	5
156	26000	21821	204408	85	85	205014	565.30	5
158	29100	25429	205045	30	31	205621	565.44	5
160	29100	28974	205621	-0	0	205642	565.44	5
162	32300	29154	205651	9	9	206162	565.56	5
164	37200	32402	206179	17	17	206955	565.74	5
166	46700	37487	207006	51	51	208478	566.08	5
168	59500	49900	0	0	0	210065	566.43	12
170	90300	74658	0	0	0	212650	567.00	10
172	164200	164200	0	0	0	212650	567.00	10

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
174	272500	214224	222272	1455945	222282	569.09
176	372200	240060	257848	1605873	244124	573.60
178	376400	271358	284868	1724424	261486	576.97
180	300200	288973	293079	1739756	266771	577.98
182	193500	279400	265722	1640177	249143	574.59
184	127000	249470	233218	1501455	228900	570.49

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	STG-IND SUR CURVE	STORAGE AVAIL. ASSUM.	STORAGE AVAIL. COMP.	RESER. CAPAC. END PD.	RESERVOIR POOL ELEV END PD.	ICASE
186	95900	208405	0	0	0	210304	566.48	11
188	80000	144202	0	0	0	199692	564.09	8
190	68200	106201	0	0	0	193411	562.61	8
192	59000	82601	0	0	0	189510	561.58	8
194	51400	67000	0	0	0	186932	560.74	8
196	45000	56000	0	0	0	185114	560.15	8

ASSUMED ENERGY HEAD = 53.98

COMPUTED ENERGY HEAD = 53.98

DESIGN HEAD O.K.

EXHIBIT 5

TEST RUN NO. 5

SPILLWAY RATING AND FLOOD ROUTING

TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)

LIMITED SERVICE TRAPEZOIDAL SPILLWAY BOTTOM WIDTH IS 100 FEET

OUTLET WORKS IS MORNING GLORY DROP INLET WITH 5.5 DIAMETER THROAT

ITYSP	INDCON	ISPITW	IABCOA	ISPILN	ISRCD	ISPCTW	ITABLE
-0	10	-0	-0	-0	10	10	-0

ABUTMENT CONTRACTION COEFFICIENT

KA	0.005	0.030	0.053	0.074	0.092	0.112	0.123
KA	0.137	0.150	0.162	0.174	0.182	0.189	0.194

SS	ELTFC	STFC	ELST	PER	TIME	CHCAP	QMIN1	PERHD
2.00	462.00	200900	462.00	2.00	0.00	800	400	100

ELTSUR	ELSURO	QSURO	TS	C	CLINEP	CONMIN	QMIN2	ERRHD
480.00	470.00	0	0.00	181.70	442.00	0.00	900.00	0.50

NGATES	SPWID	DESHD	ELSPI	APEL	APWID	APLOSS	PDPTH
0.0	100.00	11.00	477.00	440.00	100.00	2.000	3.0

EXHIBIT 5

DESIGN HEAD = 11.00

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
450.00	118600	0	0.0	0	514	0.0	514	514	400
452.00	130600	0	0.0	0	575	0.0	575	575	400
454.00	143200	0	0.0	0	629	0.0	629	629	400
456.00	156500	0	0.0	0	680	0.0	680	680	400
458.00	170600	0	0.0	0	727	0.0	727	727	400
460.00	185300	0	0.0	0	771	0.0	771	771	400
462.00	200900	0	0.0	0	813	0.0	813	813	400
464.00	217500	0	0.0	0	852	0.0	852	852	400
466.00	235100	0	0.0	0	890	0.0	890	890	400
468.00	253800	0	0.0	0	926	0.0	926	926	400
470.00	273500	0	0.0	0	961	0.0	961	961	400
472.00	294500	0	0.0	0	995	0.0	995	995	400
474.00	316700	0	0.0	0	1028	0.0	1028	1028	400
476.00	340300	0	0.0	0	1059	0.0	1059	1059	400
477.00	352850	0	0.0	0	1075	0.0	1075	1075	400
478.00	365400	231	440.5	231	1090	400.0	1090	1321	1307
480.00	391800	1224	441.7	1224	1120	400.0	1120	2344	2344
482.00	419700	2678	442.8	2678	1149	400.0	1149	3827	3827
484.00	448800	4505	443.9	4505	1178	400.0	1178	5683	5683
486.00	479100	6666	445.1	6666	1205	400.0	1205	7872	7872
488.00	510800	9130	446.2	9130	1232	400.0	1232	10362	10362
490.00	543900	11878	447.4	11878	1259	400.0	1259	13137	13137
492.00	578500	14907	448.6	14907	1285	400.0	1285	16192	16192
494.00	614900	18215	449.7	18215	1310	400.0	1310	19525	19525
496.00	653300	21827	450.9	21827	1335	400.0	1335	23162	23162
498.00	693700	25728	452.1	25728	1360	400.0	1360	27088	27088

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
-2	0	0	400	1215645	200900	462.00
0	1300	400	400	1216545	216245	463.85
2	1300	400	400	1217445	216256	463.85
4	1300	400	400	1218345	216267	463.85
6	1700	400	400	1219645	216284	463.85
8	2900	400	400	1222145	216315	463.86
10	3900	400	400	1225645	216359	463.86
12	5100	400	400	1230345	216419	463.87
14	6600	400	400	1236545	216497	463.88
16	7900	400	400	1244045	216591	463.89
18	9400	400	400	1253045	216705	463.90
20	10800	400	400	1263445	216836	463.92
22	12000	400	400	1275045	216982	463.94
24	17400	400	400	1292045	217197	463.96
26	24000	400	400	1315645	217495	464.00
28	30300	400	400	1345545	222371	464.55
30	77300	400	400	1422445	235099	466.00
32	136600	400	400	1558645	257594	468.39
34	193900	400	400	1752145	289578	471.53
36	207500	400	400	1959245	323809	474.60
38	203100	706	1013	2161945	357263	477.35
40	192800	1621	2228	2353732	388862	479.78
42	169500	2940	3651	2521004	416393	481.76
44	140400	4351	5050	2657752	438881	483.32
46	110100	5632	6214	2762802	456148	484.49
48	83900	7019	7825	2840488	478453	485.96
50	63300	7846	7867	2895963	479032	486.00
52	48100	8087	8307	2936197	484635	486.35
54	37100	9282	10257	2964990	509463	487.92
56	29200	10265	10272	2983933	509657	487.93
58	23400	10278	10283	2997060	509792	487.94
60	18300	10286	10289	3005077	509874	487.94
62	14300	10291	10293	3009088	509915	487.94
64	10900	10293	10293	3009695	509921	487.94
66	8700	9764	9234	3008102	496444	487.09
68	6600	9217	9200	3005468	496011	487.07
70	5000	9173	9146	3001267	495321	487.02
72	3900	9112	9078	2996021	494460	486.97
74	3100	9040	9001	2990043	493478	486.91
76	2300	8958	8915	2983341	492378	486.84
78	2000	8870	8826	2976427	491242	486.77
80	1800	8780	8735	2969401	490088	486.69
82	1700	8690	8644	2962366	488933	486.62
84	1600	8599	8553	2955322	487776	486.55
86	1400	8507	8461	2948168	486601	486.47
88	1400	8415	8370	2941107	485442	486.40
90	1300	8324	8279	2934038	484281	486.33

ASSUMED ENERGY HEAD = 11.00

COMPUTED ENERGY HEAD = 10.94

DESIGN HEAD O.K.

EXHIBIT 5

41

TEST RUN NO. 10
SPILLWAY RATING AND FLOOD ROUTING
TEST RUN ON PROGRAM NO. 22-10 (FORTRAN)
LIMITED SERVICE TRAPEZOIDAL SPILLWAY   BOTTOM WIDTH IS 100 FEET
OUTLET WORKS IS MORNING GLORY DROP INLET WITH 5.5 DIAMETER THROAT

ITYSP	INDCON	ISPITW	IABCOA	ISPILN	ISRCD	ISPCTW	ITABLE
-0	10	-0	-0	-0	10	10	-0

ABUTMENT CONTRACTION COEFFICIENT

KA	0.005	0.030	0.053	0.074	0.092	0.112	0.123
KA	0.137	0.150	0.162	0.174	0.182	0.189	0.194

SS	ELTFC	STFC	ELST	PER	TIME	CHCAP	QMIN1	PERHD
2.00	462.00	200900	462.00	2.00	0.00	800	400	100

ELTSUR	ELSUR0	QSUR0	TS	C	CLINEP	CONMIN	QMIN2	ERRHD
480.00	470.00	0	0.00	181.70	442.00	0.00	900.00	0.50

NGATES	SPWID	DESHD	ELSPI	APEL	APWID	APLOSS	PDPTH
0.0	100.00	11.00	462.00	440.00	100.00	2.000	3.0

DESIGN HEAD = 11.00

RESER. ELEV.	RESER. CAP.	SPILLWAY Q-FREE	SPILLWAY TAILWATER	SPILL QCORR	CONDUIT QFREE	CONDUIT TAILWATER	CONDUIT Q-CORR	TOTAL Q	ASSUMED Q
450.00	118600	0	0.0	0	514	0.0	514	514	400
452.00	130600	0	0.0	0	575	0.0	575	575	400
454.00	143200	0	0.0	0	629	0.0	629	629	400
456.00	156500	0	0.0	0	680	0.0	680	680	400
458.00	170600	0	0.0	0	727	0.0	727	727	400
460.00	185300	0	0.0	0	771	0.0	771	771	400
462.00	200900	0	0.0	0	813	0.0	813	813	400
464.00	217500	660	441.1	660	852	399.3	852	1512	900
466.00	235100	1900	442.2	1900	890	399.5	890	2790	1900
468.00	253800	3548	443.3	3548	926	399.6	926	4475	3548
470.00	273500	5547	444.5	5547	961	399.8	961	6508	5547
472.00	294500	7861	445.6	7861	995	400.0	995	8857	8085
474.00	316700	10470	446.8	10470	1028	400.0	1028	11498	10918
476.00	340300	13357	448.0	13357	1059	400.0	1059	14417	14029
478.00	365400	16526	449.2	16526	1090	400.0	1090	17616	17422
480.00	391800	19982	450.3	19982	1120	400.0	1120	21102	21102
482.00	419700	23742	451.5	23742	1149	400.0	1149	24891	24891
484.00	448800	27785	452.7	27785	1178	400.0	1178	28963	28963
486.00	479100	32109	454.0	32109	1205	400.0	1205	33315	33315
488.00	510800	36716	455.2	36716	1232	400.0	1232	37949	37949
490.00	543900	41606	456.4	41606	1259	400.0	1259	42865	42865
492.00	578500	46781	457.6	46781	1285	400.0	1285	48066	48066
494.00	614900	52242	458.9	52242	1310	400.0	1310	53552	53552
496.00	653300	57990	460.1	57990	1335	400.0	1335	59326	59326
498.00	693700	64029	461.4	64029	1360	400.0	1360	65389	65389

EXHIBIT 5

TIME HOURS	INFLOW AV CFS	OUTFLOW AV CFS	OUTFLOW END PER CFS	S+Q/2 END PER	CAPACITY END PER	POOL EL END PER
-2	0	0	400	1215645	200900	462.00
0	1300	631	862	1216545	216242	463.85
2	1300	862	862	1216983	216247	463.85
4	1300	862	862	1217421	216253	463.85
6	1700	863	863	1218258	216263	463.85
8	2900	863	864	1220295	216289	463.85
10	3900	864	865	1223332	216327	463.86
12	5100	865	866	1227567	216381	463.87
14	6600	867	868	1233301	216453	463.87
16	7900	870	871	1240333	216542	463.88
18	9400	873	874	1248861	216649	463.90
20	10800	876	878	1258787	216774	463.91
22	12000	880	882	1269909	216915	463.93
24	17400	886	889	1286426	217123	463.95
26	24000	893	897	1309538	217414	463.99
28	30300	1004	1111	1338940	221221	464.42
30	77300	1503	1895	1415129	234999	465.99
32	136600	2826	3757	1549834	255860	468.21
34	193900	5469	7180	1739977	287006	471.29
36	207500	9251	11323	1940297	319775	474.26
38	203100	13408	15493	2132074	351129	476.86
40	192800	17482	19472	2309381	380107	479.11
42	169500	21158	22844	2459410	404626	480.92
44	140400	24157	25471	2576966	423840	482.28
46	110100	27166	28861	2661595	448074	483.95
48	83900	28902	28943	2716634	448660	483.99
50	63300	29202	29462	2750991	452274	484.23
52	48100	31279	33097	2769630	477587	485.90
54	37100	33100	33103	2773632	477628	485.90
56	29200	31502	29901	2769729	455335	484.43
58	23400	29825	29749	2763228	454273	484.36
60	18300	29614	29480	2751779	452403	484.24
62	14300	29302	29124	2736599	449923	484.07
64	10900	28914	28703	2718375	446946	483.87
66	8700	28475	28246	2698372	443678	483.65
68	6600	27998	27751	2676726	440141	483.40
70	5000	27491	27231	2653975	436423	483.15
72	3900	26964	26698	2630644	432611	482.89
74	3100	26428	26158	2607047	428755	482.62
76	2300	25885	25613	2583188	424857	482.35
78	2000	25343	25073	2559576	420998	482.09
80	1800	24812	24551	2536303	417195	481.82
82	1700	24297	24044	2513451	413459	481.55
84	1600	23795	23545	2491008	409791	481.29
86	1400	23300	23054	2468862	406171	481.03
88	1400	22813	22573	2447209	402632	480.78
90	1300	22337	22101	2425936	399155	480.53

ASSUMED ENERGY HEAD = 11.00

COMPUTED ENERGY HEAD = 23.90

DESIGN HEAD O.K.

EXHIBIT 5

EXHIBIT 6

DEFINITIONS

a. Tables

ELEV(30), CT(30) - The elevation and capacity points in the capacity tables. The capacity is in acre-feet.

Q(30) - Spillway and conduit (or sluice) discharge in c.f.s.

TWEL(30), TWQ(30) - The tailwater rating curve table. This table must be read in even if it is not going to be used. It can be used for the spillway tailwater and it will be used for the conduit tailwater if a conduit is given.

ZINFL(50) - The inflows of the design flood in c.f.s.

IPERDQ(10), IPERSR(10) - Percents of discharge and feet of surcharge which depict an approximate induced surcharge envelope curve based on several projects in the Tulsa District.

EC(14) - 14 values of coefficients used in determining the coefficients of discharge.

HDDHE(18) - 18 values of (HD + D) /HE.

IS(252) - 18 x 14 matrix of submergence coefficients.

ZKA(14) - 14 values of abutment contraction coefficients corresponding to the HE/HD values.

HEHD(14) - 14 values of HE/HD.

ZKP (14) - 14 values of KP pier contraction coefficients.

HDHE(14) - 14 values of HD/HE.

CC(14) - 14 values of coefficients used in determining the coefficient of discharge over an ogee concrete spillway.

b. Elevations

ELTOP - Maximum elevation which will have a computed discharge.

ELEV (N) - Current elevation.

ELMAX - Maximum elevation in ELEV(N) table.

ELST - Starting elevation for the flood routing. Must correspond to the starting time (TIME).

ELAS - The assumed reservoir elevation.

ELSPI - Elevation of the spillway crest.

ELSURO - The elevation of the induced surcharge envelope curve when the total discharge is zero. Normally ELSURO will be equal to the top of flood control pool and QSURO will be approximately channel capacity.

ELTSUR - The elevation of the reservoir when the maximum induced surcharge is reached. This is normally equal to the top of flood control pool plus the feet of surcharge used (3' to 8').

APEL - Elevation of the spillway apron.

ELEVC - The current computed elevation of the reservoir.

CLINEP - Elevation of the centerline of pressure on the conduit for the range of discharge when the spillway is operating.

ZTWEL - Current interpolated tailwater elevation.

TWEL(N) - Tailwater elevation table.

ELTFC - Elevation of top of flood control pool.

ELTOP - Maximum elevation that a spillway discharge can be computed.

ZXTWEL - Tailwater elevation for conduit or sluice calculated from TWEL(N) and TWQ(N) table.

ZMAXWS - Maximum water surface in flood routing.

PEL - Previous period's computed elevation.

ELSUR - Elevation of induced surcharge envelope curve.

ELMIN - The minimum elevation allowed in the flood routing.

c. Discharges (All are in c.f.s.)

QMAX - Maximum discharge in the tailwater discharge table (TWQ(N)).

QC - The current outflow end of period in c.f.s.

CQFREE - Conduit discharge free flow (c.f.s.)

CQCOND - Conduit discharge corrected for submergence by the discharge of the spillway (c.f.s.)

AQCOND - Assumed conduit discharge corrected (c.f.s.)

QMIN1, QMIN2 - The minimum outflow in c.f.s. to be used of rising limb of hydrograph. "QMIN1" is used when pool elevation is below spillway crest and "QMIN2" is used when above. Both must be less than the conduit discharge at the spillway crest, in addition "QMIN2" must be equal to or less than "QSURO".

QSURO - The discharge on the induced surcharge envelope curve for elevation ELSURO in c.f.s. (normally zero).

PQIN - Previous inflow in c.f.s.

QCAVE - The average discharge in c.f.s. from the reservoir for the period based on the assumed reservoir elevation (ELAS).

QFREF - The discharge capacity of the spillway and conduit for the current elevation (end of period) with all gates fully open in c.f.s.

QAFREE - The average free flow discharge for the current period.

PQC - Previous outflow end of period in c.f.s.

QTOPSR - Discharge at top of induced surcharge pool in c.f.s.

QN, QNM3 - Discharge values from spillway rating table which are used to interpolate for the discharge at spillway crest elevation.

QTOTAL - Total discharge for spillway and conduit.

CQELSP - Conduit discharge at spillway crest elevation.

QCT - Previous computed discharge.

QAT - Previous assumed discharge.

Q(N) - The computed discharge in c.f.s.

QASSM - Assumed discharge.

QIN - The inflow of water into the reservoir in cubic feet per second.

SUBQ - Percent of submergence due to tailwater and apron elevation.

QCORR - Discharge with submergence in c.f.s.

PQFREE - The previous period's QFREE (end of period) in c.f.s.

MXQPGO - Maximum discharge from partial gate opening.

XQSUR - Previous trial of "QSUR".

CONMIN - The minimum conduit release desired. This may be a power release or for water supply purposes. Normally this discharge is separate from flood control requirements.

XQCAVE - Previous trial of "QCAVE".

PQAV - Previous "QCAVE".

QSUR - Discharge on induced surcharge envelope curve for "IPERDQ(N)" in c.f.s.

CHCAP - Channel capacity (in c.f.s.) to be used as minimum release between antecedent and spillway design floods.

TWQ(N) - Tailwater discharge (in c.f.s.) corresponding to a TWEL(N).

ZINFL(N) - Table of inflows in c.f.s.

Q1 - The average inflow for the last one hour based on estimated rate of rise of reservoir.

PQPGO - Previous discharge based on partially open gates.

d. Storages

CTELSP - Reservoir capacity at spillway crest elevation.

CTNSRO - Reservoir capacity at elevation of zero surcharge. (Should be at top of flood control pool)

CUMSTG - The capacity of the reservoir for the current period in acre-feet.

PCUMST - The previous capacity of the reservoir in acre-feet.

SA - The assumed surcharge storage available in acre-feet between the current pool elevation and the induced surcharge envelope curve.

STG - The assumed capacity of the reservoir in acre-feet.

CSA - The computed surcharge storage available in acre-feet between the current pool elevation and the induced surcharge envelope curve.

XCSA - The previous "TRY'S" computed storage available in acre-feet.

XSA - The previous "TRY'S" assumed storage available in acre-feet.

CT(N) - Capacity table (in acre-feet) corresponding to ELEV(N).

STFC - Storage (in acre-feet) at top of flood control pool.

STGTSR - Storage (in acre-feet) at top of induced surcharge pool.

e. Indicators

TRIAL - A counter which shows the number of trials used in trying to balance assumed and computed water surface elevation.

GUESS - A counter which shows the number of times the computed outflow was greater than the inflow. If the discharge on the induced surcharge envelope curve is greater than the inflow, then the outflow is assumed to be equal to the inflow in order to prevent the pool elevation from falling before the reservoir peaks.

ITRY - A counter which shows the number of times the storage available has been assumed in trying to balance the SA and CSA.

FINSUR - An indicator which when = 0, signifies that the gate regulation method should be used in determining the reservoir outflow, when equal to 10, the outflow comes from the free flow discharge rating curve.

INDSTR - Indicator to signal the start of a routing for heading print.

TRYPGO - Counter to keep track of the number of tries in computing partial gate opening discharge.

TRYTOP - Counts the number of times the reservoir release was made to bring pool down to top of flood control pool.

ICASE - The value of "ICASE" shows what criteria was used in computing the reservoir release (see Table No. 2).

INDPGO - Indicator, which when changed from "0" to "10", indicates the reservoir release needs to be computed for partial gate opening.

NTRY - Counter to count number of times "QTOPSR" is assumed for QCAVE in computing reservoir release by gate schedule curves.

ITYSP - See Table 1.

INDWN - See Table 1.

ISPITW - See Table 1

IABCOF - See Table 1.

ISPILN - See Table 1.

ISRCD - See Table 1.

ISPCTW - See Table 1.

INDCON - See Table 1.

f. Others

NUMEL - The number of elevations that will be in the ELEV(N) table.

NJ - Subscript used to locate a specific value of the submerged crest coefficient IS(NJ). This single subscript will take the place of the double subscripting formerly used for this matrix. This is accomplished by making NJ + 14(N-1) + J, where N and J are the two subscripts defining the matrix.

NJM1 - This single subscript replaces the double subscript (N, J-1).

NM1J - This single subscript replaces the double subscript (N-1, J).

NM1JM1 - This single subscript replaces the double subscript (N-1, J-1).

TEMP, RATIO, Z, CON, TIM, B - Temporary storage positions.

Y, X, A, H, L - Temporary storage position.

FIXED - $\frac{Q^2}{(64.4)} \times (APWID)^2$ - Used when computing tailwater by specific energy.

VALUE - D^2 (.9(HE+C) - D) - This value is also used when solving for tailwater elevation by specific energy equation.

ZVALUE - Previous "VALUE".

ZA, ZBA, ZB - Computed coefficients used in determining the percent of submergence.

EALL, AER - Allowable error.

ERROR, DIFF - Difference between assumed and computed.

N, K, I, J, IXY - Counters.

TIME - Starting time in hours.

PER - The period of flood routing in hours, such as a 2-hour or a 6-hour routing. The inflow ordinates, of course, must be for the same period.

TS - A constant which represents the ratio between the rates of change of storage and flow as shown in EM 1110-2-3600 of 25 May 1959.

FTSUR - Distance in feet from the elevation of the top of surcharge to the bottom of surcharge (FTSUR = 5, for 5 feet of induced surcharge).

SURPER - The percentage of the feet of surcharge utilized up to the current elevation.

DESHD - Design head of the spillway crest profile in feet. Generally equal to the difference in elevation between the maximum pool and the spillway crest (see Exhibit 1).

CEE - The vertical distance between the elevation of the spillway crest and the elevation of the apron.

PDPTH - Approach depth. Distance in feet from the spillway crest elevation to the spillway approach channel elevation (see Exhibit 1).

APWID - Apron width of the spillway. Normally equal to the gross width of the spillway.

SPWID - Total length of spillway over which water can pass (net length of spillway).

C - Coefficient of discharge for the conduit ($Q/\sqrt{H}$ for free flow conditions).

ZHEHD - Computed value of HE/HD current period. A value of 1.3 is used when the computed value exceeds 1.3.

ZPHD - Computed value of P/HD current period.

ZCC and ZEC - Interpolated coefficients to be used in determining the coefficient of discharge.

COFQ - XCC*(XPHD**XEC) - The current computed coefficient of discharge.

ZXKP - Computed current pier contraction coefficient.

ZXKA - Computed current abutment contraction coefficient.

ZEFFL - Effective length of spillway after pier and abutment contraction has been subtracted.

DASSM - The assumed depth used in computing the tailwater elevation by specific energy equation.

ZDASSM - Previous DASSM.

D - Depth of water in feet.

XD - Previous D.

ZHD - Current HD.

ZHDDH - Current (HD + D)/HE.

ZN - Number of intermediate piers.

NUMINF - Number of inflows used for routing.

NGATES - Number of spillway gates.

APLOSS - Approach loss (in feet) from spillway axis to reservoir for the design head.

ERRHD - Allowable error.

ZHDHE - Computed value of HD/HE.

HEAD - Distance (in feet) from maximum water surface elevation to spillway crest.

HE - Distance (in feet) from current elevation to "ELSPI".

PERHD - Percent of design, see Table 5.

HLOSS - Head loss in feet for current pool elevation.

TTS - TS in hours.

SS - Side slope for trapezoidal section.

HV - Velocity head.

HVC - Velocity head computed.

HEC - Energy head computer.

TW - Top width across a trapezoidal spillway section.

AREA - Cross-sectional area of spillway.

NUMTW - Number of tailwater points used in table.

```
C     SPILLWAY RATING AND FLOOD ROUTING PROGRAM-22-J2-L210                   1001
C     HYDROLOGIC ENGINEERING CENTER      12 OCT 1966                          1002
C     BY BILL EICHERT                                                         1003
C     IN FORTRAN II FOR ON LINE PRINTER                                       1004
C     ITYSP-10 CONTROLLED SPILLWAY-(WITH OR WITHOUT INDUCED SURCHARGE)        1005
C     ITYSP-0 STORAGE INDICATION TYPE ROUTING-UNC. SPILLWAY OR                1006
C     CONTROLLED SPILLWAY WITH NO INDUCED SURCHARGE.                          1007
C     INDCON-10 CONDUIT OR SLUICE USED                                        1008
C     ISPITW-10 SADDLE SPILLWAY - TAILWATER COMPUTED BY                       1009
C     COMPUTER ON BASIS OF SPECIFIC ENERGY                                    1010
C     IABCOA - 10 - ADJACENT CONCRETE ABUTMENT CONTRACTION COEFFICIENTS.      1011
C     IABCOA - 0 - ADJACENT EARTHEN NON-OVERFLOW SECTION.                     1012
C     ISPILN-10 ALLOWS EFFECTIVE LENGTH OF SPILLWAY TO                        1013
C                    EXCEED NET IN COMPUTING DISCHARGE                        1014
C     ISRCD-10 SPILLWAY RATING FOR CRITICAL DEPTH FOR TRAVAZOIDAL             1015
C     SECTION.                                                                1016
C     ISPCTW-10 SPILLWAY DOES NOT CAUSE CONDUIT SUBMERGENCE.                  1017
C     Q FOR INDUCED SURCHARGE ENV. CURVE COMPUTED.                            1018
C     A TAILWATER CURVE MUST BE READ IN.                                      1019
C     TAILWATER CURVE FOR SPILLWAY MUST BE SAME AS                            1020
C     CONDUIT OR IT MUST BE COMPUTED.                                         1021
C     LIBRARY SUBR IN STAT NO 7270                                            1022
C     CALL SUBROUTINES STAT. NOS. 1420,1430
      DIMENSION ELEV(40),Q(50),HEHD(14),TWEL(30),TWQ(30),ZKP(14),CC(14)      1023
      DIMENSION HDHE(14),EC(14),HDDHE(18),IS(252),ZKA(14),ZKAC(14)            1024
      DIMENSION CT(40),IPERSR(10),IPERDQ(10),ZINFL(80)                        1025
      COMMON ELEV,CT,Q,INDCON,ISPITW,ISPILN,ISRCD,ISPCTW,ELMAX,QMAX,NUME      1026
     1L,NUMTW,SS,C,CLINEP,NGATES,SPWID,DESHD,ELSPI,APEL,APWID,APLOSS,PD       1027
     2PTH,ITYSP,ELTFC,STFC,ELST,PER,TIME,CHCAP,QMIN,CTELSP,ELTSUR,ELSURO      1028
     3,QSURO,TS,ELTOP,CQELSP,QSPBSR,QMIN1,QMIN2,CONMIN,ELMIN,PERHD,HEAD       1029
     4,TWQ,ZKP,HEHD,CC,EC,HDDHE,ZKA,IS,HDHE,TWEL,TTIME,TTS                    1030
     5,STG,PCUMST,CTNSRO,ICASE, IPERSR,IPERDQ,NUMIN,ZINFL                     1031
      COMMON QIN,PQIN,QCAVE,QTOPSR,PQAV,PEL,ELEVC,ISTOP                       1032
      READ 1000,(HDHE(N), HEHD(N), CC(N), EC(N), ZKP(N), N= 1, 14)            1033
      READ 1000,(HDDHE(N), N= 1, 18)                                          1035
C                              BRANCH TO  1000 FROM     .11  1070.02
C                                  1080.00
 1000 FORMAT(10F8.0)                                                          1036
 1010 FORMAT (10F8.3)                                                         1037
C                              BRANCH TO  1020 FROM  1070.01  1090.00
C                                  1090.01
```

EXHIBIT 7

EXHIBIT 7

```
 1020 FORMAT(10I8)
C                                    BRANCH TO  1030 FROM  1110.03  1120.00
C
 1030 FORMAT(15A3,11A3,A2)
 1040 FORMAT(7F8.4)
 1050 FORMAT(10F8.2)
C                                    BRANCH TO  1060 FROM  1200.00  1210.00
C                                       1210.02  1220.00  1230.01  1230.02
 1060 FORMAT (1X,F7.0,9F8.0)
C                                    BRANCH TO  1070 FROM  1120.01  1300.02
C                                       1320.03  1330.02  1370.01  1380.01
C                                       1390.04  1390.05  1500.01
 1070 FORMAT (1H0)
C     SKIP ONE SPACE
      READ  1020,(IS(N), N= 1, 252)
C      EARTH ABUTMENTS
      READ 1000,(ZKA(N), N= 1, 14)
C      CONCRETE ABUTMENTS
 1080 READ 1000,(ZKAC(N),N= 1, 14)
 1090 READ 1020,(IPERSR(N), N= 1, 10)
      READ 1020,(IPERDQ(N), N= 1, 10)
C                                    BRANCH TO  1100 FROM  1420.01  1430.01
C                                       1500.02  1520.01
 1100 PRINT 1110
C                                    BRANCH TO  1110 FROM  1390.00
 1110 FORMAT(1H1)
C     SLEW
      ISTOP=0
      DO 1120 I=1, 5
C
C     READ IN 5 HEADING CARDS.
C
      READ 1030,(Q(N), N= 1, 26),Q(27)
C                                    BRANCH TO  1120 FROM  1110.02
 1120 PRINT 1030,  (Q(N),N=1,26),Q(27)
      PRINT 1070
C                                    BRANCH TO  1130 FROM  1130.01
 1130 FORMAT(1X,I7,9I8)
C     READ CARD A
      READ 1130,ITYSP,INDCON,ISPITW,IABCOA,ISPILN,ISRCD,ISPCTW,N,N,ITABL
     1E
```

```
      IF(IABCOA)1160,1160,1140
 1140 DO 1150 N=1,14
 1150 ZKA(N)=ZKAC(N)
C                                        BRANCH TO  1160 FROM  1130.03
 1160 IF(ITABLE)1220,1170,1220
C     START HERE FOR NEW PROJECT-DIFFERENT TABLES(EL-CAP,TWEL-Q)
C     READ CARD B
 1170 READ 1190, NUMEL, NUMTW, NUMIN, QMIN1, QMIN2, CONMIN
      IF (NUMEL)1180,1180,1200
 1180 STOP
C                                        BRANCH TO  1190 FROM  1170.00
 1190 FORMAT (1X,I7,2I8,5F8.0)
C     READ CARD C
C                                        BRANCH TO  1200 FROM  1170.01
 1200 READ 1060, (ELEV(I), CT(I), I=1,NUMEL)
      ELMAX=ELEV( NUMEL)
      IF(NUMEL-50)1210,1210,1510
C     READ CARD D
 1210 READ 1060,(TWEL(I), TWQ(I), I= 1, NUMTW)
      QMAX=TWQ( NUMTW)
C     READ CARD E
      READ 1060,(ZINFL(I), I=1, NUMIN )
      IF(NUMIN-80)1220,1220,1510
C     START RATING FOR NEW SPILLWAY SAME TW-Q, AND EL-CAP TABLES.
C     READ CARD F
C                                        BRANCH TO  1220 FROM  1160.00
 1220 READ 1060,SS, ELTFC, STFC, ELST, PER, TIME, CHCAP
      CTELSP=0.0
      TTIME=TIME
 1230 FORMAT(3I8,F8.2,6I8)
C     READ CARD G
      READ 1060,ELTSUR, ELSURO, QSURO, TS, C, CLINEP, PERHD, ERRHD
C     READ CARD H
      READ 1060,X,SPWID,DESHD,ELSPI, APEL, APWID,APLOSS,PDPTH
      TTS=TS
      NGATES=X
      GATES=X
      IF(PERHD)1250,1240,1250
 1240 PERHD=100.
C                                        BRANCH TO  1250 FROM  1230.06
 1250 IF(ERRHD)1260,1260,1270
```

EXHIBIT 7

```
 1260 ERRHD=.5
C                                     BRANCH TO  1270 FROM  1250.00
 1270 PRINT 1280
 1280 FORMAT (62H ITYSP INDCON   ISPITW   IABCOA  ISPILN  ISRCD  ISPCTW
     1 ITABLE)
      PRINT 1290,ITYSP,INDCON,ISPITW,IABCOA,ISPILN,ISRCD,ISPCTW,ITABLE
 1290 FORMAT (I4,9I8 )
      PRINT 1300
 1300 FORMAT(/36H    ABUTMENT CONTRACTION COEFFICIENT/)
      PRINT 1310,(ZKA(N),N=1,14)
      PRINT 1070
C                                     BRANCH TO  1310 FROM  1300.01
 1310 FORMAT (3H KA,3X,7F7.3)
      PRINT 1320
 1320 FORMAT( 75H    SS     ELTFC     STFC     ELST     PER   TIME     C
     1HCAP  QMIN1    PERHD/)
      PRINT 1350,  SS,ELTFC,STFC,ELST,PER,TIME,CHCAP,QMIN1,PERHD
      PRINT 1070
      PRINT 1330
      PRINT  1360, ELTSUR,ELSURO,QSURO,TS,C,CLINEP,CONMIN,QMIN2,ERRHD
C                                     BRANCH TO  1330 FROM  1320.04
 1330 FORMAT (76H  ELTSUR    ELSURO    QSURO   TS       C      CLINEP  C
     1ONMIN   QMIN2   ERRHD/)
      PRINT 1070
      PRINT 1340
 1340 FORMAT (65H NGATES  SPWID  DESHD    ELSPI    APEL     APWID  APLOS
     1S    PDPTH/)
      PRINT 1370,   GATES,SPWID,DESHD,ELSPI,APEL,APWID,APLOSS,PDPTH
C                                     BRANCH TO  1350 FROM  1320.02
 1350 FORMAT (F8.2,F9.2,F10.0,F9.2,F7.2,F8.2,3F8.0)
C                                     BRANCH TO  1360 FROM  1320.05
 1360 FORMAT (F8.2,F10.2,F9.0,F7.2,2F9.2,F8.2,3 F9.2)
C                                     BRANCH TO  1370 FROM  1340.02
 1370 FORMAT (F6.1,F9.2,F7.2,3F9.2,F7.3,F8.1,F8.0)
      PRINT 1070
C                                     BRANCH TO  1380 FROM  1390.01
 1380 FORMAT(17H    DESIGN HEAD =,F6.2/)
      PRINT 1070
C     START SPILLWAY RATING FOR NEW DESIGN HEAD HERE
C
C
```

```
C                                                   BRANCH TO  1390 FROM  1480.01
  1390 PRINT 1110                                                                    1149
       PRINT 1380, DESHD                                                             1150
       PRINT 1400                                                                    1151
       PRINT 1410                                                                    1152
       PRINT 1070                                                                    1153
       PRINT 1070                                                                    1154
C                                                   BRANCH TO  1400 FROM  1390.02
  1400 FORMAT (83H  RESER.  RESER. SPILLWAY SPILLWAY  SPILL CONDUIT  COND 1155
      1UIT CONDUIT    TOTAL ASSUMED)                                                 1156
C                                                   BRANCH TO  1410 FROM  1390.03
  1410 FORMAT (82H  ELEV.    CAP.   Q-FREE  TAILWATER QCORR  QFREE  TAILW 1157
      1ATER Q-CORR        Q        Q)                                                1158
  1420 CALL SPIRAT                                                                   1160
       IF(ISTOP)1430,1430,1100                                                       1161
  1430 CALL RESROT                                                                   1162
       IF(ISTOP)1440,1440,1100                                                       1163
  1440 DIFA=(DESHD-HEAD*PERHD*.01)                                                   1164
       IF(DIFA)1450,1460,1460                                                        1165
  1450 DIFA=-DIFA                                                                    1166
C                                                   BRANCH TO  1460 FROM  1440.01
  1460 IF(DIFA-ERRHD)1490,1490,1470                                                  1167
  1470 IF(ISRCD)1490,1480,1490                                                       1168
  1480 DESHD=HEAD*PERHD*.01                                                          1169
       GO TO 1390                                                                    1170
C                                                   BRANCH TO  1490 FROM  1460.00  1470.00
C
  1490 PRINT 1500                                                                    1172
  1500 FORMAT(8X,/17H DESIGN HEAD O.K.)                                              1173
       PRINT 1070                                                                    1174
       GO TO 1100                                                                    1175
C                                                   BRANCH TO  1510 FROM  1200.02  1210.03
C
  1510 PRINT 1520                                                                    1177
  1520 FORMAT (10H STOP 1177)                                                        1178
       GO TO 1100                                                                    1179
       END                                                                           1180
C      22-J2-J210-PART I-SUBROUTINE SPIRAT                                           1001
C      WITH SPECIAL CONDUIT OPERATION 29 MAR 1965                                    1002
       SUBROUTINE SPIRAT                                                             1003
       DIMENSION ELEV(40),Q(50),HEHD(14),TWEL(30),TWQ(30),ZKP(14),CC(14)             1004
```

5

EXHIBIT 7

```
      DIMENSION HDHE(14),EC(14),HDDHE(18),IS(252),ZKA(14),ZKAC(14)
      DIMENSION CT(40),IPERSR(10),IPERDQ(10),ZINFL(80)
      COMMON ELEV,CT,Q,INDCON,ISPITW,ISPILN,ISRCD,ISPCTW,ELMAX,QMAX,NUME
     1L,NUMTW,SS,C,CLINEP,NGATES,SPWID,DESHD,ELSPI,APEL,APWID,APLOSS,PD
     2PTH,ITYSP,ELTFC,STFC,ELST,PER,TIME,CHCAP,QMIN,CTELSP,ELTSUR,ELSURO
     3,QSURO,TS,ELTOP,CQELSP,QSPBSR,QMIN1,QMIN2,CONMIN,ELMIN,PERHD,HEAD
     4,TWQ,ZKP,HEHD,CC,EC,HDDHE,ZKA,IS,HDHE,TWEL,TTIME,TTS
     5,STG,PCUMST,CTNSRO,ICASE, IPERSR,IPERDQ,NUMIN,ZINFL
      COMMON QIN,PQIN,QCAVE,QTOPSR,PQAV,PEL,ELEVC,ISTOP
C                                 BRANCH TO  3000 FROM  4200.00
 3000 FORMAT (1H0)
      TIME=TTIME
      TS=TTS
      ZTWEL=APEL+2.0
      QFREE=0.0
      QSPBSR=0.0
      QCORR=0.0
      A=0.0
      CQCOND=0.0
      ZXTWEL=0.0
      CQFREE=0.0
      QC=0.0
      DO 3080 N=1,30
      Q(N)=0.0
      IF(INDCON)3020,3010,3020
 3010 C=0.0
C                                 BRANCH TO  3020 FROM  3000.14
 3020 X=ELEV(N)-CLINEP
      IF(X) 3080,3080,3030
 3030 CQFREE=C*(X)**.5
      Q(N) = CQFREE
      IF(ITYSP)3040,3040,3060
 3040 IF(QMIN1-CQFREE)3050,3060,3060
 3050 Q(N)=QMIN1
C                                 BRANCH TO  3060 FROM  3030.02  3040.00
C
 3060 IF(ELEV(N)-ELSPI)3070,3120,3130
 3070 PRINT 3110,  ELEV(N),CT(N),A,A,A,CQFREE,A,CQFREE,CQFREE,Q(N)
C                                 BRANCH TO  3080 FROM  3000.12  3020.01
C
 3080 CONTINUE
```

```
      PRINT 3090
 3090 FORMAT ( 10H STOP 1177)
      GO TO 4190
C                                    BRANCH TO  3100 FROM  3150.03
 3100 PRINT 3110,  ELSPI,CTELSP,A,A,A,CQFREE,A,CQFREE,CQFREE,Q(N)
C                                    BRANCH TO  3110 FROM  3070.00  4180.00
C
 3110 FORMAT  (F8.2,2 F9.0,F7.1,2F9.0,F7.1,3F9.0)
      Z=DESHD*1.5
      GO TO 3220
C                                    BRANCH TO  3120 FROM  3060.00
 3120  N=N+1
      Q(N)=0.0
C                                    BRANCH TO  3130 FROM  3060.00
 3130 N=N-1
      IF(N-1)3150,3140,3140
 3140 RATIO=(ELSPI-ELEV(N))/(ELEV(N+1)-ELEV(N))
      CTELSP=RATIO*(CT(N+1)-CT(N))+CT(N)
C                                    BRANCH TO  3150 FROM  3130.01
 3150 CQELSP=C*(ELSPI-CLINEP)**.5
      CQFREE=CQELSP
      Q(N)=RATIO*(Q(N+1)-Q(N)) + Q(N)
      GO TO 3100
C                                    BRANCH TO  3160 FROM  3440.01
 3160 PRINT 3170
 3170   FORMAT( 10H STOP 1175)
      GO TO 4190
C                                    BRANCH TO  3180 FROM  3480.00
 3180 PRINT 3190
 3190   FORMAT( 10H STOP 1174)
      GO TO 4190
C                                    BRANCH TO  3200 FROM  3750.00
 3200 PRINT 3210
 3210   FORMAT ( 10H STOP 1170)
      GO TO 4190
C                                    BRANCH TO  3220 FROM  3110.02
 3220 ELTOP=ELSPI+Z
      K=1
C                                    BRANCH TO  3230 FROM  3240.01
 3230 IF (ELEV(K)-ELTOP)3240,3260,3250
 3240 K=K+1
```

7

EXHIBIT 7

EXHIBIT 7

```
      IF(K-NUMEL)3230,3230,3250                                                    1079
C                                         BRANCH TO  3250 FROM  3230.00
 3250 ELTOP=ELEV(K-1)                                                              1081
C                                         BRANCH TO  3260 FROM  3230.00
 3260 I=N                                                                          1083
      EL = ELTSUR                                                                  1084
      IF(ITYSP)3280,3280,4030                                                      1085
C     START COMPUTING DISCHARGE FOR NEW ELEV(I) HERE                               1086
C                                         BRANCH TO  3270 FROM  4060.01  4180.02
C
 3270 I=I+1                                                                        1088
      EL=ELEV(I)                                                                   1089
C                                         BRANCH TO  3280 FROM  3260.02
 3280 HE=EL-ELSPI                                                                  1091
      HLOSS=APLOSS*HE/DESHD                                                        1092
      HE=HE-HLOSS                                                                  1093
      ZHEHD=HE/DESHD                                                               1094
      IF(ZHEHD-1.3)3300,3300,3290                                                  1095
 3290 ZHEHD=1.3                                                                    1096
C                                         BRANCH TO  3300 FROM  3280.04
 3300 DO 3310 N=1,14                                                               1097
      IF(HEHD(N)-ZHEHD)3310,3320,3320                                              1098
C                                         BRANCH TO  3310 FROM  3300.00
 3310 CONTINUE                                                                     1099
C                                         BRANCH TO  3320 FROM  3300.01
 3320 RATIO=(ZHEHD-HEHD(N-1))/(HEHD(N)-HEHD(N-1))                                  1100
      ZCC=CC(N-1)+RATIO*(CC(N)-CC(N-1))                                            1101
      ZEC=EC(N-1)+RATIO*(EC(N)-EC(N-1))                                            1102
      ZXKP=RATIO*(ZKP(N)-ZKP(N-1))+ZKP(N-1)                                        1103
      ZXKA=ZKA(N-1)+RATIO*(ZKA(N)-ZKA(N-1))                                        1104
      ZN=NGATES-1                                                                  1105
      IF(ZN)3330,3340,3340                                                         1106
 3330 ZN=0.0                                                                       1107
C                                         BRANCH TO  3340 FROM  3320.06
 3340 ZEFFL=SPWID-2.*HE*(ZN*ZXKP+ZXKA)                                             1108
      IF(ISPILN)3370,3350,3370                                                     1109
 3350 IF(ZEFFL-SPWID)3370,3360,3360                                                1110
 3360 ZEFFL=SPWID                                                                  1111
C                                         BRANCH TO  3370 FROM  3340.01  3350.00
C
 3370 IF(ISRCD)3380,3440,3380                                                      1113
```

```
 3380 HV=.3*HE
      ELTOP=ELMAX
C                                       BRANCH TO  3390 FROM  3420.01
 3390 D=HE-HV
      TW=ZEFFL+2.0*SS*D
      AREA=ZEFFL*D+SS*D*D
      HVC=AREA*.5/TW
      HEC=HVC+D
      X=HEC-HE
      IF (X)3400,3410,3410
 3400 X=-X
C                                       BRANCH TO  3410 FROM  3390.06
 3410 T=.001*HE
      IF(X-T)3430,3430,3420
 3420 HV=(HV+HVC)*.5
      GO TO 3390
C                                       BRANCH TO  3430 FROM  3410.01
 3430 ZTWEL=D+APEL
      QFREE=AREA*(HV*64.4)**.5
      QCORR=QFREE
      GO TO 3870
C                                       BRANCH TO  3440 FROM  3370.00
 3440 ZPHD=PDPTH/DESHD
      IF(ZPHD-.07)3160,3160,3450
 3450 IF(ZPHD-1.33)3470,3470,3460
 3460 ZPHD=1.33
C                                       BRANCH TO  3470 FROM  3450.00
 3470 COFQ=ZCC*(ZPHD**ZEC)
      QFREE=COFQ*ZEFFL*HE**1.5
      TRIAL=0.0
      QASSM=QFREE
      CEE=ELSPI-APEL
C     NEW TRIAL OF SPILLWAY SUBMERGENCE
C                                       BRANCH TO  3480 FROM  3850.05  3860.01
C
 3480 IF(TRIAL-100.0)3490,3180,3490
 3490 IF(ISPITW)3500,3620,3500
 3500 FIXED=QASSM*QASSM/(64.4*APWID*APWID)
      DCRIT=(QASSM/(5.67*APWID))**.6667
      DASSM=DCRIT
      IF((1.5*DASSM)-(.9*(HE+CEE)))3510,3600,3600
```


EXHIBIT 7

EXHIBIT 7

```
 3510 DASSM=ZTWEL-APEL+.01                                                    1151
      NTRY=1                                                                  1152
C                                        BRANCH TO  3520 FROM  3580.03  3590.05
C
 3520 IF(DASSM-DCRIT)3540,3540,3530                                           1154
 3530 DASSM=DCRIT-.01                                                         1155
C                                        BRANCH TO  3540 FROM  3520.00
 3540 VALUE=(.9*(HE+CEE)-DASSM)*DASSM*DASSM                                   1156
      ERROR=VALUE-FIXED                                                       1157
      IF(ERROR)3550,3560,3560                                                 1158
 3550 ERROR = - ERROR                                                         1159
C                                        BRANCH TO  3560 FROM  3540.02
 3560 T=.001*FIXED                                                            1160
      IF(ERROR-T)3600,3600,3570                                               1161
 3570 NTRY=NTRY+1                                                             1162
      IF(NTRY-2)3580,3580,3590                                                1163
 3580 ZDASSM=DASSM                                                            1164
      ZVALUE=VALUE                                                            1165
      DASSM=DASSM-.01                                                         1166
      GO TO 3520                                                              1167
C                                        BRANCH TO  3590 FROM  3570.01
 3590 CON=(FIXED-VALUE)/(ZVALUE-VALUE)                                        1169
      TEMP=DASSM                                                              1170
      DASSM=CON*(ZDASSM-DASSM)+DASSM                                          1171
      ZDASSM=TEMP                                                             1172
      ZVALUE=VALUE                                                            1173
      GO TO 3520                                                              1174
C                                        BRANCH TO  3600 FROM  3500.03  3560.01
C
 3600 ZTWEL=APEL+DASSM                                                        1176
      ZHD=(HE+ELSPI-APEL-DASSM)                                               1177
      IF(ZHD)3610,3610,3710                                                   1178
 3610 ZHD=.001                                                                1179
      GO TO 3710                                                              1180
C                              TAILWATER TABLE LOOK UP                        1181
C                                        BRANCH TO  3620 FROM  3490.00
 3620 DO 3650 N=1, 30                                                         1183
      IF(QASSM-QMAX)3640,3640,3630                                            1184
C                                        BRANCH TO  3630 FROM  3910.00
 3630 ELTOP=ELEV(I-1)                                                         1186
      GO TO 4200                                                              1187
```

```
C                                     BRANCH TO  3640 FROM  3620.01
 3640 IF(QASSM-TWQ(N))3660,3660,3650
C                                     BRANCH TO  3650 FROM  3620.00
 3650 CONTINUE
C                                     BRANCH TO  3660 FROM  3640.00
 3660 RATIO=(QASSM-TWQ(N-1))/(TWQ(N)-TWQ(N-1))
      ZTWEL=RATIO*(TWEL(N)-TWEL(N-1))+TWEL(N-1)
C                                     BRANCH TO  3670 FROM  3700.02
 3670 D=ZTWEL-APEL
      ZHD=(HE+ELSPI-APEL-D)
      IF(ZHD)3680,3680,3710
 3680 ZTWEL=EL-.001
      DO 3690 N=1,30
      IF(ZTWEL-TWEL(N))3700,3700,3690
C                                     BRANCH TO  3690 FROM  3680.01
 3690 CONTINUE
C                                     BRANCH TO  3700 FROM  3680.02
 3700 RATIO=(ZTWEL-TWEL(N-1))/(TWEL(N)-TWEL(N-1))
      QASSM=RATIO*(TWQ(N)-TWQ(N-1))+TWQ(N-1)
      GO TO 3670
C                                     BRANCH TO  3710 FROM  3600.02  3610.01
C                                           3670.02
 3710 ZHDHE=ZHD/HE
      ZHDDH=(HE+CEE)/HE
      IF(ZHDHE-0.9)3730,3730,3720
 3720 ZHDHE=.9
C                                     BRANCH TO  3730 FROM  3710.02
 3730 IF(ZHDDH-4.5)3750,3750,3740
 3740 ZHDDH=4.5
C                                     BRANCH TO  3750 FROM  3730.00
 3750 IF(ZHDDH-1.07)3200,3200,3760
 3760 DO 3770 J=1,14
      IF(HDHE(J)-ZHDHE)3770,3780,3780
C                                     BRANCH TO  3770 FROM  3760.00
 3770 CONTINUE
C                                     BRANCH TO  3780 FROM  3760.01
 3780 DO 3790 N=1,18
      IF(HDDHE(N)-ZHDDH)3790,3800,3800
C                                     BRANCH TO  3790 FROM  3780.00
 3790 CONTINUE
C                                     BRANCH TO  3800 FROM  3780.01
```

EXHIBIT 7

```
 3800 NJ=14*(N-1)+J
      NJM1=NJ-1
      NM1J=NJ-14
      NM1JM1=NJ-15
      A = IS(NJ)
      B = IS(NJM1)
      X = IS(NM1J)
      D = IS(NM1JM1)
      TIM = (A-B)*(ZHDHE-HDHE(J-1))*.001
      ZA = B*.001 + TIM/(HDHE(J)-HDHE(J-1))
      TIM=(ZHDHE-HDHE(J-1))/(HDHE(J)-HDHE(J-1))
      ZBA = (X-D)*.001*TIM
      ZB = ZBA + D*.001
      TIM=(HDDHE(N)-ZHDDH)/(HDDHE(N)-HDDHE(N-1))
      SUBQ=ZA+(ZB-ZA)*TIM
      QCORR=QFREE-.01*SUBQ*QFREE
      QTOTAL=QCORR
      EALL=.01*QCORR
      ERROR=QASSM-QCORR
      IF(ERROR)3810,3820,3820
 3810 ERROR = -ERROR
C                                    BRANCH TO  3820 FROM  3800.19
 3820 IF(EALL-ERROR)3830,3870,3870
 3830 TRIAL=TRIAL+1.
      IF(TRIAL-2.0)3840,3850,3850
 3840 QCT=QCORR
      QAT=QASSM
      GO TO 3860
C                                    BRANCH TO  3850 FROM  3830.01
 3850 CON=(QASSM-QCORR)/(QAT-QCT)
      TEMP=QASSM
      QASSM = (CON*QAT-QASSM)/(CON-1.)
      QCT=QCORR
      QAT=TEMP
      GO TO 3480
C                                    BRANCH TO  3860 FROM  3840.02
 3860 QASSM=0.5*(QASSM+QCORR)
      GO TO 3480
C                                    BRANCH TO  3870 FROM  3430.03  3820.00
C
 3870 IF(INDCON)3880,4000,3880
```

```
 3880 CQFREE=C*(EL-CLINEP)**.5
      AQCOND=CQFREE
C                                             BRANCH TO  3890 FROM  3990.01
 3890 QTOTAL=AQCOND+QCORR
      IF(ISPCTW)3900,3910,3900
 3900 QTOTAL=AQCOND
C                                             BRANCH TO  3910 FROM  3890.01
 3910 IF(QMAX-QTOTAL)3630,3920,3920
 3920 DO 3930 N=1, 30
      IF(TWQ(N)-QTOTAL)3930,3930,3940
C                                             BRANCH TO  3930 FROM  3920.00
 3930 CONTINUE
C                                             BRANCH TO  3940 FROM  3920.01
 3940 RATIO=(QTOTAL-TWQ(N-1))/(TWQ(N)-TWQ(N-1))
      ZXTWEL=TWEL(N-1)+RATIO*(TWEL(N)-TWEL(N-1))
      CQCOND=C*(EL-ZXTWEL)**.5
      IF(CQCOND-CQFREE)3960,3950,3950
 3950 CQCOND=CQFREE
      GO TO 4000
C                                             BRANCH TO  3960 FROM  3940.03
 3960 AER=.001*CQCOND
      ERROR=CQCOND-AQCOND
      IF(ERROR)3970,3980,3980
 3970 ERROR=-ERROR
C                                             BRANCH TO  3980 FROM  3960.02
 3980 IF(AER-ERROR)3990,4000,4000
 3990 AQCOND=(AQCOND+CQCOND)*.5
      GO TO 3890
C                                             BRANCH TO  4000 FROM  3870.00  3950.01
C                                                 3980.00
 4000 QTOTAL=QCORR+CQCOND
      IF(ITYSP)4010,4010,4170
 4010 IF(EL-ELTSUR)4030,4020,4030
 4020 CQTSR=CQCOND
C                                             BRANCH TO  4030 FROM  3260.02  4010.00
C
 4030  IF(ELEV(I)-ELSURO)4060,4040,4040
 4040 IF(ELEV(I-1)-ELSURO)4050,4050,4060
 4050 RATIO =(ELSURO-ELEV(I-1))/(ELEV(I)-ELEV(I-1))
      QSPBSR=PQSPI + RATIO*(QCORR -PQSPI)
C                                             BRANCH TO  4060 FROM  4030.00  4040.00
```

EXHIBIT 7

```
 4060 PQSPI=QCORR                                                           1290
      IF(ELEV(I)-ELSPI)3270,3270,4070                                       1291
 4070 IF(ELEV(I)-ELTSUR) 4080,4170,4170                                     1292
 4080 IF(ELEV(I)-ELSURO)4130,4090,4090                                      1293
 4090 RATIO=(ELEV(I)-ELSURO)/(ELTSUR-ELSURO)                                1294
      IF(QSPBSR-QMIN2)4100,4110,4110                                        1295
 4100 X=QMIN2-QSPBSR                                                        1296
      GO TO 4120                                                            1297
C                                  BRANCH TO  4110 FROM  4090.01
 4110 X=0.0                                                                 1298
C                                  BRANCH TO  4120 FROM  4100.01
 4120 Q(I)=QCORR+X+RATIO*(CQTSR-X)                                          1299
      GO TO 4160                                                            1300
C                                  BRANCH TO  4130 FROM  4080.00
 4130 X=QFREE+CONMIN                                                        1302
      IF(QMIN2-X)4140,4140,4150                                             1303
 4140 Q(I)=X                                                                1304
      GO TO 4160                                                            1305
C                                  BRANCH TO  4150 FROM  4130.01
 4150 Q(I)=QMIN2                                                            1306
C                                  BRANCH TO  4160 FROM  4120.01  4140.01
C
 4160 IF(Q(I)-QTOTAL)4180,4180,4170                                         1308
C                                  BRANCH TO  4170 FROM  4000.01  4070.00
C
 4170 Q(I)=QTOTAL                                                           1310
C                                  BRANCH TO  4180 FROM  4160.00
 4180 PRINT 3110,  ELEV(I),CT(I),QFREE,ZTWEL,QCORR,CQFREE,ZXTWEL,           1311
     1CQCOND,QTOTAL,Q(I)                                                    1312
      IF(ELTOP-ELEV(I))4200,4200,3270                                       1313
C                                  BRANCH TO  4190 FROM  3090.01  3170.01
C                                             3190.01  3210.01
 4190 ISTOP=1                                                               1314
C                                  BRANCH TO  4200 FROM  3630.01  4180.02
C
 4200 PRINT 3000                                                            1316
      RETURN                                                                1317
      END                                                                   1318
      SUBROUTINE RESROT                                                     1001
      DIMENSION ELEV(40),Q(50),HEHD(14),TWEL(30),TWQ(30),ZKP(14),CC(14)     1002
      DIMENSION HDHE(14),EC(14),HDDHE(18),IS(252),ZKA(14),ZKAC(14)          1003
```

```
      DIMENSION CT(40),IPERSR(10),IPERDQ(10),ZINFL(80)
      COMMON ELEV,CT,Q,INDCON,ISPITW,ISPILN,ISRCD,ISPCTW,ELMAX,QMAX,NUME
     1L,NUMTW,SS,C,CLINEP,NGATES,SPWID,DESHD,ELSPI,APEL,APWID,APLOSS,PD
     2PTH,ITYSP,ELTFC,STFC,ELST,PER,TIME,CHCAP,QMIN,CTELSP,ELTSUR,ELSURO
     3,QSURO,TS,ELTOP,CQELSP,QSPBSR,QMIN1,QMIN2,CONMIN,ELMIN,PERHD,HEAD
     4,TWQ,ZKP,HEHD,CC,EC,HDDHE,ZKA,IS,HDHE,TWEL,TTIME,TTS
     5,STG,PCUMST,CTNSRO,ICASE, IPERSR,IPERDQ,NUMIN,ZINFL
      COMMON QIN,PQIN,QCAVE,QTOPSR,PQAV,PEL,ELEVC,ISTOP
C                                       BRANCH TO  6000 FROM  7610.00  7640.09
C                                           8000.00  8020.00  8030.00  8040.00
 6000 FORMAT(10F8.0)
 6010 FORMAT (10I8)
 6020 FORMAT (15A3,11A3,A2)
 6030 FORMAT(7F8.4)
C                                       BRANCH TO  6040 FROM  6060.03  6120.00
C                                           6170.00  6570.02  6570.03  6780.02
C                                           6820.03
 6040 FORMAT (1H0)
 6050 FORMAT (1H2)
C                                       BRANCH TO  6060 FROM  6150.01  6490.02
C
 6060 FORMAT (8F10.2)
C
      CTELSP=0.0
      QMIN=QMIN1
C
C
C
C
C     START FLOOD ROUTING BY SLEWING TO TOP PAGE
      PRINT 6040
      TIME=TTIME
      TS=TTS
      PQC=1.
      N=1
      I=1
      ZMAXWS=0.0
      QIN=0.0
      A=0.0
      PEL=0.0
      PQIN=0.0
```

```
      QCAVE=0.0
      PQAV=0.0
      TRYPGO=0.0
      FINSUR=10.
      TRYTOP=0.0
      PQPGO=0.0
      ICASE=0
      ELAS=ELST
      IXY=0
      QFREE=999999.
      PQFREE=999999.
      INDPGO=0
      MXQPGO=0
      IF(ITYSP)6070,6120,6070
C     CONTROLLED SPILLWAY
 6070 FINSUR=0.
      TS=TS/24.
      X=ELSURO
C                                 BRANCH TO  6080 FROM  6110.03
 6080 DO 6090 N=1,30
      IF(ELEV(N)-X)6090,6090,6100
C                                 BRANCH TO  6090 FROM  6080.00
 6090 CONTINUE
C                                 BRANCH TO  6100 FROM  6080.01
 6100 RATIO=(X-ELEV(N-1))/(ELEV(N)-ELEV(N-1))
      QTOPSR=RATIO*(Q(N)-Q(N-1))+Q(N-1)
      STGTSR=RATIO*(CT(N)-CT(N-1))+CT(N-1)
      IF(X-ELSURO)6110,6110,6120
 6110 TQBSR=QTOPSR
      X=ELTSUR
      CTNSRO=STGTSR
      GO TO 6080
C                                 BRANCH TO  6120 FROM  6060.27  6100.03
C                                     6820.04
 6120 PRINT 6040
C     USING ASSUMED ELEVATION - FIND CAPACITY
C                                 BRANCH TO  6130 FROM  6420.02  6670.02
C
 6130 TRACE=1.
      IF(ELAS-ELEV(1))6140,6160,6160
 6140 PRINT 6150
```

```
6150  FORMAT ( 10H STOP  730)
      PRINT 6060,    ELAS,ELEV(1)
      GO TO 7540
C                                         BRANCH TO  6160 FROM  6130.01
6160 IF(ELTOP-ELAS)6170,6190,6190
6170 PRINT 6040
6180 FORMAT (12H ERROR 11717)
     GO TO 7540
C                                         BRANCH TO  6190 FROM  6160.00
6190 DO 6200 N=1,NUMEL
     IF(ELAS-ELEV(N))6210,6200,6200
C                                         BRANCH TO  6200 FROM  6190.00
6200 CONTINUE
C                                         BRANCH TO  6210 FROM  6190.01
6210 X=ELEV(N)
     Y=ELEV(N-1)
     RATIO=(ELAS-Y)/(X-Y)
     STG=(CT(N)-CT(N-1))*RATIO+CT(N-1)
     IF(Y-ELSPI)6230,6220,6220
C                                         BRANCH TO  6220 FROM  6230.00
6220 QN=Q(N)
     QNM1=Q(N-1)
     GO TO 6270
C                                         BRANCH TO  6230 FROM  6210.04
6230 IF(X-ELSPI)6220,6220,6240
6240 IF(ELAS-ELSPI)6250,6260,6260
6250 QN=CQELSP
     QNM1=Q(N-1)
     X=ELSPI
     GO TO 6270
C                                         BRANCH TO  6260 FROM  6240.00
6260 QN=Q(N)
     QNM1=CQELSP
     Y=ELSPI
C                                         BRANCH TO  6270 FROM  6220.02  6250.03
C
6270 IF(FINSUR)6300,6280,6300
6280 IF(I-1)6290,6290,6830
6290 PQC=QSURO
     QC=QSURO
     GO TO 6310
```


EXHIBIT 7

EXHIBIT 7

```
C                                       BRANCH TO  6300 FROM  6270.00
 6300 RATIO=(ELAS-Y)/(X-Y)
      QC=(QN-QNM1) *RATIO+QNM1
      STIND=QC*.5+STG*12.1/PER
      NSTIND = N
      IF(I-1)6310,6310,6680
C                                       BRANCH TO  6310 FROM  6290.02
 6310 INDSTR=0
C     ROUTING STARTS BY S+Q/2 WITH FIRST INFLOW
      IF(QC-QMIN1)6320,6330,6330
 6320 QCAVE=QMIN1
      QC=QMIN1
C                                       BRANCH TO  6330 FROM  6310.01
 6330 IF(ZINFL(I)-QC)6360,6360,6340
 6340  QIN=0.0
      TIME=TIME-PER
      GO TO 6370
C                                       BRANCH TO  6350 FROM  6360.02
 6350 TIME=TIME+PER
C                                       BRANCH TO  6360 FROM  6330.00
 6360 QIN=ZINFL(I)
      I=I+1
      IF(ZINFL(I)-QC)6350,6350,6370
C                                       BRANCH TO  6370 FROM  6340.02  6570.04
C
 6370 CUMSTG=STG
      QCAVE=0.0
      SA=0.0
      CSA=0.0
      ELAS=0.0
      STG=0.0
      ELEVC=ELST
      IF(FINSUR)7010,6820,6380
 6380 PRINT 6390
      PRINT 6400
      PRINT 6410
C                                       BRANCH TO  6390 FROM  6380.00
 6390 FORMAT(32H TIME   INFLOW  OUTFLOW  OUTFLOW)
C                                       BRANCH TO  6400 FROM  6380.01
 6400 FORMAT(58H HOURS    AV       AV     END PER S+Q/2   CAPACITY POOL
     1EL)
```

```
C                                          BRANCH TO  6410 FROM  6380.02
 6410 FORMAT(10X,48H CFS     CFS       CFS    END PER  END PER  END PER)      1152
      IF(INDSTR)6620,6620,6420                                                1153
 6420 PQC=PQFREE                                                              1154
C     INDSTR=10 FOR GATED SPILLWAY WHEN CHANGING TO S+Q/2                     1155
      ELAS=PEL                                                                1156
      GO TO 6130                                                              1157
C     BRANCH TO PRINT OUT STARTING CONDITIONS FOR FREEFLOW ROUTING.           1158
C                                          BRANCH TO  6430 FROM  6540.03  6890.00
C                                              6900.00  6910.03  6990.04
 6430 INDPGO=0                                                                1161
C                                                                             1162
C                                          BRANCH TO  6440 FROM  6560.03  6940.04
C                                              6950.04
 6440 CUMSTG=PCUMST+(QIN-QCAVE)*PER/12.1                                      1163
      IF(CT(1)-CUMSTG)6470,6470,6450                                          1164
 6450 PRINT 6460                                                              1165
 6460 FORMAT (12H ERROR 17177)                                                1166
      GO TO 7030                                                              1167
C                                          BRANCH TO  6470 FROM  6440.01
 6470 DO 6480 N=1,NUMEL                                                       1169
      IF(CT(N)-CUMSTG)6480,6480,6500                                          1170
C                                          BRANCH TO  6480 FROM  6470.00
 6480 CONTINUE                                                                1172
      PRINT 6490                                                              1173
 6490 FORMAT (13H EXTEND TABLE)                                               1174
      XN=N                                                                    1175
      PRINT 6060,  ELAS,XN,CT(N),CUMSTG                                       1176
      GO TO 7540                                                              1177
C                                          BRANCH TO  6500 FROM  6470.01
 6500 RATIO=(CUMSTG-CT(N-1))/(CT(N)-CT(N-1))                                  1179
      ELEVC=(ELEV(N)-ELEV(N-1))*RATIO+ELEV(N-1)                               1180
      QFREE=(Q(N)-Q(N-1))*RATIO+Q(N-1)                                        1181
      QAFREE=(QFREE+PQFREE)*.5                                                1182
 6510 IF(INDPGO)7010,6520,6950                                                1183
 6520 IF(ELEVC-ELTSUR-.001)6550,6550,6530                                     1184
 6530 TRYTOP=TRYTOP+1.                                                        1185
      IF(TRYTOP-3.)6540,6540,6570                                             1186
 6540 QCAVE=QIN+(PCUMST-STGTSR)*12.1/PER                                      1187
      QC=QCAVE                                                                1188
      ICASE=10                                                                1189
```


EXHIBIT 7

```
      GO TO 6430
C                                        BRANCH TO  6550 FROM  6520.00
 6550 IF(QAFREE-QCAVE)6560,6580,6580
 6560 QC=QAFREE
      QCAVE=QAFREE
      ICASE=11
      GO TO 6440
C                                        BRANCH TO  6570 FROM  6530.01
 6570 FINSUR=10.
      INDSTR=10
      PRINT 6040
      PRINT 6040
      GO TO 6370
C                                        BRANCH TO  6580 FROM  6550.00
 6580 TIME=TIME+PER
C
C     NORMAL PRINT FOR GATE REGULATION ROUTING
C                                        BRANCH TO  6590 FROM  6600.01
 6590 FORMAT(I4  ,6F9.0,F9.2,I6)
C                                        BRANCH TO  6600 FROM  6820.04
 6600 IT=TIME
      PRINT 6590,  IT  ,QIN,QCAVE,STG,SA,CSA,CUMSTG,ELEVC,ICASE
      GO TO 6640
C                                        BRANCH TO  6610 FROM  6760.06  6770.00
C
 6610 TIME=TIME+PER
C
C     NORMAL PRINT FOR FREE FLOW ROUTING.
C                                        BRANCH TO  6620 FROM  6410.01
 6620 IT=TIME
      PRINT 6630,  IT  ,QIN,QCAVE,QC,STIND,CUMSTG,ELEVC
 6630 FORMAT (I4,3F9.0,2F9.0,F9.2)
C                                        BRANCH TO  6640 FROM  6600.02
 6640 PCUMST=CUMSTG
      PQC=QC
      PQIN=QIN
      ELAS=ELEVC
      TRIAL=1.
      PQFREE=QFREE
      GUESS=0.0
      PQAV=QCAVE
```

```
      PEL=ELEVC                                                         1229
      TRYTOP=0.0                                                        1230
      INDPGO=0                                                          1231
      IF(ZMAXWS-ELEVC)6650,6660,6660                                    1232
 6650 ZMAXWS=ELEVC                                                      1233
C                                   BRANCH TO  6660 FROM  6640.11
 6660 IF(I-NUMIN)6670,6670,7030                                         1235
 6670 QIN=ZINFL(I)                                                      1236
      I=I+1                                                             1237
      IF(FINSUR)6130,6130,6680                                          1238
C                                   BRANCH TO  6680 FROM  6300.04
 6680 TEMP=STIND                                                        1240
      XSIND=0.0                                                         1241
      STIND=STIND-QC+QIN                                                1242
      IF(STIND-TEMP)6700,6690,6690                                      1243
 6690 N=NSTIND                                                          1244
      GO TO 6720                                                        1245
C                                   BRANCH TO  6700 FROM  6680.03
 6700 N=NSTIND-3                                                        1247
      IF(N)6710,6710,6720                                               1249
 6710 N=1                                                               1250
C                                   BRANCH TO  6720 FROM  6690.01  6700.01
C                                      6730.01  6750.01
 6720 PXSIND=XSIND                                                      1251
      XSIND=.5*Q(N)+CT(N)*12.1/PER                                      1252
      IF(XSIND-STIND)6730,6730,6740                                     1253
 6730 N=N+1                                                             1254
      GO TO 6720                                                        1255
C                                   BRANCH TO  6740 FROM  6720.02
 6740 IF(PXSIND-STIND)6760,6760,6750                                    1257
 6750 N=1                                                               1258
      GO TO 6720                                                        1259
C                                   BRANCH TO  6760 FROM  6740.00
 6760 RATIO=(STIND-PXSIND)/(XSIND-PXSIND)                               1261
      NSTIND=N                                                          1262
      QC= Q(N-1)+RATIO*(Q(N)-Q(N-1))                                    1263
      ELEVC=ELEV(N-1)+RATIO*(ELEV(N)-ELEV(N-1))                         1264
      QCAVE=.5*(QC+PQC)                                                 1265
      CUMSTG=CT(N-1)+RATIO*(CT(N)-CT(N-1))                              1266
      IF(ITYSP)6610,6610,6770                                           1267
C     ITYSP=0 FOR UNCONTROLLED SPILLWAY,=10-GATED                       1268
```


EXHIBIT 7

```
 6770 IF(ELEVC-ELTSUR)6780,6610,6610
 6780 FINSUR=0.0
      INDSTR =10
      PRINT 6040
      GO TO 6820
C
C     START REGULATED GATES ROUTING
C
C     PRINT HEADINGS FOR GATE REGULATION ROUTING.
C                                          BRANCH TO  6790 FROM  6820.00
 6790 FORMAT(69H TIME   INFLOW OUTFLOW  STG-IND  STORAGE  STORAGE    RESE
     1R.  RESERVOIR)
C                                          BRANCH TO  6800 FROM  6820.01
 6800 FORMAT(76H HOURS    AV       AV        SUR      AVAIL.   AVAIL.    CAPA
     1C.  POOL ELEV  ICASE)
C                                          BRANCH TO  6810 FROM  6820.02
 6810 FORMAT(9X,60H CFS    CFS      CURVE     ASSUM.    COMP.      END PD.  E
     1ND  PD.)
C                                          BRANCH TO  6820 FROM  6370.07  6780.03
C
 6820 PRINT 6790
      PRINT 6800
      PRINT 6810
      PRINT 6040
      IF(INDSTR)6120,6600,6120
C     BRANCH TO STARTING PRINT OUT FOR GATE REGULATION ROUTING
C     START TRIAL AND ERROR SOLUTION FOR SA AND CSA
C                                          BRANCH TO  6830 FROM  6280.00
 6830 ITRY=1
      IF(QIN-PQAV)6840,7060,7060
 6840 IF(ELEVC-ELTFC)6970,6970,7000
C                                          BRANCH TO  6850 FROM  7100.05  7180.00
C                                              7510.03
 6850 IF(QCAVE-PQAV)6860,6900,6900
 6860 IF(QIN-PQIN)6890,6870,6880
 6870 IF(PQPGO)6890,6880,6890
C                                          BRANCH TO  6880 FROM  6860.00
 6880 IF(PQAV-CHCAP)6900,6980,6890
C                                          BRANCH TO  6890 FROM  6860.00  6870.00
C
 6890 IF(INDPGO)6430,6920,6430
```

```
C                                        BRANCH TO  6900 FROM  6850.00  6880.00
C
  6900 IF(QCAVE-QMIN)6910,6430,6430
  6910 QCAVE=QMIN
       QC=QMIN
       ICASE=6
       GO TO 6430
C      GO COMPUTE ELEVATION WITH DESIRED RELEASE
C                                        BRANCH TO  6920 FROM  6890.00  7000.02
C
  6920 HEAD=ELEVC-ELSPI-2.0
       N=1
       STG=0.
       TRYPGO=TRYPGO+1.0
C                                        BRANCH TO  6930 FROM  6930.03
  6930 XD=PQAV/(((64.4*HEAD)**.5)*SPWID)
       HEAD=ELEVC-ELSPI-.5*XD
       N=N+1
       IF(N-5)6930,6940,6940
  6940 N=1
       INDPGO=10
       ICASE=7
       QCAVE=PQAV
       GO TO 6440
C                                        BRANCH TO  6950 FROM  6510.00
  6950 H=ELEVC-ELSPI-.5*XD
       QCAVE=((H/HEAD)**.5)*PQAV
       PQPGO=QCAVE
C      TRACE OF PARTIAL GATE OPENING DISCHARGE
C
       N=N+1
       IF(N-5)6440,6960,6960
  6960 IF(ELEVC-ELTFC)6970,6970,6990
C                                        BRANCH TO  6970 FROM  6840.00
  6970 QCAVE=(QIN +PQAV)*.5
       ICASE=8
       IF(QCAVE-CHCAP)6980,6980,6990
C                                        BRANCH TO  6980 FROM  6880.00
  6980 QCAVE=CHCAP
       ICASE=9
C                                        BRANCH TO  6990 FROM  6960.00  6970.02
```


EXHIBIT 7

EXHIBIT 7

```
C
 6990 QC=QCAVE
      SA=0.0
      CSA=0.0
      STG=0.0
      GO TO 6430
C                                        BRANCH TO  7000 FROM  6840.00
 7000 SA=0.
      CSA=0.
      GO TO 6920
C                                        BRANCH TO  7010 FROM  6370.07  6510.00
C
 7010 PRINT 7020
 7020        FORMAT ( 11H STOP 11777)
C                                        BRANCH TO  7030 FROM  6460.01  6660.00
C
 7030 HEAD=ZMAXWS-ELSPI
      X=DESHD/(PERHD*.01      )
      PRINT 7050, X
      PRINT 7040, HEAD
 7040 FORMAT(/27H   COMPUTED ENERGY HEAD =                ,F6.2)
C                                        BRANCH TO  7050 FROM  7030.02
 7050 FORMAT(/27H   ASSUMED ENERGY HEAD =            ,F6.2)
      RETURN
C                                        BRANCH TO  7060 FROM  6830.01
 7060 GUESS=0.0
      QSUR=0.0
      IF(PEL-ELTSUR)7070,7500,7500
 7070 IF(QIN-QSURO)7500,7500,7080
 7080 QCAVE=QSURO
      ICASE=0
      NTRY=0
      STG=0.0
      ITRY=1
      GO TO 7250
C                                        BRANCH TO  7090 FROM  7280.00
 7090 X=CSA+PCUMST
      IF(X-CTNSRO)7100,7110,7110
 7100 QCAVE=QMIN
      QC=QMIN
      ICASE=2
```

```
      CSA=0.0
      SA=0.0
      GO TO 6850
C                                      BRANCH TO  7110 FROM  7090.01
 7110 FTSUR=ELTSUR-ELSURO
      QCAVE=PQAV
C                                      BRANCH TO  7120 FROM  7160.03  7200.01
C                                         7480.00  7490.01
 7120 N=1
C                                      BRANCH TO  7130 FROM  7150.01
 7130 A = IPERDQ(N)
      QSUR = A*.0001*(QTOPSR-QSURO)+QSURO
      IF(QSUR-QCAVE)7140,7140,7190
 7140 N=N+1
      IF(N-10)7150,7150,7160
 7150 XQSUR=QSUR
      GO TO 7130
C                                      BRANCH TO  7160 FROM  7140.01
 7160 QCAVE=QTOPSR
      ICASE=3
      NTRY=NTRY+1
      IF(NTRY-5)7120,7120,7170
 7170 SA=0.
      CSA=0.
      STG=0.
C                                      BRANCH TO  7180 FROM  7230.01  7340.01
C
 7180 IF(QCAVE-QIN)6850,6850,7500
C                                      BRANCH TO  7190 FROM  7130.02
 7190 IF(N-1)7200,7200,7210
 7200 QCAVE=QSURO
      GO TO 7120
C                                      BRANCH TO  7210 FROM  7190.00
 7210 RATIO=(QCAVE-XQSUR)/(QSUR-XQSUR)
      A = IPERSR(N)
      B = IPERSR(N-1)
      SURPER = RATIO*(A-B) + B
      ELSUR=FTSUR*.0001*SURPER+ELSURO
      N=1
C                                      BRANCH TO  7220 FROM  7230.01
 7220 IF(ELEV(N)-ELSUR)7230,7240,7240
```


EXHIBIT 7

```
 7230 N=N+1
      IF(N-NUMEL)7220,7220,7180
C                                            BRANCH TO  7240 FROM  7220.00
 7240 RATIO=(ELSUR-ELEV(N-1))/(ELEV(N)-ELEV(N-1))
      STG=(CT(N)-CT(N-1))*RATIO+CT(N-1)
      ITRY=ITRY+1
      SA=STG-PCUMST
C                                            BRANCH TO  7250 FROM  7080.05
 7250 Q1=(.5-.5/PER)*(QIN-PQIN)+PQIN
      IF(QCAVE)7260,7260,7270
 7260 CSA=1.9835*TS*Q1
      GO TO 7280
C                                            BRANCH TO  7270 FROM  7250.01
 7270 CSA=1.9835*TS*(Q1-QCAVE*(1.+LOGF(Q1/QCAVE)))
C                                            BRANCH TO  7280 FROM  7260.01
 7280 IF(ITRY-1)7290,7090,7290
 7290 X=CSA-SA
      IF(X)7300,7310,7310
 7300 X=-X
C                                            BRANCH TO  7310 FROM  7290.01
 7310 Y=SA
      IF(Y)7320,7330,7330
 7320 Y=-Y
C                                            BRANCH TO  7330 FROM  7310.01
 7330 L=X-.005*Y
      IF(L)7340,7340,7350
 7340 ICASE=5
      GO TO 7180
C                                            BRANCH TO  7350 FROM  7330.01
 7350 IF(ITRY-2)7520,7360,7370
 7360 XSA=SA
      XCSA=CSA
      XQCAVE=QCAVE
      GO TO 7450
C                                            BRANCH TO  7370 FROM  7350.00
 7370 TEMP=QCAVE
      IG=SA
      IF(IG)7400,7380,7400
 7380 IF(Q1-QCAVE)7390,7390,7420
 7390 ICASF=12
       QCAVE=Q1
```

```
      GO TO 7510
C                                     BRANCH TO  7400 FROM  7370.02
 7400 IXS=XSA
      IF(IXS)7410,7420,7420
 7410 QCAVE=XQCAVE-((XSA*(XQCAVE-QCAVE))/(XSA-SA))
      GO TO 7440
C                                     BRANCH TO  7420 FROM  7380.00  7400.01
C
 7420 A=(XQCAVE-QCAVE)*(CSA-SA)
      B=(CSA-SA)-(XCSA-XSA)
      QCAVE=A/B+QCAVE
      IF(QCAVE)7430,7430,7440
 7430 QCAVE=1.0
C                                     BRANCH TO  7440 FROM  7410.01  7420.03
C
 7440 XQCAVE=TEMP
      XSA=SA
      XCSA=CSA
      GO TO 7480
C                                     BRANCH TO  7450 FROM  7360.03
 7450 IF(QCAVE)7460,7460,7470
 7460 QCAVE=1.0
      GO TO 7480
C                                     BRANCH TO  7470 FROM  7450.00
 7470 QCAVE=1.1*QCAVE
C                                     BRANCH TO  7480 FROM  7440.03  7460.01
C
 7480 IF(QCAVE-Q1 )7120,7490,7490
 7490 GUESS=GUESS+1.
      IF(GUESS-5.0)7120,7120,7500
C                                     BRANCH TO  7500 FROM  7060.02  7070.00
C                                            7180.00
 7500 QCAVE=Q1
      ICASE=12
C     CHECK GATE REGULATION RELEASE FOR DESIRED
C                                     BRANCH TO  7510 FROM  7390.02
 7510 SA=0.0
      CSA=0.0
      STG=0.0
C     BRANCH BACK TO MAIN RESERVOIR ROUTING
      GO TO 6850
```


EXHIBIT 7

```
C                                                  BRANCH TO  7520 FROM  7350.00
 7520 PRINT 7530                                                                      1497
 7530    FORMAT ( 10H STOP STOP)                                                      1498
C                                                  BRANCH TO  7540 FROM  6150.02  6180.01
C                                                      6490.03
 7540 ISTOP=1                                                                         1499
      RETURN                                                                          1500
      END                                                                             1501
```

EXHIBIT 8

INPUT DATA DESCRIPTION

Heading Cards. - Five heading cards must be inserted just before the indicator card. All five cards must be used even if they are all blank. The purpose of the cards is to print headings to describe the run. The following is an example:

SUGGESTED HEADINGS

CARD 1

Reservoir Name | Date of Computation

CARD 2

Description of project purpose

(a) F.C. and W.S.
or (b) W.S. only (Federal)
or (c) W.S. only (non-Federal)
or (d) Site Selection - M.P. (no power)
or . . . .

CARD 3

(a) Controlled valley spillway - concrete ogee
or (b) Controlled saddle - concrete ogee
or (c) Limited service - (SPF Freq) - Unc. trapezoidal concrete control section

CARD 4

(a) 1 - 19-foot diam - conduit - gated
(b) 1 - 6-foot diam uncontrolled morning glory

CARD 5

Basis of Design Flood

CARD A* Indicator Card (all numbers must be integers)

1. ITYSP - Type of spillway. Use ten for gated spillway and zero for an uncontrolled spillway.
2. INDCON - Use ten for using either a conduit or sluice in the rating and routing. Use zero otherwise.

* All data is read using 10 numbers per card with 8 columns per number except for the 1st number on each card which has column 1 reserved for the identification of the alphanumeric character of the card series (A-H).

3. ISPITW - Use ten if spillway tailwater is to be computed by specific energy equation and zero if by tailwater lookup. The conduit tailwater will be by table lookup in either case.
4. IABCOA - Use ten for abutment contraction coefficients based on adjacent concrete non-overflow sections and zero for adjacent earth.
5. ISPILN Use ten if effective length of spillway, for spillway rating, may exceed net and zero if it may not.
6. ISRCD - Use ten to compute spillway rating for trapezoidal channels based on critical depth (variable ITYSP should equal zero), use zero for "ogee" rating of spillway.
7. ISPCTW - Use ten if conduit discharge only should be used in computing conduit submergence, and use zero if both spillway and conduit cause submergence.
8. Blank field.
9. Blank field.
10. ITABLE - Use ten to start program over again reading in only the 5 output title cards, Card A and Cards F, G and H. The tables of elevation-capacity, tailwater and inflows read for the previous run are the same in the next run. Use zero for first run and if any of the tables will change. In this case all table cards must be read in.

CARD B

1. NUMEL - (INTEGER) The number of elevations in the C cards.
2. NUMTW - (INTEGER) The number of tailwater elevations in the D cards.
3. NUMIN - (INTEGER) The number of inflows in the E cards.
4. QMIN1 - For uncontrolled spillways only. Minimum reservoir outflow on rising limb of hydrograph when pool elevation is below the spillway crest. Must be less than conduit discharge at the spillway crest. See Exhibit 3.
5. QMIN2 - For uncontrolled spillways only. Minimum reservoir outflow on rising limb of hydrograph when pool elevation is above the spillway crest and below "ELSURO". Must be less than or equal to QSURO and the conduit discharge at the spillway crest elevation. See Exhibit 3.
6. CONMIN - For uncontrolled spillways only. The minimum conduit release for other than flood control purposes.

C CARDS (8 or less) - NUMEL (B.1) pairs

The elevation-capacity table is stored on these cards. The starting elevation (ELST) must be above or equal to ELEV(1) in the elevation table. Card C.1 stores five elevations and capacities, the first elevation appears in Columns 2-8 and the first capacity in Columns 9-16, the second elevation in Columns 17-24, etc. The second card of the C series must have the next 5 points on the elevation capacity curve. After the last set of elevations and capacities have been listed on the card the remaining columns may be blank and any remaining cards must be omitted. A maximum of 40 points may be used on the eight cards, although this figure may change with various source decks.

D CARDS (6 or less) - NUMTW (B.2) pairs

The tailwater elevation-discharge curve is stored on these cards. A maximum of 30 points may be used on six cards. The first card contains the first five elevations and discharges alternated in Columns 2 8, 9-16, 17-24, etc.

E CARDS (8 or less) - NUMIN (B.3) values

The inflows of the design flood (in cubic feet per second) are stored on these cards. The full eight cards do not have to be read into the computer, if fewer cards will hold the necessary inflows. A maximum of 80 inflows may be used on the eight cards, although this limit may vary with various source decks.

CARD F

1. SS - Side slope of trapezoidal spillway for critical depth rating only, variable "ISRCD" = 10 (horizontal over vertical - 2.0 for 2:1 side slopes) use "0" if variable "ISRCD" = 0.
2. ELTFC - Elevation of top of flood control pool.
3. STFC - Storage (in acre-feet) at top flood control pool.
4. ELST - Starting elevation for the routing.
5. PER - Period of flood routing in hours (6-hour, 12-hour, etc.)
6. TIME - Starting time in hours.
7. CHCAP - Channel capacity in c.f.s. - used as minimum discharge when pool elevation is receding.

CARD G

1. ELTSUR - Elevation of top of induced surcharge.
2. ELSURO - Elevation of bottom of induced surcharge (should be equal to top of flood pool elevation). Must be greater than ELEV(1), card C.
3. QSURO - Discharge on induced surcharge envelope curve at "ELSURO" (should be channel capacity or less).
4. TS - Constant representing recession of hydrograph in hours. See EM 1110-2-3600. Can be zero if ITYSP (A.1) is zero.
5. C - Coefficient of discharge of conduit or sluice = $Q/\sqrt{HEAD}$. Can be zero if INDCON (A.2) is zero.
6. CLINEP - Elevation of centerline of pressure of conduit or sluice. Can be zero if INDCON (A.2) is zero.
7. PERHD* - Percent of energy head desired for design of spillway (DESHD). Normally 100 but is greater for overdesigned spillways and less for underdesigned weirs.
8. ERRHD* - Allowable error in design head of spillway (.5 for final design).

CARD H

1 NGATES - Number of spillway gates or Intermediate piers less one (for unc. spillways).
2. SPWID - Width of spillway - (in feet) excluding piers.
3. DESHD - Design head in feet (see Exhibit 1).
4. ELSPI - Elevation of spillway crest (see Exhibit 1).
5. APEL - Apron elevation of spillway (see Exhibit 1).
6. APWID - Spillway apron width (ft.)
7. APLOSS - Approach loss of spillway (in feet) at the design head.
8. PDPTH - Approach depth of spillway in feet (minimum of 10 percent of design head) - (see Exhibit 1).

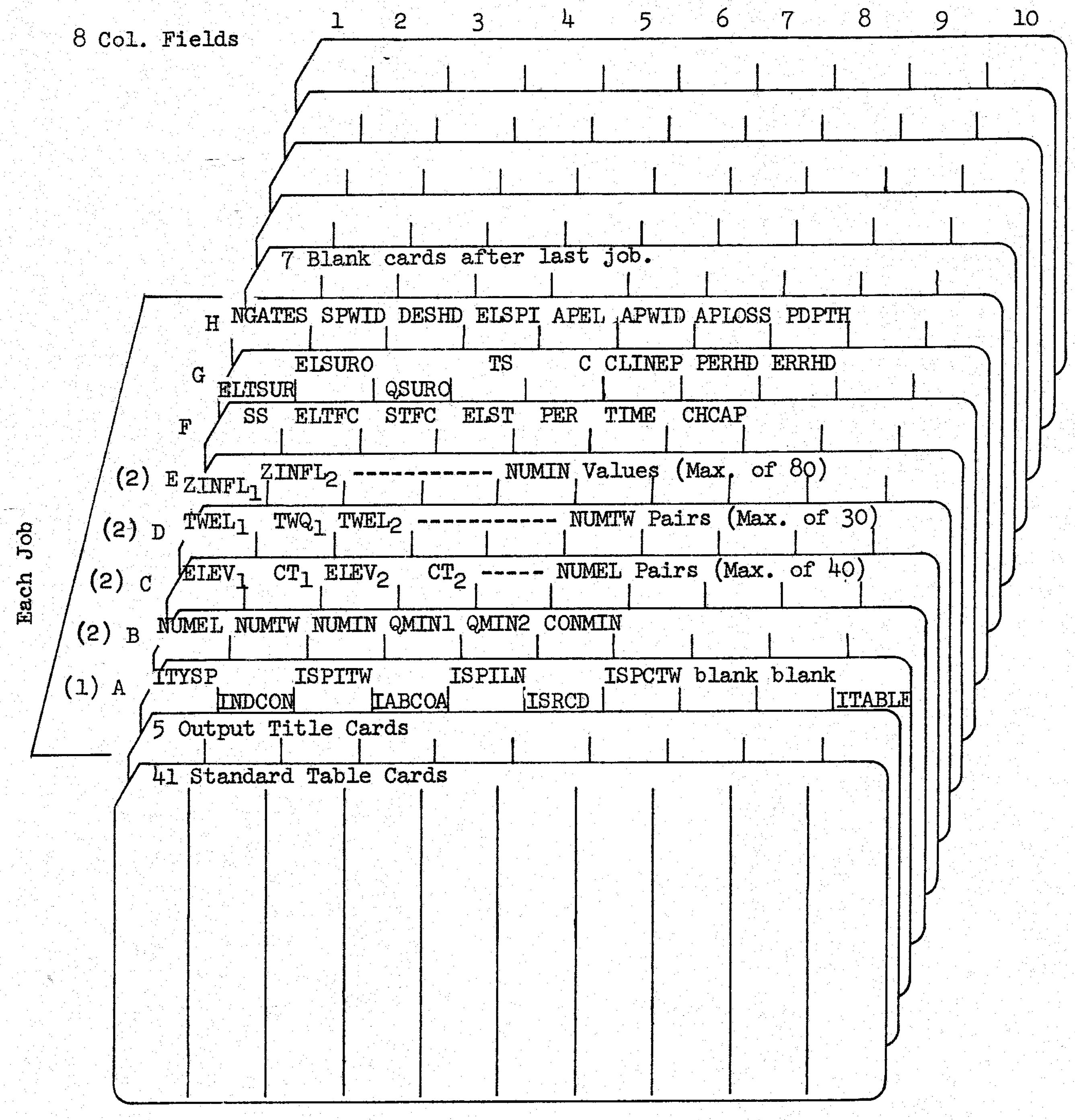
Cards for next jobs (Heading, A-H) follow first job.

Seven blank cards after last job will end run on stop instead of "Reader no feed".

*Not required for programs that are in two parts.

EXHIBIT 9

SUMMARY OF REQUIRED CARDS
22-J2-L210



CARD	NOTE	
A	(1)	ITABLE must equal zero for the A card on Job 1 in order to initialize the table values.
F	(2)	If "ITABLE" (Card A.10) is equal to ten, the table cards B, C, D and E are not read in between Cards A and F.

Appendix 5

Spillway Gate Regulation Curve

GATE REGULATION CURVE

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 23-J2-L236

FEBRUARY 1966

GATE REGULATION CURVE
HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 23-J2-L236

CONTENTS

EXHIBITS

GATE REGULATION CURVE
HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 23-J2-L236

1. ORIGIN OF PROGRAM

This program was written in Fortran II for the IBM 1620 and the GE 225 in the Hydrologic Engineering Center, Corps of Engineers, 650 Capitol Mall, Sacramento, California by Bill S. Eichert. Up-to-date information and copies of current source statement cards for various types of computers can be obtained from the Center upon request by Government and cooperating organizations.

2. PURPOSE OF PROGRAM

This program will compute the gate regulation schedule curves for a reservoir utilizing the area capacity curves, the induced surcharge envelope curve, and a constant T_s which represents the slope of the recession leg of an inflow hydrograph. The induced surcharge inflow curve can be read into the computer or a standard curve can be used by specifying the discharge at the top of the induced surcharge, the discharge at the lower limit of the induced surcharge and the elevations of the bottom and top of the surcharge storage. By specifying the storages on the induced surcharge envelope curve corresponding to the various reservoir releases, the induced surcharge envelope curve relating pool elevation to outflow will not be required.

3. METHOD OF COMPUTATION

a. The method of computation is based on EM 1110-2-3600. The two basic equations required are as follows:

(1) SA = 1.9835 * TS * (Q1-Q(NOUT) * (1+LOG(Q1/Q(NOUT))))

(2) Q1 = ZINFL (INF) * 12.1 * XAREA + Q (NOUT)

where

SA = storage available between the current pool elevation and the induced surcharge envelope curve corresponding to the reservoir release.

TS is a constant representing the slope of the recession leg of an inflow hydrograph.

Q1 represents the inflow into the reservoir which is expressed as a discharge in cfs.

Q(NOUT) represents the reservoir outflow

ZINFL(INF) represents the inflow expressed in terms of rate of rise of the reservoir and

XAREA represents the reservoir surface area.

b. For the inflow parameter in cfs the reservoir release can be obtained by a direct solution of equation 1. However, for the rate of rise parameter a trial and error solution must be made since the inflow in cfs is a function of the reservoir area which in turn is a function of the reservoir elevation. Using an assumed reservoir area, a reservoir area is calculated based on knowing the inflow and outflow from the reservoir. This process is repeated until the difference between the assumed and computed areas is less than one percent of the calculated area.

4. INPUT

See Exhibit 5.

5. OUTPUT

The output is shown in Exhibit 2 and consists of the following items:

Induced Surcharge Envelope Curve

a. N - A counter

b. X - The induced surcharge elevation in feet

c. PERSR(N) - Percent of vertical rise of the induced surcharge

d. Y - Reservoir release in cfs corresponding to the elevation of the induced surcharge envelope curve

e. PERDQ(N) - Percent of the change in discharge from the bottom to the top of the induced surcharge storage

Gate Regulation Curve

a. EL - The elevation of the reservoir

b. STG - The reservoir storage in acre-feet

c. CAREA - The reservoir area in acres

d. ZINFL(INF) - The reservoir inflow either expressed as a rate of rise in feet per hour or as a discharge in cfs

e. Q(NOUT) - The reservoir release in cfs

6. OPERATING INSTRUCTIONS

Standard Fortran II operating instructions. No sense switches are used except for printing out intermediate answers using sense switch 1.

7. DEFINITIONS

The definitions are shown in Exhibits 4 and 5 and paragraph 5.

8. EXAMPLE

An example of the input and output cards are shown in Exhibits 1 and 2.

9. PROPOSED FUTURE DEVELOPMENT

It is anticipated that additions to this program will be made from time to time. It is requested that any user of this program who finds an inadequacy or desirable addition or modification notify the Hydrologic Engineering Center.

TEST INPUT

```
              TEST NO 1
              FOR KEYSTONE RESERVOIR
              PROGRAM NO 23-J2-J236
                   INFLOW PARAMETERS
              7 JUNE 1965
    9       0       0    1.75     755      757    35000   680000
  680   56030    4970
  700  227700   12520
  724  689300   27040
  728  803500   30060
  732  929800   33110
  740 1222000   39590
  744 1386000   43520
  748 1569000   47980
  757 2051500   59485
    2  100000  600000
    4   10000   30000   60000  100000
    6   10000   30000   60000  100000  300000  500000
     TEST NO 2  PROGRAM 23-36
     KEYSTONE RESERVOIR
     GATE REGULATION CURVE
     RATE OF RISE
     IND. SUR. CURVE READ IN
   10       6      10    1.75     755      757    35000   680000
  680   56030    4970
  700  227700   12520
  724  689300   27040
  728  803500   30060
  732  929800   33110
  740 1222000   39590
  744 1386000   43520
  748 1569000   47980
  752 1771000   52830
  757 2051500   59485
  755   35000   755.5   85000     756  140000   756.5  275000   756.7  450000
  757  680000
    2      .3     1.2
    4   50000  100000  300000  600000
    5   50000  100000  150000  200000  250000
              TEST NO 3
              TEST OF HYDROLOGIC ENGINEERING CENTER PROGRAM 23-36
```

EXHIBIT 1

```
                              COMPUTATIONS FOR SPILLWAY GATE REGULATION SCHEDULE
                              ALLOTOONA RESERVOIR
                              EXAMPLE FROM EM 1110-2-3600
      9      -1       0     .67                             145000
    850  500000   10000
  856.6  606900   13000
  858.1  633700   15000
  859.2  654300   17000
  860.1  671700   20000
  861.2  694000   23000
  862.2  715400   26000
  865.0  800000   29000
  900.0 1000000   50000
      2   10000   20000
      2       0   10000
      2  660500  675900
      3       0   10000   20000
      3  660500  675900  687800
                          EMERGENCY SPILLWAY RELEASE DIAGRAM
                          NEW EXCHEQUER DAM
                           9 NOV 1965
                          5 FT INDUCED SURCHARGE
                          MERCED RIVER CALIFORNIA
     10       2       0    0.54     867     872    6000  240000
    830  787000    5810
    835  816593    5975
    840  846931    6145
    845  878131    6318
    850  910206    6500
    855  943156    6685
    860  977006    6862
    865 1011744    7045
    870 1047382    7225
    875 1084000    7410
    867    6000     872  240000
     14   20000   40000   60000   80000  100000  120000  140000  160000  180000
  20000  220000  240000  260000  280000
      3       0   10000   20000
      4       0   10000   20000   40000
      5       0   10000   20000   40000   60000
      6       0   10000   20000   40000   60000   80000
```

2

6	0	20000	40000	60000	80000	100000			
7	0	20000	40000	60000	80000	100000	120000		
8	0	20000	40000	60000	80000	100000	120000	140000	
9	0	20000	40000	60000	80000	100000	120000	140000	160000
10	0	20000	40000	60000	80000	100000	120000	140000	160000
180000									
11	0	20000	40000	60000	80000	100000	120000	140000	160000
180000	200000								
12	10000	20000	40000	60000	80000	100000	120000	140000	160000
180000	200000	220000							
13	10000	20000	40000	60000	80000	100000	120000	140000	160000
180000	200000	220000	240000						
10	60000	80000.	100000.	120000	140000	160000	180000	200000	220000
240000									
4	110000	120000	140000	160000					

3

EXHIBIT 1

TEST OUTPUT

TEST NO 1
FOR KEYSTONE RESERVOIR
PROGRAM NO 23-J2-J236
INFLOW PARAMETERS
7 JUNE 1965

ELSURO	ELTSUR	QSURO	QTOPSR	NENVC		NELCT	IROR	TS
755.00	757.00	35000	680000	0	0	9	0	1.75

INDUCED SURCHARGE ENVELOPE CURVE

COUNT	INDUCED SURCHARGE-- ELEVATION--PER CENT		CORRESPONDING DISCHARGE CFS	PERCENT
1	755.00	0.00	35000.00	0.00
2	755.40	20.00	59510.00	3.80
3	755.80	40.00	96275.00	9.50
4	756.20	60.00	147875.00	17.50
5	756.40	70.00	196250.00	25.00
6	756.60	80.00	254300.00	34.00
7	756.80	90.00	351050.00	49.00
8	756.92	96.00	467150.00	67.00
9	756.96	98.00	576800.00	84.00
10	757.00	100.00	680000.00	100.00

ELEV	CAP	AREA	INFLOW	OUTFLOW	ELEV
750.66	1711802.	51385.	100000.00	10000.	750.66
752.80	1826673.	54124.	100000.00	30000.	752.80
754.79	1933551.	56672.	100000.00	60000.	754.79
755.82	1988714.	57987.	100000.00	100000.	755.82
STORAGE EXTRAPOLATED					
677.95	38433.	4196.	600000.00	10000.	677.95
702.59	277693.	14092.	600000.00	30000.	702.59
717.85	571154.	23323.	600000.00	60000.	717.85
730.26	875094.	31788.	600000.00	100000.	730.26
750.73	1715582.	51475.	600000.00	300000.	750.73
756.35	2017171.	58666.	600000.00	500000.	756.35

TEST NO 2 PROGRAM 23-36
KEYSTONE RESERVOIR

EXHIBIT 2

GATE REGULATION CURVE
RATE OF RISE
IND. SUR. CURVE READ IN

ELSURO	ELTSUR	QSURO	QTOPSR	NENVC		NELCT	IROR	TS
755.00	757.00	35000	680000	6	0	10	10	1.75

INDUCED SURCHARGE ENVELOPE CURVE

COUNT	INDUCED SURCHARGE-- ELEVATION	--PER CENT	CORRESPONDING DISCHARGE CFS	PERCENT
1	755.00	0.00	35000.00	0.00
2	755.50	25.00	85000.00	7.75
3	756.00	50.00	140000.00	16.27
4	756.50	75.00	275000.00	37.20
5	756.70	85.00	450000.00	64.34
6	757.00	100.00	680000.00	100.00

ELEV	CAP	AREA	INFLOW	OUTFLOW	ELEV
748.55	1597118.	48655.	.30	50000.	748.55
750.51	1695861.	51025.	.30	100000.	750.51
753.64	1863149.	55016.	.30	300000.	753.64
755.09	1944654.	56950.	.30	600000.	755.09
STORAGE EXTRAPOLATED					
728.21	810309.	30224.	1.20	50000.	728.21
731.92	927375.	33051.	1.20	100000.	731.92
734.31	1014407.	34986.	1.20	150000.	734.31
736.10	1079696.	36434.	1.20	200000.	736.10
737.63	1135668.	37675.	1.20	250000.	737.63

2

TEST NO 3
TEST OF HYDROLOGIC ENGINEERING CENTER PROGRAM 23-36
COMPUTATIONS FOR SPILLWAY GATE REGULATION SCHEDULE
ALLOTOONA RESERVOIR
EXAMPLE FROM EM 1110-2-3600

ELSURO	ELTSUR	QSURO	QTOPSR	NENVC		NELCT	IROR	TS
0.00	0.00	0	145000	-1	0	9	0	.67

ELEV	CAP	AREA	INFLOW	OUTFLOW	ELEV
858.82	647210.	16311.	10000.00	0.	858.82
860.30	675899.	20565.	10000.00	10000.	860.30
858.11	633921.	15021.	20000.00	0.	858.11
860.10	671822.	20016.	20000.00	10000.	860.10
860.89	687799.	22165.	20000.00	20000.	860.89

EMERGENCY SPILLWAY RELEASE DIAGRAM
NEW EXCHEQUER DAM
9 NOV 1965
5 FT INDUCED SURCHARGE
MERCED RIVER CALIFORNIA

ELSURO	ELTSUR	QSURO	QTOPSR	NENVC		NELCT	IROR	TS
867.00	872.00	6000	240000	2	0	10	0	.54

3

INDUCED SURCHARGE ENVELOPE CURVE

COUNT	INDUCED SURCHARGE--ELEVATION	--PER CENT	CORRESPONDING DISCHARGE CFS	PERCENT
1	867.00	0.00	6000.00	0.00
2	872.00	100.00	240000.00	100.00

ELEV	CAP	AREA	INFLOW	OUTFLOW	ELEV
863.96	1004577.	7007.	20000.00	0.	863.96
866.62	1023321.	7103.	20000.00	10000.	866.62
867.29	1028131.	7127.	20000.00	20000.	867.29
860.88	983155.	6894.	40000.00	0.	860.88
864.65	1009324.	7032.	40000.00	10000.	864.65
866.37	1021558.	7094.	40000.00	20000.	866.37
867.72	1031177.	7143.	40000.00	40000.	867.72
857.74	961733.	6782.	60000.00	0.	857.74
862.19	992245.	6942.	60000.00	10000.	862.19
864.57	1008822.	7029.	60000.00	20000.	864.57
867.15	1027127.	7122.	60000.00	40000.	867.15
868.15	1034223.	7158.	60000.00	60000.	868.15
854.56	940312.	6669.	80000.00	0.	854.56

EXHIBIT 2

859.54	973904.	6845.	80000.00	10000.	859.54
862.38	993562.	6949.	80000.00	20000.	862.38
865.88	1018030.	7076.	80000.00	40000.	865.88
867.74	1031289.	7143.	80000.00	60000.	867.74
868.58	1037269.	7173.	80000.00	80000.	868.58
851.31	918890.	6548.	100000.00	0.	851.31
859.98	976921.	6861.	100000.00	20000.	859.98
864.19	1006169.	7015.	100000.00	40000.	864.19
866.74	1024208.	7107.	100000.00	60000.	866.74
868.25	1034968.	7162.	100000.00	80000.	868.25
869.00	1040315.	7189.	100000.00	100000.	869.00
848.01	897468.	6427.	120000.00	0.	848.01
857.40	959405.	6769.	120000.00	20000.	857.40
862.23	992558.	6943.	120000.00	40000.	862.23
865.38	1014503.	7058.	120000.00	60000.	865.38
867.44	1029168.	7133.	120000.00	80000.	867.44
868.74	1038421.	7179.	120000.00	100000.	868.74
869.43	1043361.	7204.	120000.00	120000.	869.43
844.66	876046.	6306.	140000.00	0.	844.66
854.71	941285.	6674.	140000.00	20000.	854.71
860.10	977741.	6865.	140000.00	40000.	860.10
863.73	1002988.	6998.	140000.00	60000.	863.73
866.29	1020955.	7091.	140000.00	80000.	866.29
868.05	1033510.	7154.	140000.00	100000.	868.05
869.21	1041752.	7196.	140000.00	120000.	869.21
869.86	1046407.	7220.	140000.00	140000.	869.86
841.23	854624.	6187.	160000.00	0.	841.23
851.89	922724.	6570.	160000.00	20000.	851.89
857.78	962040.	6783.	160000.00	40000.	857.78
861.89	990147.	6931.	160000.00	60000.	861.89
864.88	1010975.	7040.	160000.00	80000.	864.88
867.05	1026391.	7118.	160000.00	100000.	867.05
868.61	1037493.	7175.	160000.00	120000.	868.61
869.66	1045008.	7213.	160000.00	140000.	869.66
870.29	1049510.	7235.	160000.00	160000.	870.29
837.73	833202.	6068.	180000.00	0.	837.73
849.00	903825.	6463.	180000.00	20000.	849.00
855.37	945664.	6698.	180000.00	40000.	855.37
859.89	976295.	6858.	180000.00	60000.	859.89
863.25	999646.	6981.	180000.00	80000.	863.25
865.81	1017585.	7074.	180000.00	100000.	865.81

4

867.73	1031210.	7143.	180000.00	120000.	867.73
869.13	1041248.	7194.	180000.00	140000.	869.13
870.12	1048273.	7229.	180000.00	160000.	870.12
870.71	1052639.	7251.	180000.00	180000.	870.71
863.96	1004577.	7007.	20000.00	0.	863.96
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
867.29	1028131.	7127.	20000.00	20000.	867.29
837.99	834787.	6076.	220000.00	10000.	837.99
842.94	865280.	6246.	220000.00	20000.	842.94
850.18	911418.	6506.	220000.00	40000.	850.18
855.47	946347.	6701.	220000.00	60000.	855.47
859.55	973997.	6846.	220000.00	80000.	859.55
862.76	996235.	6963.	220000.00	100000.	862.76
865.33	1014159.	7057.	220000.00	120000.	865.33
867.35	1028496.	7129.	220000.00	140000.	867.35
868.93	1039819.	7186.	220000.00	160000.	868.93
870.15	1048484.	7230.	220000.00	180000.	870.15
871.00	1054765.	7262.	220000.00	200000.	871.00
871.57	1058899.	7283.	220000.00	220000.	871.57
834.61	814297.	5962.	240000.00	10000.	834.61
839.80	845722.	6138.	240000.00	20000.	839.80
847.43	893724.	6406.	240000.00	40000.	847.43
853.08	930517.	6614.	240000.00	60000.	853.08
857.49	960031.	6773.	240000.00	80000.	857.49
861.02	984133.	6899.	240000.00	100000.	861.02
863.87	1003921.	7003.	240000.00	120000.	863.87
866.17	1020122.	7087.	240000.00	140000.	866.17
868.02	1033309.	7153.	240000.00	160000.	868.02
869.50	1043838.	7207.	240000.00	180000.	869.50
870.62	1051982.	7248.	240000.00	200000.	870.62
871.44	1057980.	7278.	240000.00	220000.	871.44

CAN NOT BALANCE
ICASE=3

5

EXHIBIT 2

ICASE=4

871.44	0.	7278.	240000.00	240000.	871.44
850.61	914240.	6522.	260000.00	60000.	850.61
855.34	945468.	6697.	260000.00	80000.	855.34
859.15	971284.	6832.	260000.00	100000.	859.15
862.27	992787.	6945.	260000.00	120000.	862.27
864.85	1010703.	7039.	260000.00	140000.	864.85
866.94	1025604.	7115.	260000.00	160000.	866.94
868.66	1037848.	7176.	260000.00	180000.	868.66
870.04	1047707.	7226.	260000.00	200000.	870.04
871.09	1055420.	7265.	260000.00	220000.	871.09

CAN NOT BALANCE
ICASE=3

ICASE=4

871.09	0.	7265.	260000.00	240000.	871.09
858.94	969833.	6824.	280000.00	110000.	858.94
860.55	980890.	6882.	280000.00	120000.	860.55
863.36	1000393.	6985.	280000.00	140000.	863.36
865.72	1016883.	7070.	280000.00	160000.	865.72

6

LISTING OF SOURCE PROGRAM

```
**     23-J2-J236
*10074
C      HYDROLOGIC ENGINEERING CENTER PROGRAM ON
C      GATE REGULATION CURVE BY BILL EICHERT 20 JAN 1966
C      SENSE SWITCH 1 ON FOR TRACE
C      TS IS IN DAYS
C      IF NENVC IS -1,READ IN FOR OUTFLOWS THE STORAGE ON IND. SUR. ENV.
C      CURVE
       DIMENSION ELEV(40),Q(40),CT(40),AREA(40), PERSR(30), PERDQ(30)
       DIMENSION ZINFL(40) ,CTISEC(40)
C                                      BRANCH TO    1 FROM  110.00  130.00
C                                           3017.00
     1 FORMAT (10F8.0)
C                                      BRANCH TO    4 FROM   99.01  100.00
C
     4 FORMAT (26A3,A2)
     5 FORMAT (7F8.4)
C                                      BRANCH TO    6 FROM  129.00  140.00
C
     6 FORMAT(I8,7F10.2)
     7 FORMAT(I8,8F9.0)
     8 FORMAT(1H  )
C                                      BRANCH TO    9 FROM  150.00
     9 FORMAT(I8,9F8.0,/(10F8.0))
C                                      BRANCH TO   10 FROM  100.02
    10 FORMAT(3I8,7F8.0)
C                                      BRANCH TO   11 FROM 3199.01 3199.03
C
    11 FORMAT(6F12.2)
       XAREA=1000.
       CON=0.0
C      READ IN 5 HEADING  CARDS
C                                      BRANCH TO   99 FROM 3650.01
    99 DO 100 I=1,5
       READ 4,(Q(N),N=1,26),Q(27)
   100 PUNCH 4,(Q(N),N=1,26),Q(27)
       PUNCH 104
       READ 10,NELCT,NENVC,IROR,TS, ELSURO,ELTSUR,QSURO,QTOPSR
   104 FORMAT (/75H   ELSURO  ELTSUR   QSURO  QTOPSR   NENVC             NE
      1LCT    IROR          TS/)
C                                      BRANCH TO  105 FROM  110.02
```

EXHIBIT 3

```
  105 FORMAT(2F9.2,6I8,F8.2)
      DO 110 N=1,NELCT
  110 READ 1,ELEV(N),CT(N),AREA(N)
      NINF=0
      PUNCH 105,ELSURO,ELTSUR,QSURO,QTOPSR,NENVC,NINF,NELCT,IROR,TS
      IF(NENVC)150,112,112
C     HEADING FOR INDUCED SURCHARGE ENVELOPE CURVE
  112 PUNCH 125
      FTSUR=ELTSUR-ELSURO
      PUNCH 126
      PUNCH 127
  125 FORMAT (/32HINDUCED SURCHARGE ENVELOPE CURVE/)
  126 FORMAT ( 51H    COUNT INDUCED SURCHARGE--CORRESPONDING DISCHARGE)
  127 FORMAT ( 45H          ELEVATION--PER CENT     CFS    PERCENT/)
      IF(NENVC)128,128,130
C     NENVC = NUMBER OF POINTS ON INDUCED SURCHARGE ENVELOPE CURVE
  128 NENVC=10
       PERSR(1)=0.0
       PERSR(2)=20.
       PERSR(3)=40.
       PERSR(4)=60.
       PERSR(5)=70.
       PERSR(6)=80.
       PERSR(7)=90.
       PERSR(8)=96.
       PERSR(9)=98.
       PERSR(10)=100.
       PERDQ(1)=0.
       PERDQ(2)=3.80
       PERDQ(3)=9.50
       PERDQ(4)=17.50
       PERDQ(5)=25.00
       PERDQ(6)=34.00
       PERDQ(7)=49.00
       PERDQ(8)=67.00
       PERDQ(9)=84.00
       PERDQ(10)=100.0
      DO 129 N=1,10
      ELSUR=FTSUR*.01*PERSR(N)+ELSURO
      QSUR=PERDQ(N)*.01*(QTOPSR-QSURO)+QSURO
  129 PUNCH 6,N,ELSUR,PERSR(N),QSUR,PERDQ(N)
```

2

```
      GO TO 150
C     READ IN AS ELEVATION AND DISCHARGE
C                                      BRANCH TO  130 FROM  127.01
  130 READ 1,(PERSR(N),PERDQ(N),N=1,NENVC)
      DO 140 N=1,NENVC
      X=PERSR(N)
      PERSR(N)=(PERSR(N)-ELSURO)*100./FTSUR
      Y=PERDQ(N)
      PERDQ(N)=(PERDQ(N)-QSURO)*100./(QTOPSR-QSURO)
  140 PUNCH 6,N,X,PERSR(N),Y,PERDQ(N)
C                                      BRANCH TO  150 FROM  110.03
  150 READ 9,NINF,(ZINFL(N),N=1,NINF)
      PUNCH 160
  160 FORMAT(/57H   ELEV       CAP        AREA      INFLOW    OUTFLOW     EL
     1EV/)
  170 INF=0
      COUNT=0
C                                      BRANCH TO 3010 FROM 3610.02
 3010 IF(INF-NINF)3015,3640,3640
 3015 READ 3016,MXOUT,(Q(N),N=1,MXOUT)
 3016 FORMAT(I8,9F8.0)
      IF(NENVC)3017,3018,3018
 3017 READ 1,X,(CTISEC(N),N=1,MXOUT)
 3018 INF=INF+1
      NOUT=1
      QCAVE=Q(NOUT)
C                                      BRANCH TO 3019 FROM 3611.01
 3019 IF(IROR)3020,3020,3030
C     BRANCH TO 3020  FROM  3611.01
 3020 Q1=ZINFL(INF)
      GO TO 3036
 3030 Q1=ZINFL(INF)*12.1*XAREA  +Q(NOUT)
      IF(Q1-Q(NOUT))3035,3038,3038
 3035 Q1=Q(NOUT)
C                                      BRANCH TO 3036 FROM 3020.01
 3036 IF(Q1-Q(NOUT))3037,3038,3038
 3037 Q(NOUT)=ZINFL(INF)
C                                      BRANCH TO 3038 FROM 3030.01
 3038 QCAVE=Q(NOUT)
      IF(Q(NOUT))3042,3042,3045
 3042 Q(NOUT)=.000001
```

3

EXHIBIT 3

```
3045 SA= 1.9835*TS*(Q1-Q(NOUT)*(1.+LOGF(Q1/Q(NOUT))))
     IF(NENVC)3050,3060,3060
3050 STG=CTISEC(NOUT)
     GO TO 3185
C                                  BRANCH TO 3060 FROM 3105.02
3060 N=1                                                          511
C                                  BRANCH TO 3070 FROM 3090.01
3070 A =  PERDQ(N)                                                512
     QSUR = A*.01*(QTOPSR-QSURO)+QSURO                            513
     IF(QSUR-QCAVE)3080,3080,3130                                 514
3080 N=N+1
     IF(N-NENVC)3090,3090,3100                                     51
3090 XQSUR=QSUR                                                   517
     GO TO 3070                                                   518
3100 QCAVE=QTOPSR                                                 519
     Q(NOUT)=QCAVE
     ICASE=3                                                      520
     PUNCH 3235
     PUNCH 3105
3105 FORMAT (8H ICASE=3/)
     NTRY=NTRY+1                                                  521
     IF(NTRY-5)3060,3060,3110                                     522
3110 SA=0.                                                        523
     CSA=0.                                                       524
     STG=0.                                                       525
3120 IF(QCAVE-Q1 )3610,3610,3590
C                                  BRANCH TO 3130 FROM 3070.02
3130 IF(N-1)3140,3140,3150                                        527
3140 ELSUR=ELSURO
     GO TO 3155
3150 RATIO=(QCAVE-XQSUR)/(QSUR-XQSUR)                             530
     A =  PERSR(N)                                                531
     B =  PERSR(N-1)                                              532
     SURPER = RATIO*(A-B) + B                                     533
     ELSUR=FTSUR*.01*SURPER+ELSURO                                534
3155 N=1                                                          535
C                                  BRANCH TO 3160 FROM 3170.01
3160 IF(ELEV(N)-ELSUR)3170,3180,3180                              536
3170 N=N+1                                                        537
     IF(N-NELCT)3160,3160,3175                                    538
3175 PUNCH 3197
```

```
      N=N-1
C                                                BRANCH TO 3180 FROM 3160.00
 3180 RATIO=(ELSUR-ELEV(N-1))/(ELEV(N)-ELEV(N-1))                              539
      STG=(CT(N)-CT(N-1))*RATIO+CT(N-1)                                        540
C     BRANCH TO 3185  FROM  3050.01
C                                                BRANCH TO 3185 FROM 3050.01
 3185 CTIS=STG
C                                                BRANCH TO 3186 FROM 3229.01
 3186  STG=CTIS-SA
      DO 3190 N=1,NELCT
      IF(CT(N)-STG)3190,3195,3195
 3190 CONTINUE
      N=NELCT
      PUNCH 3197
 3195 IF  (N-1) 3196,3196,3198
 3196 N=2
      PUNCH 3197
C                                                BRANCH TO 3197 FROM 3175.00 3190.02
C
 3197 FORMAT(21H STORAGE EXTRAPOLATED)
 3198 RATIO=(STG-CT(N-1))/(CT(N)-CT(N-1))
      EL=(ELEV(N)-ELEV(N-1))*RATIO+ELEV(N-1)
      STG=(CT(N)-CT(N-1))*RATIO+CT(N-1)
      CAREA=(AREA(N)-AREA(N-1))*RATIO+AREA(N-1)
      IF(SENSE SWITCH 1)3199,3204
 3199 PUNCH 3200
      PUNCH 11,Q1,Q(NOUT),SA,CTIS,EL,STG
      PUNCH 3201
      PUNCH 11,XAREA,CAREA,COUNT,CON
C                                                BRANCH TO 3200 FROM 3199.00
 3200 FORMAT (/35 H Q1    Q(NOUT)   SA    CTIS  EL STG/)
 3201 FORMAT(/23H XAREA CAREA COUNT  CON/)
C                                                BRANCH TO 3204 FROM 3198.04
 3204 IF(IROR)3610,3610,3205
 3205 ALERR=.01*CAREA
      ERROR=ABSF(CAREA-XAREA)
      IF(ALERR-ERROR)3210,3610,3610
 3210 IF(COUNT)3220,3220,3230
 3220 PXAREA=XAREA
      PCAREA=CAREA
      COUNT=1.
```


EXHIBIT 3

```
      XAREA=.5*(XAREA+CAREA)
C                                      BRANCH TO 3225 FROM 3300.03
 3225 Q1=ZINFL(INF)*12.1*XAREA   +Q(NOUT)
      IF(Q1-Q(NOUT))3226,3229,3229
 3226 IF(COUNT-15.)3229,3229,3228
 3228 PUNCH 3235
      GO TO 3610
C                                      BRANCH TO 3229 FROM 3225.01
 3229 SA= 1.9835*TS*(Q1-Q(NOUT)*(1.+LOGF(Q1/Q(NOUT))))
      GO TO 3186
C                                      BRANCH TO 3230 FROM 3210.00
 3230 CON=(XAREA-CAREA)/(PXAREA-PCAREA)
C                                      BRANCH TO 3235 FROM 3100.03 3228.00
C
 3235 FORMAT(16H CAN NOT BALANCE)
      TEMP=XAREA
      XAREA=(CON*PXAREA-XAREA)/(CON-1.)
 3300 PXAREA=TEMP
      PCAREA=CAREA
      COUNT=COUNT+1.
      GO TO 3225
C                                      BRANCH TO 3590 FROM 3120.00
 3590 ICASE=4
      PUNCH 3600
C     CHECK GATE REGULATION RELEASE FOR DESIRED                         586
C                                                                       587
 3600 FORMAT(8H ICASE=4/)
C                                      BRANCH TO 3610 FROM 3120.00 3204.00
C                                          3205.02 3228.01
 3610 PUNCH 3612,EL,STG,CAREA,ZINFL(INF),Q(NOUT),EL
      COUNT=0.0
      IF(NOUT-MXOUT)3611,3010,3010
 3611 NOUT=NOUT+1
      GO TO 3019
C                                      BRANCH TO 3612 FROM 3610.00
 3612 FORMAT (F8.2,2F10.0,F12.2,F10.0,F12.2)
 3620 FORMAT (/1H )                                                     592
 3630 STOP                                                              593
C                                      BRANCH TO 3640 FROM 3010.00
 3640 TYPE 3650
 3650 FORMAT(/20HCOMPUTATION COMPLETE)
      GO TO 99
      END
```

DEFINITIONS

Counters

a. COUNT - The number of trials in balancing assumed and computed reservoir areas

b. ICASE - An indicator to tell what case controlled the reservoir release. ICASE=3 exists when the outflow exceeds the maximum outflow for the induced surcharge envelope curve. For this condition the reservoir release is set equal to the discharge at the top of induced surcharge envelope curve. When ICASE=4 the reservoir outflow has been greater than the reservoir inflow more than 5 times and therefore cannot balance the equation.

c. INF - The current value of the counter for reservoir inflow

d. NINF - The total number of inflows read into the computer

e. NOUT - Current value of the counter for reservoir outflow

f. NTRY - The number of trials used in computing the discharge on the induced surcharge envelope curve corresponding to the reservoir outflow

Discharges

a. QCAVE - Another designation for reservoir outflow

b. Q1 - The reservoir inflow in cfs

c. QSUR - Discharge on the induced surcharge envelope curve corresponding to current reservoir release

d. XQSUR - Previous assumed value of QSUR

Storages

a. CTIS - The storage capacity corresponding to the current induced surcharge envelope curve elevation

b. SA - Storage available in the reservoir from the current pool elevation up to the limit of the induced surcharge envelope curve for the designated outflow

c. STG - Storage capacity of the reservoir for elevation EL

Areas

a. ALERR - Allowable error between the estimated and computed reservoir areas

b. CAREA - The current computed reservoir area

c. ERROR - The actual error between the estimated and computed reservoir area

d. PCAREA - Previous computed reservoir area

e. PXAREA - Previous assumed reservoir area

f. XAREA - The current assumed reservoir area

Temporary Storage

Y, A, RATIO, B, TEMP, CON

Constants

a. ELSUR - Elevation of the induced surcharge envelope curve for the assumed outflow

b. FTSUR - The number of feet of induced surcharge storage in the reservoir

c. SURPUR - The interpolated percentage of the vertical induced surcharge rise from the table of PERSR(N), corresponding to the discharge QSUR

DESCRIPTION OF INPUT

INPUT - Use Standard Format 10F8.0 (10 numbers per card, 8 columns per number.) (See Exhibit 5)

Group A - 5 heading cards used to describe computation

Group B -

(1) NELCT - Number of cards with elevations, capacities and areas read in on group C cards

(2) NENVC - Number of points on elevation discharge curve read in on group D cards to describe induced surcharge envelope curve. If zero or blank standard curve will be used and group D cards will be omitted. If negative, group D cards are not used but the storages of the induced surcharge envelope curve for each outflow in group F are read in as group G.

(3) IROR - Indicator for rate of rise or inflow parameters option. Zero or blank for inflow parameter and plus (IROR = 1) for the rate of rise parameters

(4) TS - The recession constant of the inflow hydrograph in days

(5) ELSURO - The elevation of zero surcharge (normally the top of flood control pool or gross pool)

(6) ELTSUR - The elevation of the maximum induced surcharge

(7) QSURO - The discharge corresponding to "ELSURO" (normally the non-damaging flood release)

(8) QTOPSR - The total discharge capacity of the reservoir at "ELTSUR"

Group C - The elevations, capacities and areas for the reservoir. The number of cards required is equal to "NELCT" with one elevation, capacity and area per card.

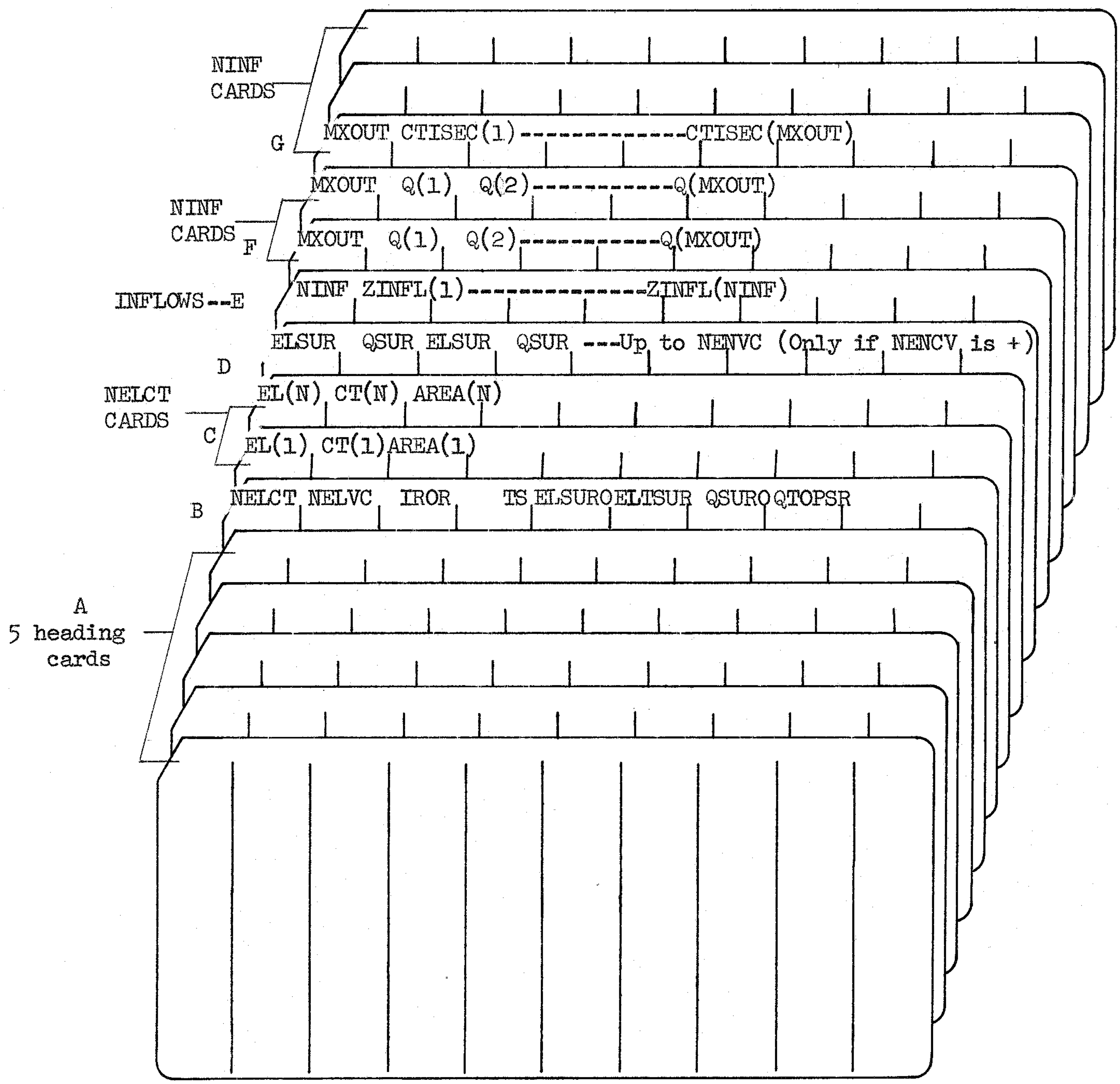
Group D - The elevations and discharges of the induced surcharge envelope curve. Not required if "NENVC" is negative or zero.

Group E - The first value (must be an integer) is the number of inflows or rate of rise parameters to be evaluated (NINF), followed by "NINF" values of either the inflows (for IROR = 0) or the rate of rise parameters (IROR = 1).

Group F - The first value (an integer) is the number of outflows to be read in (MXOUT) for one inflow parameter, followed by "MXOUT" values of the outflows to be evaluated. There must be "NINF" sets of outflow cards in order to evaluate all inflows.

Group G - These cards are used only if NENVC is negative. Storages are used instead of the induced surcharge envelope curve in order to reduce the computation time required. The first value is the number of storages on the induced surcharge envelope curve that correspond to the outflows in group F (MXOUT), followed by "MXOUT" values of these storages. There must be "NINF" sets of storage cards.

SUMMARY OF INPUT CARDS
PROGRAM 23-J2-J236



*Required only if NENVC is negative

EXHIBIT 6

Appendix 6

Glossary

GLOSSARY

1. RESERVOIR POOL ELEVATIONS.

a. References to reservoir pool "level" or "elevation" apply to water surface elevations in the reservoir near the dam site, exclusive of wave action and wind-tide effects.

b. Normal Full Pool Elevation: This term corresponds to the top reservoir level that would be attained for routine storage of water for flood control, hydroelectric power, low-flow augmentation, recreation, sediment control, or other authorized storage uses; this level corresponds to the "total design capacity" of the reservoir selected initially on the basis of planning and design studies, excluding surcharge storage that is provided primarily to reduce costs of constructing and maintaining the dam and appurtenances or to improve safety of operation during emergencies.

c. Surcharge Pool Elevation: Any accumulation of storage above the "Normal Full Pool Elevation" is referred to as "surcharge". The highest surcharge pool level attained during the passage of a particular flood is referred to as the "Maximum Surcharge Elevation" for that flood. Inasmuch as the accumulation of surcharge storage during a particular flood is dependent upon the plan of reservoir operation adhered to, and the initial pool level, these should be identified with any designation of maximum surcharge elevation.

d. Induced Surcharge Elevation: The accumulation of surcharge storage above the normal full pool level during a particular flood may be "induced", entirely or in part, by operating the regulating outlets and/or spillway gates at partial openings. Such operations can serve to reduce peak reservoir outflow rates and/or permit a more gradual increase in downstream river stages, while higher surcharge elevations are caused in the reservoir. Although induced surcharge may be utilized to obtain additional flood control effectiveness or safer operation of a project in some cases, the storage space used is not identified as primary flood control capacity and does not affect the designation of the "Normal Full Pool Elevation", as previously defined.

e. Storage Rule Curve Elevations: In multiple-purpose reservoirs, it is common practice to establish elevation guide lines to govern the accumulation and drawdown of storage for various uses, with appropriate variations by seasons to conform with functional needs and runoff probabilities. For example, a "rule curve" or "guide line" may permit a relatively high reservoir level to be maintained for the benefit of hydroelectric power development during seasons of the year when flood problems are a minimum, and require drawdown to lower levels to provide greater storage space for flood control as the most severe flood season approaches. When it is necessary to store water above the "power pool rule curve" in order to control floods, such storage would normally be evacuated as promptly as possible without adding to downstream flood conditions, making releases not only through the power turbines but also through flood control outlets if necessary; in some cases, evacuation of storage above the power rule curve may be delayed to avoid or reduce wasting of water, if flood forecasts or probability analyses warrant such action. Elevation rule curves are also used to govern seasonal changes in recreation pool levels, storage accumulations and drawdown for water supply, low-flow augmentation, and other multiple-purpose reservoir storage uses. These rule curves, established on the bases of economic studies and hypothetical reservoir operation and analyses usually have an important bearing on project design requirements.

f. Inactive Pool Elevation: Refers to the lowest elevation to which a reservoir would be drawn to attain primary project design objectives. Any releases made when the pool is below this level normally would be the minimum required to meet legal requirements or emergency provisions.

g. Dead Storage Elevation: The lowest elevation at which it is practicable to release water from the reservoir, as governed by design of outlet facilities.

2. RESERVOIR STORAGE SPACE CATEGORIES.

a. Unless otherwise indicated, references to "storage space" correspond to the reservoir capacity available between two flat pool elevations as indicated by appropriate elevation-capacity curves.

b. Sediment Storage Capacity Allowances: Refers to storage space allowance provided for deposition of sediment within reservoir limits during the assumed life of the project. If the sediment accumulation expected is so small as to have a relatively small effect in depleting storage required for primary reservoir functions, allowances for sediment are usually included as a part of the "inactive storage" capacity; otherwise, special studies are required to establish acceptable estimates of amounts that various storage use allocations will be affected by sediment depositions.

c. Inactive Storage Capacity: Includes the gross capacity below the "inactive storage elevation."

d. Drawdown Storage Capacities: Refers to storage space reserved for impoundment of runoff during some periods for the express purpose of retaining the water for later release when needed for industrial and municipal water supplies, irrigation, hydroelectric power generation, water quality improvement downstream, enhancement of downstream navigation, and other water uses. The same drawdown storage space may serve several of the water use objectives referred to, provided the total space is large enough to regulate flows within acceptable provisions of scheduling; in such cases, the drawdown storage space is referred to as a "joint use" pool, further designated by design purposes involved.

e. Primary Flood Control Storage Capacity: Refers to any storage space below the "Normal Full Pool Elevation" in which storage runoff and subsequent releases therefrom are made, with control of downstream floods as a primary objective. The primary flood control storage capacity reserved in a reservoir may be varied on a fixed rule curve basis to provide the largest capacity during seasons when flood control needs are greatest.

f. Joint Use Flood Control Storage Capacity: Refers to storage capacity that is made available for flood control use on a flood-runoff forecast basis, and/or with certain limitations on use in conjunction with some other storage function, such as hydroelectric power or irrigation. The term does not apply to "incidental" flood control use of storage that is not governed by specific rules to assure availability of the storage space according to conditions established prior to the flood occurence.

3. SPILLWAY.

In broad terms, a "spillway" may be defined as any passageway, channel, or structure designed expressly or primarily to discharge "excess" water from a reservoir after the design storage capacity and design discharge capacities of regulating outlets, turbines, and other project facilities have been used to perform normal operating functions.

4. REGULATING OUTLETS.

In design studies it is usually desirable to distinguish between "regulating outlets" provided primarily for routine operation of a reservoir and "spillway" facilities intended primarily for use in discharging excess waters, inasmuch as many different design considerations are involved. However, regulating outlets and spillways usually are complementary structures. A variety of combinations have been adopted to conform with various functional needs and design advantages. Under some circumstances, regulating outlets are inoperable during severe floods because of lack of access to operating towers, or because heads exceed those for which the outlets were designed. On the other hand, some regulating outlets that are provided primarily to serve routine operating functions, before the design storage capacity of the reservoir is exceeded, are also designed to discharge "excess" waters when required, usually with the objective of reducing the frequency of emergency or limited-service spillway operations; such a structure may be designated as a "service spillway", if the capacity to discharge excess waters is a major portion of its total capacity. In contrast, some spillways are used regularly or occasionally to make routine reservoir releases associated with flood control operations or to augment downstream flows for navigation, pollution control, or other purposes.

5. CONTROLLED AND UNCONTROLLED SPILLWAYS.

Many types and plans of controlled and uncontrolled spillways are used to conform with advantages and requirements of various dam and reservoir sites. A spillway is designated as an "uncontrolled" type when there are no gates, stoplogs, or other means of preventing free overflow when the reservoir exceeds the crest elevation; the terms "ungated" or "free overflow" are commonly used in the same sense. A "controlled" spillway type is equipped with crest gates, stoplogs, or other movable structures to permit various degrees of variation in outflow rates when reservoir levels exceed the spillway crest elevation; the term "gated" is usually supplemented with information to identify the structural or mechanical type of gate involved.

6. STANDARD PROJECT FLOOD (SPF).

The SPF hydrograph represents critical concentrations of runoff from the most severe combination of precipitation (and snowmelt, if pertinent) that is considered "reasonably characteristic" of the drainage basin involved. The SPF peak discharge and volume is usually equal to about 40% to 60% of the PMF estimate for the same drainage basin, when the comparison is related to rainfall concentrated in approximately 4 days or less. In studies involving reservoirs in which storage effects are important, the SPF derived from relatively short period rainfall (4 days or less) is usually assumed to follow a period of substantial flood runoff, the combination being referred to as the "SPF Series."

7. PROBABLE MAXIMUM FLOOD (PMF).

This term identifies estimates of hypothetical flood characteristics (peak discharge, volume and hydrograph shape) that are considered to be the most severe "reasonably possible" at a particular location, based on relatively comprehensive hydrometeorological analyses of critical runoff-producing precipitation (and snowmelt, if pertinent) and hydrologic factors favorable for maximum flood runoff.

8. SPILLWAY DESIGN FLOOD (SDF).

This term refers to the reservoir inflow-discharge hydrograph used in estimating the maximum spillway discharge capacity and maximum surcharge elevation finally adopted as a basis for project design assuming the initial reservoir pool elevation and general plan of water releases (through the spillway, regulating outlets, hydropower turbines and other outflow facilities) specified in the reservoir regulation plan established for use under critically severe flood conditions. The spillway design flood estimate for a particular project may conform with the PMF, the SPF, or some other magnitude of flood, depending upon the degree of hazard that might result from overtopping of the dam.

Hydrologic Engineering Methods for Water Resources Development

Volume 1	Requirements and General Procedures, 1971
Volume 2	Hydrologic Data Management, 1972
Volume 3	Hydrologic Frequency Analysis, 1975
Volume 4	Hydrograph Analysis, 1973
Volume 5	Hypothetical Floods, 1975
Volume 6	Water Surface Profiles, 1975
Volume 7	Flood Control by Reservoir, 1976
Volume 8	Reservoir Yield, 1975
Volume 9	Reservoir System Analysis for Conservation, 1977
Volume 10	Principles of Groundwater Hydrology, 1972
Volume 11	Water Quality Determinations, 1972
Volume 12	Sediment Transport, 1977