A United States Contribution to the International Hydrological Decade

HEC-IHD-0100

Hydrologic Engineering Methods For Water Resources Development

Volume 1
Requirements and General Procedures

October 1971

Approved for Public Release. Distribution Unlimited.

IHD-1

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the date needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** October 1971	**3. REPORT TYPE AND DATES COVERED** IHD Volume 1	
4. TITLE AND SUBTITLE Requirements and General Procedures			**5. FUNDING NUMBERS**
6. AUTHOR(S) Leo R. Beard, Augustine J. Fredrich, Edward F. Hawkins			
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-1
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 volume is the first of a projected 12-volume report entitled, "Hydrologic Engineering Methods for Water Resources Development". The report is being prepared by the Hydrologic Engineering Center as part of the U.S. Army Corps of Engineers participation in the International Hydrological Decade. Volume 1 describes the general nature of water resources improvements and the general procedures used in hydrologic engineering studies. The types of water resources improvements covered in this volume include electric power development, multipurpose reservoirs, and water resources systems. Remaining volumes of the report will describe detailed hydrologic engineering methods. As a part of this volume, three generalized computer program descriptions covering different phases of hydrologic engineering are included. The HEC-1, Flood Hydrograph Package covers most type of problems generally associated with flood hydrograph analysis. HEC-2, Water Surface Profiles, is primarily concerned with investigations related to river hydraulics problems. The third program, HEC-3, Reservoir System Analysis, deals with problems related to the planning, design, and operation of a system of reservoirs for conservation purposes.

14. SUBJECT TERMS Water Resources Development, Flood Control, Water Resources Systems, International Hydrological Decade			**15. NUMBER OF PAGES** 654 **16. PRICE CODE**
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	**18. SECURITY CLASSIFICATION OF THIS PAGE** UNCLASSIFIED	**19. SECURITY CLASSIFICATION OF ABSTRACT** UNCLASSIFIED	**20. LIMITATION OF ABSTRACT** UNLIMITED

Hydrologic Engineering Methods for Water Resources Development

Volume 1
Requirements and General Procedures

October 1971

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-1

FOREWORD

This report is intended to respond to the need throughout the world for hydrologic engineering methods that can be applied in regions of sparse data. The report is to consist of 12 volumes, of which this is Volume 1. It constitutes a contribution of the United States to the International Hydrological Decade and is prepared by the Corps of Engineers, U. S. Army, which agency has the Federal responsibility for Navigation and Flood Control and for many multipurpose water resources studies and developments in the United States. The report, prepared in The Hydrologic Engineering Center, describes procedures and methods that have been used successfully in Corps of Engineers studies or are believed to be of significant interest. It also contains descriptions of computer programs and many recently developed techniques for use in hydrologic studies. This report is provisional and comments are invited. The final report will be published near the end of the Decade, in 1974.

This report was conceived by Mr. A. L. Cochran, Chief of the Hydrology and Hydraulics Branch of the Office, Chief of Engineers (recently retired). It is being prepared by Messrs. A. J. Fredrich, E. F. Hawkins, and others under the direction of Mr. Leo R. Beard, Director of the Hydrologic Engineering Center.

CONTENTS

CONTENTS

LIST OF FIGURES

Chapter 1

Introduction

CHAPTER 1. INTRODUCTION

Section 1.01. The Corps of Engineers International Hydrological Decade Program

The International Hydrological Decade (IHD) is a worldwide effort to advance knowledge of the science of water and to improve techniques needed to meet the rapidly increasing demand for this resource. More than 100 nations are participating. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) provides international sponsorship for the program through the Coordinating Council for the IHD. Long-range objectives of the IHD program are to evaluate the world water balance through five major types of activities: collection of basic data, inventories and balances, research, education and training, and exchange of information.

The United States National Committee for the IHD, established under the National Academy of Sciences, is an official member of the UNESCO Coordinating Council. Its representation on the Council is supported by the United States Government through the State Department. The Committee is comprised of 21 scientists drawn from Federal, State, university, and private institutions. Day-to-day activities are handled by a Secretariat under the National Academy of Sciences. Executive responsibility for components of the program is vested in the governmental agencies concerned. The United States program involves five major components: large-scale water balances; river, lake, and groundwater studies; hydrologic processes and techniques; education and training; and supporting services.

Early discussions leading to initiation of the IHD stressed the objective of stimulating "scientific research in hydrology." There was some reluctance to include in the IHD program any proposals that emphasized practical applications of techniques to problem solutions. It was argued that the IHD program should be designed to avoid risks and that resources needed to stimulate worldwide activity in fundamental "scientific hydrology" might be diverted to the solution of immediate problems relating to water resources development.

The need for emphasizing "scientific research in hydrology" as the primary objective of the IHD program has been generally accepted, and this emphasis has prevailed predominately in the formulation of IHD programs, particularly in the United States. However, it has been recognized that attention should also be given to improving methods and criteria required to utilize available information and new findings from research efforts to facilitate more efficient planning and design of water resource systems. It is reasoned that "methods" research and testing, and training of personnel in efficient use of the best techniques, should parallel efforts to acquire new knowledge through research in scientific hydrology. Based on this conclusion, the project entitled "Hydrologic Engineering Methods for Water Resources Development" was adopted as part of the United States IHD program, with the objective to develop, test, and document "methods suitable for practical applications in hydrologic engineering." These applications are required for efficient planning and design of water resources development, giving special attention to circumstances under which hydrologic records are deficient in time, accuracy, and general coverage.

Methods development has been documented in generalized computer programs, which will constitute a major portion of this report. Most of the testing has been accomplished in conjunction with the special assistance program of The Hydrologic Engineering Center, but certain testing programs have been conducted entirely as an IHD project in cooperation with governmental agencies in Peru and Guatemala. These latter projects provide more realistic conditions for application in areas of sparse data.

Section 1.02. Water Resources Development

Water resources development can be divided into two general categories--that which is intended to protect against damaging waters (flood control) and that which is intended primarily to regulate and distribute water for the benefit of mankind (conservation).

The nature of water resources development projects is closely allied to the degree and nature of cultural development in a region. In the early stages of regional development, flood-control measures are usually limited to minor channel improvements and occasional low levees. As population centers develop, major channel improvement and levee structures are constructed. Occasionally, major reservoirs immediately upstream of a population center are also constructed. As the general region develops and population centers become more numerous within a river basin, a comprehensive plan of flood protection, including headwater improvements, major channel and levee improvements, bypasses, and reservoirs, might be warranted.

Hydrologic determinations required for minor channel and levee improvements consist essentially of peak-flow frequency estimates for the location. Exceedence of channel capacity is not a serious factor in this type of improvement, and drainage of areas protected by low levees is by gravity, either around the end of a long levee or by use of culverts with automatic flap gates. In case of major levee and bypass improvements, more reliable estimates of flow frequency are required; and consideration must be given to the possibility of exceeding design capacities, because disastrous consequences might result. Major gravity drains and pumping plants associated with high levees require sophisticated hydrologic design. General procedures used in the functional design of levee and channel improvements are discussed in the following chapter.

In the case of reservoir design for flood control, the runoff volume potential corresponding to various frequencies and pertinent durations is the critical hydrologic factor insofar as the size of the reservoir is concerned. In addition, the safety of the structure is essential, and estimates of runoff that might occur on extremely rare occasions are required for spillway design purposes. Outlet structures and related intake facilities require special hydrologic analyses. The limiting size of gates and heads under which they can operate must be taken into account and requirements for energy dissipation must be considered. Procedures used in the design of reservoirs for flood control are described in Chapter 3.

Water resources development for water-use (conservation) purposes may be classified into the three general categories of water supply, low-flow regulation, and power generation. Basic reservoir design procedures are similar for all of these applications. In the early stages of a region's development, low-flow regulation is not ordinarily a project objective; and water is usually diverted from the unregulated flow of a river by use of a low structure and delivered by open canal to the area of use for irrigation, municipal supply, or power generation. Very little reservoir storage is ordinarily involved in these early stages. Run-of-river power plants are common. For a given location, the principal hydrologic determination is a flow-duration curve which simply portrays the proportion of time that flows exceed various magnitudes at the specified location.

As the regional economy develops, the need for low-flow regulation and ensured supplies of water and energy usually leads to the construction of water supply reservoirs and power reservoirs, accompanied by major conveyance facilities. Reservoirs are first constructed to regulate only the seasonal variation of runoff and are designed to fill each year. Where the service requirement is fairly uniform and the reservoir is relatively small in relation to annual runoff, hydrologic determinations might consist of frequency determinations of low-flow volumes for durations of less than 1 year. However, where there are substantial variations in demands, a detailed simulation study of proposed project operation, using runoff records for long periods of time, is needed to determine storage requirements. These studies are particularly critical in arid and semiarid regions, where the relation between seasonal variations in demand and seasonal variations in streamflow is often a major factor in the determination of storage requirements.

As regional development increases the demand for water, a stage is reached where storage is required for saving water from years of high runoff to supply needs during drought periods of a year or more. In determining storage requirements for this type of development, detailed simulation studies of project operation and elaborate studies of the stochastic characteristics of runoff, losses, and needs are required. The integrated operation of groundwater and surface water supplies becomes feasible and necessary. Procedures used in designing improvements are discussed in Chapters 4 to 7.

Determinations of scour and sedimentation become increasingly important as a region develops. When dams and reservoirs are constructed, the sedimentation problem becomes an important and sometimes critical factor in the design of projects. General procedures are discussed in Chapter 4, and sedimentation determinations will be discussed in considerable detail in Volume 12.

In the advanced stages of river basin development, the interaction of many projects independently constructed greatly complicates the analysis required for project design and operation. Projects constructed to serve special needs and possibly operated by different agencies can be operated independently only until a stage is reached when the operation of one interferes seriously with the operation of another. As development continues, the problem of coordinated operation becomes increasingly difficult, and a stage is reached where the individual project objectives must be reexamined in the interest of satisfactory service for the entire region. Procedures useful for this type of study are discussed in Chapter 7.

Section 1.03. Scope of Hydrologic Engineering

Hydrologic engineering concerns the physical management of natural waters on and below the surface of the earth for the benefit of mankind. It is primarily concerned with changing the spatial, temporal, and quality distributions of waters in such a manner as to serve the purposes of society at principal points of diversion and use.

Traditionally, one of the primary concerns of the hydrologic engineer has been the estimation of the frequency with which streamflows of various magnitudes (floods and droughts) will occur at each specified location under natural and particular modified conditions. The frequency of other hydrologic variables that affect the management of natural waters, such as rainfall, evaporation, snowmelt, and sediment transport, has also been of primary concern.

Since the covariation of these various hydrologic factors is of importance in water management, and since the sequences in which events occur are also important, it has recently been recognized that a simple frequency analysis of hydrologic events is rarely sufficient for making design and operation decisions. Accordingly, the space and time interrelations among pertinent hydrologic variables are the subject of the relatively new field of stochastic hydrology, which is greatly changing procedures and methods used in hydrologic engineering.

Since extrapolation of recorded data in space and time to estimate probabilities of extreme events is highly uncertain, it is almost always necessary to estimate extreme flood potential through the examination of rainfall and snowmelt potential, based on realistic combinations of extreme meteorological factors. Thus the measurement of storm magnitude by means of isohyetal maps, depth-area-duration relations, etc., adjustment and transposition of storm rainfall, temperature patterns, etc., snowmelt evaluation, and computation of runoff from snowmelt and rainfall are all within the scope of hydrologic engineering.

The computation of water-surface profiles is essential for flood insurance and flood information and zoning services as well as for levee and channel design. In the case of levees, proper drainage of protected areas requires the study of runoff in the protected area, particularly the runoff that is coincident with high river stages. This usually involves frequency studies, rainfall-runoff studies, and water-surface profile studies as well as duration-curve and coincident probability studies. Stability of channel and levee improvements require studies of scour and sedimentation in channel and overbank areas.

The planning, design, and operation of reservoirs for flood control, water supply, power generation, recreation, and low-flow regulation require a variety of hydrologic engineering studies of water quantity and quality. These include estimating the frequencies and probabilities of floods, droughts, and sequences of all types of hydrologic events. Studies are required to determine the optimum amounts and allocation of reservoir storage, sizes and locations of outlets and spillway, sizes and general characteristics of power generation facilities, operation plans for all functions including emergency spillway discharges, and means of monitoring hydrologic variables and project operation. The integrated operation of groundwater basins and surface water storage must be included in many hydrologic investigations. Studies of reservoir temperature stratification and other quality characteristics are becoming increasingly important, as are detailed sedimentation analyses. Operation studies include consideration of many hydrologic, economic, legal, political, ecologic, environmental, and social factors and require the use of the most modern computers and mathematical techniques.

The large scope of hydrologic engineering and the necessity to provide continuity in planning, design, and operation stages and to demonstrate project objectives and accomplishments to a variety of interested parties require that a hydrologic engineer be fully acquainted with all aspects of a project, document all work effectively, and participate in training programs to take advantage of best available techniques and to pass knowledge on to others.

Section 1.04. Computer Applications

Hydrologic engineering methods that are most useful in areas of sparse data are not necessarily less complex nor do they require less computation than those methods most suitable to areas where data are more plentiful. The shortage of data can often be offset to some degree by use of elaborate correlations with climatic and drainage basin characteristics that might not be necessary or especially helpful where data are more plentiful. Consequently, the problems encountered in areas of sparse data can be more complex and can require more computation by electronic computer than do problems encountered in areas of more plentiful data. It should not be surprising, then, that most of the methods discussed herein will emphasize the use of electronic computers and generalized computer programs that can be readily adapted to new problems, both in areas of plentiful data and areas of sparse data.

Experience has shown that the most effective manner of performing engineering computations on electronic computers involves programming directly by the experienced engineer. Through the use of a programming language such as FORTRAN, it is easier for an engineer to construct a program directly than to instruct a programmer in sufficient detail that the programmer can adequately construct the program. Where the use of FORTRAN or a similar programming language for scientific use is at all feasible, programming in machine language or symbolic language is rarely justified. Use of FORTRAN, however, requires considerable computer memory, which might not be available in some of the smaller second-generation computers. This is ordinarily not a problem with most modern computers. Nevertheless, it is highly desirable and economical to use as large a memory as is available, because limits in memory size can greatly increase the difficulty and the time and money required to develop an adequate program. It is also desirable and economical to use the highest-speed computer available because costs per unit of work accomplished decrease rapidly with the speed of the computer. As long as the turnaround time between submission and return of a job is satisfactory, it will prove to be far more economical, from the standpoint of programming costs and computer costs and time required for the accomplishment of a job, to use the largest and fastest computers available.

The performance of hydrologic engineering computations has been greatly facilitated during the past few years through the development of a number of generalized computer programs that can be applied to each new problem in a given type of application with a minimum of program change, often with no change in the program. These generalized programs are designed for a particular type of problem so that the peculiar features of each new problem can be specified along with the data needed to solve that particular problem. They are designed for maximum simplicity of input, so that they can be readily used by engineers who are familiar with the procedures involved but not necessarily with the program. The development of these generalized programs requires extensive testing. Consequently, once they are accepted, they are probably more thoroughly checked than is a program that is designed specifically for a particular problem. The generalized programs are also designed to accept varying quantities of data and are therefore highly adaptable to areas of sparse data. In general, the programs are constructed in such a manner that they are not machine-dependent, that is, they can be readily adapted to a large variety of computers.

It is imperative that the engineer understand thoroughly the methods and procedures used in the generalized computer programs that he employs. Programs that constitute a part of this IHD report often provide a choice of methods, and each is described sufficiently for the engineer to determine whether the method is satisfactory for his needs. Virtually all of the computation details are managed in these computer programs, and many low-level decisions are also accomplished within them. As computer technology and program sophistication develop, more decisions can be preprogrammed and the engineer can utilize his own time for higher-level decision making.

Three of the more highly developed and most generalized computer programs available in The Hydrologic Engineering Center are included as appendices to this volume. They alone contain a sufficient variety of methods and procedures to accomplish many hydrologic engineering analyses required in the planning and design of water resources projects. The remaining programs that will be contained in other volumes of this report encompass other areas of hydrologic engineering or are more specialized than the three contained herein.

Section 1.05. Scope of This Report

This is Volume 1 of a projected 12-volume report describing methods used in the planning, design, and operation of water resources projects. The report does not intend to describe all methods in literature or in use, but only selected methods essential for complete analysis and demonstrated as satisfactory in the light of experience in the Corps of Engineers. Other organizations or individuals might well select or prefer other methods, but the ones described herein are considered to be suitable in a great variety of applications and have generally been tested in actual field application.

Volume 1 describes the general nature of water resource improvements and the general procedures used in hydrologic engineering studies. Remaining volumes in the report describe detailed hydrologic engineering methods and are scheduled to be completed by July 1972:

Volume No.	Title
2	Hydrologic Data Management
3	Hydrologic Probabilities

(Continued)

Volume No.	Title
4	Hydrograph Analysis
5	Hypothetical Floods
6	Water-Surface Profiles
7	Reservoir Operation for Flood Control
8	Reservoir Yield
9	Reservoir System Analysis
10	Principles of Groundwater Hydrology
11	Water-Quality Determinations
12	Sediment Transport

The number and nature of methods required for hydrologic studies change continually with changing problems, objectives, and mathematical and computation capability. Many features of the methods and computer programs described herein are recently developed, and it is anticipated that new techniques will evolve each year. Accordingly, it is planned to review all volumes before the end of the Decade, and the final issue will be updated and will reflect additional testing by use during the intervening years.

Chapter 2

Local Flood Protection

CHAPTER 2. LOCAL FLOOD PROTECTION

Section 2.01. General Basis of Design

Local flood protection consists of channel and levee improvements, floodproofing, and floodplain management used to prevent damages in a particular urban or agricultural area. When there is a need to protect a particular area, the first step is to evaluate the relation of river stage and flooded areas at various points along the damage reach to the flow in the river at a key location. This ordinarily requires detailed water-surface profile studies as described in Section 2.04.

Flood damage is usually related primarily to maximum instantaneous river stage. Accordingly, when water-surface profiles for various representative damaging flows are determined, areas inundated by each flow can be delineated. Through knowledge of improvements and crops in the inundated areas, a relation between peak flow at an index station and total damage in the area to be protected (stage-damage curve) can be developed. These determinations should be checked, to the extent possible, using data on damages during actual floods. This process can then be repeated for each alternative plan of improvement.

For plans where only clearing and snagging are proposed, only the roughness coefficients might be changed in the new computations for project conditions. Where channel excavation is involved, new cross sections must be used in the water-surface profile studies, as well as new roughness coefficients for the excavated area. Where levees are proposed, the cross-section specification is more elaborate; and it is usually desirable to compute water-surface profiles for stages exceeding the top of levee as well as for stages below levee grade, in order to assess the possible consequences of inadequate levee height.

When damage functions of discharge have been developed for each plan of improvement and adjusted as necessary to projected conditions in the future, they can be used in conjunction with flow-frequency curves to derive frequency curves of damage. The average annual damage for each plan of development is simply the integral of this function. Often the computation is done graphically, and the area under the damage frequency curve is the average annual damage.

Where damages in relation to river stage and duration vary seasonally, as in the case of agricultural damages, the frequency of river discharges and duration must be determined separately for each season when damages are substantially a unique function of river stage. The above procedure can then be repeated for each season, and the total average annual damage would be the sum of those computed from each season's damage-frequency curve.

The optimum plan of improvement would ordinarily be the plan that provides the most benefits in relation to cost, provided sufficient funds are available and other political, social, and economic aspects of the plan of improvement are satisfactory.

Whenever levees are included in the plan of development, some provision must be made for draining runoff from the protected area. Frequently it will be satisfactory to provide gravity drains through the levee and some ponding area on the land side of the levee to accommodate runoff that occurs during high river stages (runoff that will not drain by gravity at the time). Whenever such gravity drains are provided, a manually operated slide gate or, more frequently, an automatic flap gate at the river end of the conduit is required in order to prevent river flow during high stages from entering the protected area through the conduit. Where gravity drainage in combination with available ponding areas is inadequate, pumping facilities for draining the protected area during high stages should be provided. Considerable information on the design of interior drainage facilities is contained in reference 2.04.

Section 2.02. Flood-Frequency Determinations

At most locations, flood stages are a unique function of flood discharges for most practical purposes. Accordingly, it is usual practice to establish a frequency curve of river discharges as the basic hydrologic determination for project design purposes. In special cases, factors other than river discharge (such as tidal action or accumulated runoff volume) may greatly influence river stages. In such cases, a direct study of stage frequency based on recorded stages is often warranted.

Where runoff data at or near the site are available, flood-frequency determinations can ordinarily be made most reliably through a direct study of this data. Before frequency studies of recorded flows are made, the flows must be converted to a specified uniform condition, usually to conditions without major regulation or diversion. This might require detailed routing studies of flows through upstream reservoirs. Since damaging flows occur during a very small fraction of the total time, only a small fraction of the runoff is ordinarily used in flood-frequency studies. This consists of the largest flow that occurs each year and secondary peak flows that cause damage.

Experience in making flow-frequency studies has indicated that frequency estimates are subject to extremely large errors, even when fairly long records are available. In order to increase the reliability of frequency estimates, theoretical frequency relations that have been demonstrated to apply generally are used in specific frequency studies. These require that a complete set of data be used. In order to comply with the requirement, the basic frequency study ordinarily is based on the maximum flow for each year of record, since the complete set of annual maximum events is easy to manage and contains most of the available pertinent information. Supplementary studies that include the other damaging events are ordinarily made separately.

The underlying general assumption made in all frequency studies is that each event observed represents an approximately equal proportion of the future events that will occur at the location, if controlling conditions do not change. Detailed procedures for selecting data and computing flood-frequency curves will be described in Volume 3. A computer program accompanying that volume can be used for computing frequency curves analytically as well as for arranging data for graphical analysis and presentation. Because of the great variation in frequency characteristics of streamflows at different locations, it is essential that the data and adopted frequency curve be plotted together, in order to ensure that the derived frequency relation is reasonably consistent with the frequency of observed streamflow values.

Where runoff data at or near the site do not exist or are too fragmentary to support direct frequency calculations, regional correlation of frequency statistics may be used for estimating frequencies. These correlations generally relate means and standard deviation (general magnitude and variability) of flows to drainage basin characteristics and location. Techniques of regional correlation will be described in Volume 2.

Frequency curves for modified or regulated conditions upstream of the site are usually determined from studies of the effects of upstream changes on representative hydrographs for the complete range of magnitudes of damaging floods. The frequency of regulated flow is considered to equal the frequency of unregulated flow for the same representative flood. (See Section 3.08, paragraph f.)

In the design of local protection projects, protection against floods larger than the maximum recorded events is often warranted. Inasmuch as extrapolation of derived frequency relations is hazardous, special studies of the potential magnitudes of extreme flood events are usually desirable. The most practical approach is through examination of rainstorms that have occurred in the region and determination of the runoff that would result at the project location if these storms should occur in the tributary area. This subject is discussed in the following section.

Section 2.03. Hypothetical Floods

Hypothetical floods are usually used in the design of local flood protection projects primarily for substantiating the estimates of flood peak frequency, although they may also be used as a primary basis of design. Where inadequate runoff data are available for establishing frequency curves of peak discharge, hypothetical floods can be used to establish flood magnitudes for a specified frequency from rainstorm events of that frequency. This is a hazardous procedure in many areas where the variations of ground conditions and rainfall distribution characteristics greatly influence flood magnitudes. However, in many areas where infiltration losses are small, it may be feasible to compute hypothetical floods from rainfall amounts of a specified frequency and to assign that frequency to the flood event. A hypothetical flood that is more commonly used to substantiate flow-frequency curves is the standard project flood. This flood would result from the largest storm that is reasonably characteristic of the region occurring over the tributary area at a time when ground conditions are conducive to high runoff. While the frequency of the standard project flood cannot be specified accurately, it can be used as a guide in extrapolating frequency curves because it is considered to lie within a reasonable range of rare frequency, such as between once in 200 years and once in 1000 years.

The unit hydrograph technique is ordinarily used in the computation of hypothetical floods. This technique employs area-average precipitation amounts for a specified interval of time and does not account for differences in areal or time patterns within the intervals. Rainfall losses that occur within each time interval are a function of the ground condition and the average intensity of rainfall during the time interval. Each rainfall excess (rainfall minus losses) value is multiplied by successive ordinates of the unit hydrograph to obtain the hydrograph component resulting from that excess alone; and such hydrograph components are added for all intervals during the storm period, taking into account the time sequences of precipitation and unit-hydrograph ordinates. Appendix 1 describes a computer program that is capable of performing all of the computations necessary in deriving a hydrograph from specified storm rainfall.

Hypothetical storms to be used for any particular category of hypothetical flood computation must be based on data observed within a region. For application in the design of local flood protection projects, only peak flows and runoff volumes for short durations are ordinarily important. Accordingly, the maximum pertinent duration of storm rainfall is only on the order of the time of travel of flows from the headwaters to the location concerned. After a reasonable maximum duration of interest is established, rainfall amounts for this duration and for all important shorter durations must be established. In the case of standard project storm determinations, this would consist of the amounts of observed rainfall in the most severe storms within the region that correspond to area sizes equal to the drainage area above the project. In the case of hypothetical storms and floods of a specified frequency, these amounts would correspond to amounts observed to occur with the specified frequency at stations spread over an area the size of the project drainage area. Larger rates and smaller amounts of precipitation would occur for the shorter durations, as compared with the longer durations of interest. Once a depth-duration curve is established that represents the desired hypothetical storm rainfall, a time pattern must be selected that is reasonably representative of observed storm sequences. The computer program described in Appendix 1 has the capability of accepting any depth-duration relation and selecting a reasonable time sequence. It is also capable of accepting specified time sequences for hypothetical storms.

Where snowmelt is an appreciable factor in contributing to runoff, it is necessary to specify an initial snow cover; and this may be done separately for each elevation zone where the variation of elevation within a drainage basin appreciably affects snowfall and snowmelt. During the flood computation, snowfall and snowmelt within each elevation zone must be computed. The snowmelt is added to the rainfall during each interval and subtracted from the snow cover for that zone. Snowfall is added to the snow cover, and a continuous record of snow cover is maintained for each elevation zone. The computer program in Appendix 1 is capable of performing these operations also.

Where runoff records are not available at or near the location of interest, unit hydrograph and loss characteristics must be determined from regional studies of such characteristics observed at gaged locations. Runoff and loss coefficients can be related to drainage basin characteristics by multiple correlation analysis and mapping procedures. Techniques for doing this will be described in Volume 2 of this report.

Where local protection projects are being considered for more than one location in a drainage basin, or where the effect of an upstream improvement must be evaluated, computation of hypothetical floods for an entire stream system is often required. Since the rainfall amounts will differ for each location of interest, a large number of hypothetical floods for any specified degree of severity must be computed in many cases. If the relation of storm intensity to drainage area size is specified, the computer program in Appendix 1 is capable of performing a series of flood computations that will reflect the correct storm intensity for each project location and the normal contribution from any upstream location. This contribution can be used in evaluating the average effects of upstream improvements.

Section 2.04. Water-Surface Profiles

In some cases, a local flood protection project is such that one design elevation can be used at all points, and such that this value can be determined from a rating curve located in the vicinity of the project. Since design floods are usually larger than any experienced event, such a rating curve must usually be extrapolated beyond observed events. In the general case, however, water-surface profiles are required to establish a design profile, because there is substantial change in elevation along the reach to be improved. A series of rating curves along the reach, derived from observed profiles, might be adequate to define a design profile for protection against a specified flow. However, water levels often are complicated functions of flow areas, and furthermore, these flow areas are subject to change due to project construction and natural changes. Accordingly, profiles are best calculated by analytical methods.

Assuming steady-flow conditions, water-surface profiles are calculated for a range of discharges, including the design flood. The results are used to establish the design elevation profile for the local flood protection and to develop stage-discharge and stage-duration curves at locations requiring interior drainage studies.

The computation of water-surface profiles, to be discussed in detail in Volume 6, is based on the solution of the one-dimensional energy equation for gradually varied flow. The Standard Step Method is the most generally applicable method since it can be used in hand computations or in computations by the electronic computer. When flow velocity is less than critical, calculations should proceed in the upstream direction since effects at control sections are reflected upstream. When flow velocity is greater than critical, calculations must proceed in the downstream direction since velocity effects influence downstream stages. The calculations are made by successive approximation. Beginning with a known water-surface elevation at the start of a reach, a water-surface elevation is estimated for the end of the reach, and energy losses are calculated. The ending water-surface elevation is then computed by adding the calculated losses to the known water-surface elevation at the start of the reach. If there is a significant difference between the estimated and computed elevations, a new estimate is made and the computation repeated. When the difference between these estimated and computed elevations is less than some allowable error (about 1 or 2 cm), the computed elevation is accepted; and computations are advanced to the next cross section. If hand calculations are used, one should recognize when terms such as contraction losses, expansion losses, and velocity head can be neglected and when slide rule accuracy is sufficient.

Basic data required for calculating water-surface profiles are discharge, starting water-surface elevation, boundary geometry, roughness coefficients, and occasionally other types of energy loss coefficients. The Manning formula for open channel flow is used in this report, and boundary geometry is expressed in terms of a plan of channel alignment, cross-section coordinates, and distance between cross sections. Detailed surveys are needed to establish the boundary geometry at bridges, and photographs of the structure are desirable.

Channel geometry, as determined from field surveys, will change as the discharge changes in alluvial rivers; however, present procedures for calculating this change are not very reliable. As a result, this influence is usually reflected in estimating the roughness coefficients by reproducing experienced events.

In all cases, field measurements of cross sections, discharges, and water-surface profiles of actual floods are necessary to verify the accuracy of calculated profiles in the vicinity of the local flood protection. When bridges and other constrictions are encountered, contraction and expansion losses are frequently more predominant than friction losses and must also be verified by field measurement.

When tributaries enter within the study reach, the change in discharge should be considered, but the magnitude of losses due to mixing of the flows is not well defined. It is usually ignored in subcritical flow situations, but energy losses for supercritical conditions can be estimated by assuming full momentum transfer.

Alignment of the levee or floodwall is determined by trial and error, using its effect on the water-surface profile, estimated current directions, and velocities as guides.

Section 2.05. Freeboard

After the design water-surface profile is determined for a levee or channel improvement, the profile of the top of levee or of channel wall is determined by adding some amount of freeboard. This freeboard constitutes a safety factor to allow for wave action, errors in measuring cross sections, errors in estimating roughness coefficients, and errors in the overall water-surface profile determinations. The freeboard allowance is usually greater for long levees and steep channel slopes than for short levees and flatter slopes. In the case of long levees, it is good practice to provide less freeboard at the downstream end in order that water will inundate the protected area gradually in the event of failure.

Selection of the amount of freeboard is usually dependent upon experience during actual flood-fighting operations. In the case of protection of urban areas with high levees, a minimum of 1 m is usually selected. In the case of protection of agricultural areas, a freeboard of about 1/2 m is considered satisfactory. Where very low levees or no levees are involved, minimum freeboard from 0 to 30 cm is usually adequate.

There is a tendency to depend on freeboard for carrying more water than the project is designed for. This is an unwise use of freeboard. Freeboard is intended to compensate for computation uncertainties, inadequacies of data, and other sources of error. It is possible that a levee can be overtopped at one location while adequate freeboard prevails at another. Accordingly, benefit estimates and operation plans should be based on design profile discharge capacity as though freeboard is not effective in increasing that capacity.

Section 2.06. Interior Drainage

Where streams of substantial size enter a river along a reach where levees are planned, it is ordinary practice to construct tie-back levees along the stream to high ground in order to allow the stream to flow naturally into the river. Runoff from smaller streams and overland flow within the protected area must be removed by gravity drainage or pumping. Frequently there are no records of runoff from the areas requiring interior drainage; and where records might be available, development within the area usually changes the runoff regime to the extent that the records are not representative for existing or future conditions. Accordingly, interior drainage runoff is usually estimated from rainfall, using unit hydrograph techniques as described in Section 2.03.

Usually, a design flood corresponding to some prespecified standard is selected for determining interior drainage requirements. This might be a flood that is exceeded on the average once in 10 years for agricultural areas or once in 50 years for urban areas, although these criteria will differ in different regions and under different conditions. When the exceedence frequency of interior drainage protection is selected, a rainstorm is selected that will have rainfall intensities of that specified frequency for all pertinent durations. These durations may be fairly long, since they must encompass the longest duration for which pondage will occur behind the levee.

Unit hydrograph and loss coefficients are best derived from studies where records are available in the region. In urban areas, the degree of development is accounted for in selecting percentage of area imperviousness and time of concentration. Change in time of concentration can be approximated by estimating flow velocities using Manning's formula and comparing travel time from source to point of concentration for different development plans. The computer program described in Appendix 1 is capable of performing computations required for this purpose.

When a design flood for each drainage system behind the levee has been computed, it is necessary to determine the size of facilities needed for gravity drainage--ordinarily, these include a culvert and ponding area. It is necessary to route the design hydrograph through the culvert and determine the amount of ponding that would occur. Different culvert sizes should be tried until the amount of ponding is within acceptable limits.

It is also necessary to estimate in the same manner the amount of runoff that would occur coincident with high river stages with the design exceedence frequency. This will be a much smaller flood, since high storm intensities often occur when the river stage is low, thus contributing to the frequency of flooding to be drained by gravity but not to the frequency of flooding to be stored or pumped. It will be necessary to pond the entire runoff from this storm as long as the river stage is high, unless pumping facilities are provided. If the entire amount cannot be safely ponded, a pumping facility large enough to remove the excess water during the runoff period must be provided.

Detailed studies required for interior drainage and pumping plant design will be discussed in Volume 5, and additional computer programs usable in these studies will be described.

Section 2.07. General Study Procedure

After areas to be protected by local protection works are delineated and the various alternative plans of improvement are selected, the following steps are suggested for conducting the necessary hydrologic engineering studies:

a. Obtain detailed topographic maps of the tributary area and of the general region, outline the drainage area, and locate all precipitation, snowpack, and streamflow measurement stations. Determine the size of tributary areas for the proposed project and all stream-gaging stations that will be used in the study. Prepare a normal seasonal isohyetal map for the drainage areas concerned in order to appraise typical areal precipitation patterns.

b. Obtain all available data on historical flood discharges at the site and on associated water-surface profiles. Obtain from maps or field observation cross-section data along the reach to be protected.

Reconstitute observed profiles to establish roughness coefficients, using the computer program described in Appendix 2.

c. Obtain all available peak discharge data recorded at the location (or as near as available upstream and downstream of the location), adjust as necessary to a specified condition of upstream development, and compute a frequency curve of annual maximum peak flows for the site. If records upstream and downstream of the site must be used, flow magnitudes corresponding to each frequency should be interpolated in relation to tributary area on logarithmic scales. If records are available only upstream or downstream, adjustment of flow magnitudes to the site should be made on the basis of tributary area raised to a power less than 1.0, as determined by regional studies.

d. If stream-gaging stations are not available reasonably near the site, a regional frequency study should be made. This is done by computing frequency curves of peak flow for unregulated conditions at many long-record stations in the region and relating frequency statistics to drainage basin characteristics. The relation derived can then be applied to conditions at the site. Methods used will be discussed in Volume 3.

e. After a frequency curve of peak flows has been established for the site and adjusted as necessary to conform with upstream conditions that will prevail during the project life, various flow magnitudes should be selected that will span the range of possible design flows. Water-surface profiles for each flow should then be computed. The computer program described in Appendix 2 can be used for this purpose.

f. Select various trial flows for alternative design magnitudes, establish the flow lines corresponding to each, add freeboard, and develop a plan of channel and levee improvement that will best protect against the flow. Determine the amounts of runoff from the protected area that must be directed into the river. This is accomplished by making a frequency study of runoff in the protected area or, more commonly, from rainfall frequency data as described in Section 2.03.

g. Where levees constitute a portion of the contemplated improvement and where drainage from the protected area must therefore be conducted through or over the levee, maximum ponding area limits must be established and culverts provided to drain the inflows to these ponding areas. A special frequency study of runoff coincident with high river stages should be made in order to determine whether the runoff would exceed pond capacity unreasonably frequently. If it does, pumping facilities adequate to remove the excess inflow should be provided.

h. Establish a frequency curve of river stages for each plan of development, assuming that the stage under project conditions will have the same frequency as the stage under nonproject conditions for the same flood. These stage-frequency curves can be used for evaluating damages that would occur without a project and with each contemplated project for use in benefit studies and in project selection.

i. Where loss of life or major property damage would result from exceedence of project design capacity, compute a standard project flood and water-surface profile, as described in Sections 2.03 and 2.04, for possible selection as a design flood if economically feasible. A probable maximum flood is ordinarily not pertinent to the design of a local protection project.

Chapter 3

Flood Control by Reservoirs

CHAPTER 3. FLOOD CONTROL BY RESERVOIRS

Section 3.01. General Design and Operation Considerations

Where damages at a large number of locations on a river can be prevented or reduced by construction of one or more reservoirs, or where a reservoir site immediately upstream of one damage center would provide more economical protection than would local protection works, control by reservoirs in lieu of local protection projects should be considered. Whenever such reservoirs can serve needs other than flood control, the integrated design and operation of the project for multipurpose use should be considered.

In planning and designing the flood-control features of a reservoir, it is important that the degree and extent of continuous ensured protection be no less than that provided by a local protection project, if the alternatives of reservoir construction or channel and levee improvement are to be evaluated fairly. This means that the storage space and release schedule for flood control must be provided at all times when the flooding potential exists. In some regions this may be for the entire year, but more commonly there are dry seasons when the flood potential is greatly reduced and storage reservation for flood control can be reduced correspondingly. Except where spring snowmelt floods can be forecasted reliably or where safe release rates are sufficient to empty flood space in a very short time, it is not ordinarily feasible to provide flood-control space only after a flood is forecasted. Space must be provided at all times during the flood season unless it can be demonstrated that the necessary space can be evacuated on a realistic forecast basis. Also, use of parameters reflecting ground wetness as a means of releasing space for other purposes when flood potential is low is not ordinarily satisfactory because as the ground becomes wet and space is needed, runoff increases, making it difficult or impossible to evacuate needed space.

Whereas the peak rates of runoff are critical in the design of local protection projects, runoff volumes for pertinent durations are critical in the design of reservoirs for flood control. The critical durations will be a function of the degree of flood protection selected and of the release rate or maximum rate of flow at the key downstream control point. As the proposed degree of protection is increased and as the proposed rates of controlled flows at key damage centers are reduced, the critical duration is increased. If this critical duration corresponds to the duration of a single rainstorm period or a single snowmelt event, the computation of hypothetical floods from rainfall and snowmelt can constitute the principal hydrologic design element. On the other hand, if the critical duration is much longer, hypothetical floods and sequences of hypothetical floods computed from rainfall or snowmelt become less dependable as guides to design. It then is necessary to base the design primarily on the frequency of observed runoff volumes for long durations. Even when this is done, it will be advisable to construct a typical hydrograph that corresponds to runoff volumes for the critical durations and that reasonably characterizes hydrographs at the location, in order to examine the operation of the proposed project under realistic conditions.

When a tentative design flood is selected, it must be routed through the proposed reservoir under the operation rules that would be specified for that particular design. In effect, a simulation study of the proposed project and operation scheme would be conducted for the design flood. It is also wise to simulate the operation for major floods of historical record in order to ensure that some peculiar feature of a particular flood does not upset the plan of operation.

Section 3.02. Regulated Release Rates

Reservoirs must store for flood purposes only the water that cannot be released without causing important damage downstream. If more water can be released during a flood, less water need be stored; that is, less storage space need be planned for flood control. Since reservoir space is costly and usually in high demand for other purposes, good flood-control practice consists of releasing water whenever necessary at the highest practical rates so that a minimum amount of space need be reserved for flood control. As these rates increase, it becomes costly also to improve downstream channels and to provide adequate reservoir outlets, so there is an economic balance between release rates and storage capacity for flood control. In general, it is economical to utilize the full nondamage capacity of downstream channels; and it may pay to provide some additional channel or levee improvements downstream.

Channel capacities should be evaluated by examination of water-surface profile data from actual flood events whenever possible. Under natural channel conditions, it will ordinarily be found that floods which occur more frequently than once in two years are not seriously damaging, while larger floods are.

In some cases, it is most economical to sustain minor damages by releasing flows above nondamaging stages in order to accommodate major floods and thereby protect the more important potential damage areas from flooding. In such situations, a stepped release schedule designed to protect all areas against frequent minor floods, with provision to increase releases after a specified reservoir stage is reached, might be considered. However, such a plan has serious drawbacks in practice because protection of the minor damage areas would result in greater improvements in those areas; and it soon becomes highly objectionable, if not almost impossible, to make the larger releases when they are required for protection of major damage areas. In any case, it is necessary to make sure that the minor damage areas are not flooded more frequently or severely with the project than they would have been without it.

While it is important on all streams in developed areas to provide for proper maintenance of channel capacity and zoning of the floodplain where appropriate, this is vital where upstream reservoirs are operated for flood control, because proper reservoir regulation depends as much on the ability to release without damage as it does on the ability to store. Minor inadequacies in channel capacity can lead to loss of control and consequent major flooding. This situation is aggravated because the reduced frequency of flooding below reservoirs and the ability to reduce reservoir releases when necessary often increase the incentive to develop the floodplain and sometimes even remove the incentive for maintaining channel capacity.

When a reservoir is located some distance upstream from a damage center, allowance must be made for any runoff that will occur in the intermediate area. This runoff must be forecasted, a possible forecast error added, and the resulting quantities subtracted from project channel capacity in order to determine permissible release rates.

Experience in flood-control operation of reservoirs has demonstrated that the actual operation does not make 100 percent use of downstream channel capacities. Average outflows during floods are less than maximum permissible values. Many factors contribute to this. It is usually wise to approach maximum release rates with caution, in order to ascertain any changes in channel capacity that have taken place since the last flood, and this practice reduces operational efficiency. It may be necessary to delay flood releases to permit removal of equipment, cattle, etc., from areas that would be flooded. Releases might be curtailed temporarily in order to permit emergency repairs to canals, bridges, and other structures downstream. If levees fail, releases might be reduced in order to hasten the drainage of flooded areas. Releases can be reduced in order to facilitate rescue operations. These and various other conditions result in reduced operation efficiency during floods. To account for this, less nondamage flow capacity than actually exists (often about 80 percent) is assumed for design studies. It is important, however, that every effort be made in actual operation to effect the full nondamage releases in order to attain maximum flood-control benefits.

During flood operations, reservoir releases must be increased and decreased gradually in order to prevent damage and undue hardship downstream. Gradually increasing releases will usually permit an orderly evacuation of people, livestock, and equipment from the river areas downstream. If releases are curtailed too rapidly, there is some danger that the saturated riverbanks will slough and result in loss of valuable land or damage to levees.

Section 3.03. Flood Volume Frequencies

Flood volume frequency studies usually consist of deriving frequency curves of annual maximum volumes for each of various specified durations that might be critical in project design. Critical durations range from a few hours in the case of regulating "cloudburst" floods to a few months where large storage and very low release rates prevail. The annual maximum volumes for a specific duration are usually expressed as average rates of flow for that duration. It is essential that these flows represent a uniform condition of development for the entire period of observation, preferably unregulated conditions. Procedures for computing the individual frequency curves are discussed briefly in Section 2.02 and will be described in detail in Volume 3. Also, a computer program for managing frequency computations for a number of durations simultaneously will be contained in that volume.

Determination of the flood-control space needed to provide a selected degree of protection is based on detailed hydrograph analysis, but a general evaluation can be made as illustrated in fig. 3.01. The curve of

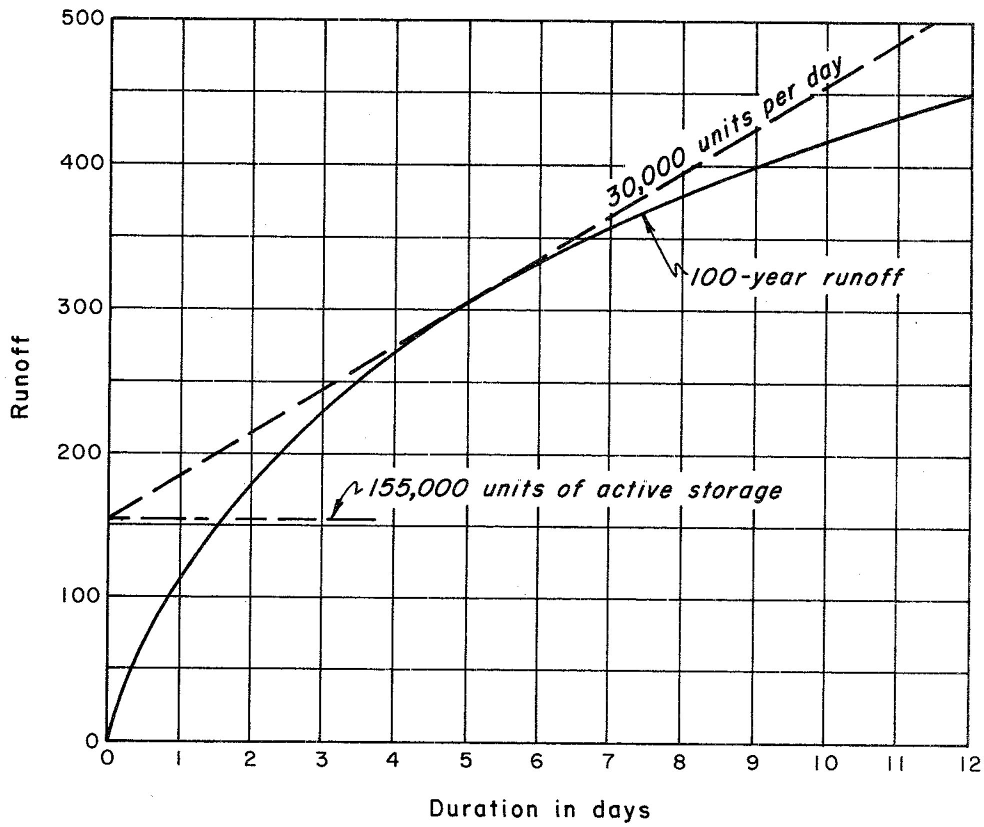


Fig. 3.01. Flood-control space requirement

runoff versus duration is obtained from frequency studies of runoff volumes or from standard project flood studies at the location. The tangent line represents a uniform flow equal to the project release capacity (reduced by an appropriate contingency factor). The intercept represents the space required for control of the flood. The chart demonstrates that a reservoir capable of storing 155,000 units of water and releasing 30,000 units per day can control 100-year runoff for any duration, and that the critical duration (period of increasing storage) is about 5 days. The volume-duration curve would be made for each damage area and should include more than 100 percent of the local uncontrolled runoff downstream from the reservoir and above the control point in order to allow for errors of forecast. If this local runoff appreciably exceeds nondamage flow capacity at the damage centers, the volume over and above that flow capacity is damaging water that cannot be stored in the project reservoir.

Section 3.04. Hypothetical Floods

Two classes of hypothetical floods are important in the design of reservoirs for flood control. One is a balanced flood that corresponds to a specified frequency of occurrence; the other is a flood that represents a maximum potential for the location, such as the standard project or probable maximum flood.

A hypothetical flood corresponding to a specified frequency should contain runoff volumes for all pertinent duration corresponding to that specified frequency. The derivation of frequency curves is as discussed in the preceding section. A balanced flood hydrograph is constructed by selecting a typical hydrograph pattern and adjusting the ordinates so that the maximum volumes for each selected duration correspond to the volumes for that duration at the specified frequency. This operation can be accomplished automatically by using the computer program described in Appendix 1.

In cases where durations of rainfloods longer than the ordinary duration of a single flood are important in the design, a sequence of flood hydrographs spaced reasonably with respect to time should be used as a pattern flood. In order to represent average natural sequences of flood events, the largest portions of the pattern flood should ordinarily occur at or somewhat later than the midpoint of the entire pattern, because rainfall sequences are fairly random but ground conditions become increasingly wet and conducive to larger runoff as any flood sequence continues.

Two types of hypothetical floods that represent maximum flood potential are important in the design of reservoirs. The probable maximum flood, which is the largest flood that is reasonably possible at the location, is ordinarily the design flood for the spillway of a structure where loss of life or major property damage would occur in the event of project failure. The standard project flood, which represents the largest flood for that location that is reasonably characteristic for the region, is a flood of considerably lesser magnitude and represents a high degree of design for projects protecting major urban and industrial areas. These floods can result from heavy rainfall or from snowmelt in combination with some rainfall.

The standard project rainstorm is usually an envelope of all or almost all of the storms that have occurred in a given region. The size of this storm is derived by drawing isohyetal maps of the largest historical storms and developing a depth-area curve for the area of maximum precipitation for each storm. Depth-area curves for storm rainfall of specified durations are derived from this storm-total curve by a study of the average time distribution of precipitation at stations representing various area sizes at the storm center. When such depth-area curves are obtained for all large storms in the region, the maximum values for each area size and duration are used to form a single set of depth-area-duration curves representing standard project storm hyetographs for selected area sizes, using a typical time distribution observed in major storms. Details of this procedure and examples will be discussed in Volume 5.

The probable maximum storm amounts are determined in much the same way as are standard project storm amounts, except that precipitation amounts are first increased to correspond to maximum meteorologic factors such as wind speed and maximum moisture content of the atmosphere.

Standard project and probable maximum flood hydrographs are computed from the storm hyetographs by unit hydrograph procedures as discussed in

Section 2.03. In the case of the standard project flood, ground conditions that are reasonably conducive to heavy runoff are used. In the case of the probable maximum flood, the most severe ground conditions that are reasonably consistent with storm magnitudes are used. Detailed methods for performing these computations will be described in Volumes 4 and 5. The computer program described in Appendix 1 contains routines for computing floods from rainfall and snowmelt and also contains standard project criteria for the eastern United States, which may serve as an example for other regions.

Satisfactory criteria and procedures have not yet been developed for the computation of standard project and probable maximum snowmelt floods. The problem is complicated in that deep snowpacks tend to inhibit rapid rates of runoff, and consequently, probable maximum snowmelt flood potential does not necessarily correspond to maximum snowpack depth or water equivalent. Snowpack and snowmelt differ at various elevations and this adds to the complexity of the problem.

Where critical durations for project design are short, high temperatures occurring with moderate snowpack depths after some melting has occurred will probably produce the most critical runoff. Where critical durations are long, as is the more usual case in the control of snowmelt floods, prolonged periods of high temperature occurring with heavy snowpack amounts will produce critical conditions.

The general procedure for the computation of hypothetical snowmelt floods is to specify an initial snowpack for the season that would be critical. In the case of standard project floods, a maximum observed snowpack should be assumed. The temperature sequence for standard project flood computation would be that which produces the most critical runoff conditions and should be selected from an observed historical sequence. In the case of probable maximum flood computation, the most critical snowpack possible should be used and it should be considerably larger or more critical than the standard project snowpack. The temperature pattern should be selected from historical temperature sequences augmented to represent probable maximum temperature for the season. Where simultaneous contribution from rainfall is possible, a maximum rainfall for the season should be added during the time of maximum snowmelt. This would require some moderation of temperatures to ensure that they are consistent with precipitation conditions.

Snowmelt computations can be made in accordance with an energy budget computation, accounting for radiation, evaporation, conductivity, and other factors, or by a simple relation with air temperature, which reflects most of these other influences. The latter procedure is usually more satisfactory in practical situations. Runoff is computed by use of unit hydrograph and loss-rate procedures described briefly in Section 2.03. Snowmelt, loss-rate, and unit hydrograph computations can be made by use of the computer program described in Appendix 1. A detailed description of the methods will be contained in Volumes 4 and 5.

Section 3.05. Operation Constraints and Criteria

As stated earlier, whenever flood releases are required, it is imperative that they be made at maximum rates consistent with the conditions downstream. This means that the outlets should be designed to permit releases at maximum rates at all reservoir levels within the flood-control space. In some cases where controlled releases are very high, such an outlet design is not economical, and releases at lower stages might be restricted because of limited outlet capacity. This constraint, of course, should be taken into account during the design studies.

Where damage centers are at some distance downstream from the reservoir, local runoff below the reservoir and above the damage center must be considered when determining releases to be made. This will ordinarily require some forecasting of the local runoff and, consequently, some estimate of the error of forecast. The permissible release at any time is determined by adding a safe error allowance to the forecasted local inflow and subtracting this sum from the nondamaging flow capacity.

The rate of change of release must be restricted to the maximum changes that will not cause critical conditions downstream. These rates of change of release should probably be considerably less than the rates of change of flow that occurred before the reservoir was built. After the main flood has passed, water stored in the flood-control space must be released; and maximum rates of release will continue until the desired amount of water is released, except that the rate of release should be decreased gradually toward the end of the release period. This reduction in release must be started while considerable flood waters remain in the reservoir in order that water retained for other purposes is not inadvertently released. Schedules for this operation will be discussed in Volume 7.

Section 3.06. Storage Capacity Determinations

The storage capacity required to regulate a specific flood (represented by a flood hydrograph at the dam) to a regulated discharge immediately downstream of the dam is determined simply by routing the hydrograph through a hypothetical reservoir with unlimited storage capacity and noting the maximum storage. However, there are many special practical considerations that complicate this process. Release rates should not be changed suddenly, and therefore the routing should conform to criteria that specify the maximum rate of change of release. Also, outlet capacities might not be adequate to supply full regulated releases with low reservoir stages. If this is the case, a preliminary reservoir design is required in order to define the relation of storage capacity to outlet capacity.

In the more common cases, where damage centers exist at some distance downstream of the reservoir, the storage requirement for a specified flood is determined by successive approximations, operating the hypothetical reservoir to regulate flows at each damage center to nondamaging capacity, and allowing for local inflow and for some forecasting error.

Although there are approximate methods for estimating storage capacity, it is essential that the final project design be tested by a detailed operation study based on actual outlet capacities and realistic assumptions for limiting rates of release change, forecast errors, and operation contingencies. It is also important to route the largest floods of record through the project to determine that the project design is adequate and that the project provides the degree of protection for which it was designed.

Where some of the flood-control space will be made available for other uses during the dry season, a seasonal distribution of flood-control storage requirement should be developed. The most direct approach to this entails the construction of runoff frequency curves for each month of the year. The average frequency of the design flood during the rainy-season months can be used to select flood magnitudes for other months. These could then serve as a basis for determining the amount of space that must be made available during the other months.

Sequential routing methods for use in planning, design, and operation of flood-control reservoirs will be described in Volume 7.

Section 3.07. Spillway Design

The spillway design flood is usually selected as a large hypothetical flood derived from rainfall and snowmelt, primarily because other means of estimating extreme flood magnitudes (such as by flood-frequency analysis) are highly undependable. The selection of a spillway design flood depends on the policies of the construction agency and regulations governing dam construction. Usually, the spillways for major dams, whose failure might constitute a major disaster, are designed to pass the probable maximum flood without a major failure; however, the spillways for many small dams are designed for smaller floods such as the standard project flood.

The hydrologic design of a spillway is accomplished by successive approximations, first estimating a design and then testing it by routing the spillway design flood. In routing the spillway design flood, the initial reservoir stage should be as high as can reasonably be expected at the start of such a major flood, considering the manner in which the reservoir is planned to operate or how the reservoir might operate in the future that is different from the planned operation. In the case of ungated spillways, it is possible that the outlets of the dam will be closed gradually as the spillway goes into operation, in order to delay damaging releases as long as possible and possibly to prevent them. However, if spillway flows continue to increase, it may be necessary to reopen the outlets. In doing so, care should be exercised to prevent releases from exceeding maximum inflow quantities. The exact manner in which outlets will be operated should be specified so that the spillway design will be adequate under conditions that will actually prevail after project construction. Consideration should be given to the possibility that some outlets or turbines might be out of service during flood periods.

In the case of gated spillways, the gates normally would be closed during the flood season if storage behind the gates is to be used for flood control. In cases where automatic gate operation is not provided and where an attendant is not on duty at all times during the flood season, the gates normally would be maintained in a fully open position during the flood season; and water normally would not be stored for flood control or other purposes above the fixed spillway crest during that time.

The operation of large spillway gates can be extremely hazardous, since opening them inadvertently might cause major flooding at downstream areas. Their operation should be controlled by rigid regulations. In particular, the opening of the gates during floods should be scheduled on the basis of inflows and reservoir storage so that the lake level will continue to rise as the gates are opened. This will ensure that inflow exceeds outflow as outflows are increased. The adequacy of a spillway to pass the spillway design flood is tested for gated spillways in the same manner as for ungated spillways described above. Methods for developing spillway-gate operation regulations will be described in Volume 7.

In order to ensure adequacy of the spillway to protect the structure from overtopping, some amount of freeboard on the dam is added to the maximum water-surface elevation. This can vary from zero for structures that can withstand overtopping to 2 m or more for structures where overtopping would constitute a major hazard. The freeboard allowance accounts for wind set and wave action. Methods for estimating these quantities will be discussed in Volume 7.

While the spillway is primarily intended to protect the structure from failure, the fact that it causes some water to be stored above ordinary full pool level is of some consequence in partially controlling floods downstream. Narrow ungated spillways require higher dams and can therefore be highly effective in regulating floods that exceed project design magnitude, whereas wide spillways and gated spillways that save on dam height are ordinarily not very effective for regulating floods exceeding design magnitude. Where rare floods can cause great damage downstream, the selection of spillway type and characteristics can appreciably influence the benefits that are obtained for flood control. Accordingly, it is not necessarily the least costly spillway that yields the most economical plan of development. In evaluating flood-control benefits, computation of frequency curves for regulated conditions should be based on spillway characteristics and operation criteria as well as on other project features.

Section 3.08. General Study Procedure

After various alternative locations are selected for a reservoir site to protect one or more damage centers, the following steps are suggested for conducting the required hydrologic engineering studies:

a. Obtain a detailed topographic map of the region showing the locations of the damage areas, of proposed reservoir sites, and of all pertinent precipitation, snowpack, and stream-gaging stations. Prepare a larger scale topographic map of the drainage basin tributary to the most downstream damage location. Locate damage centers, project sites, pertinent hydrologic measurement stations, and drainage boundaries above each damage center, project site, and stream-gaging station. Measure all pertinent tributary areas. Draw normal seasonal isohyets.

b. Establish stage-discharge relations for each damage reach, relating the stages for each reach to a selected index location in that reach; procedures for doing this are described in Chapter 2. Where local protection works are considered as part of an overall plan of improvement, establish the stage-discharge relation for each plan of local protection.

c. Obtain storage-elevation curves for each reservoir site, select alternative reservoir capacities as appropriate for each site, select outlet and spillway rating curves for each reservoir, and develop a plan of flood-control operation for each reservoir. Determine maximum regulated flows for each damage center.

d. Estimate the maximum critical duration of runoff for any of the plans of improvement, considering the relation of regulated flows at damage centers to unregulated flood hydrographs of design magnitude at those damage centers. Prepare frequency curves of unregulated peak flows and volumes of each of various representative durations, as described for peak flows in Section 2.02, for each damage center index location and for each reservoir site. If seasonal variation of flood-control space is to be considered, these curves should be developed for each season.

e. Establish a balanced hypothetical flood (base flood) for unregulated conditions in each subarea above project and damage centers as described in Section 2.03, selecting subareas such that hydrographs are obtainable at all project and damage locations by routing and combining operations. The hypothetical flood should be of intermediate magnitude. Select representative frequencies covering the range of possible damaging flood magnitudes and determine the ratios at each damage center by which the base flood must be multiplied in order to obtain magnitudes that would correspond to these selected frequencies. These ratios will be different for each damage center.

f. Select about eight ratios of the base flood that span the range of these ratios and compute a system flood for each of these system ratios and for each plan of development. This is done by multiplying each subarea hydrograph by the ratio and routing and combining these hydrographs for the entire system for each ratio and each plan of development in turn. Hydrographs of flow corresponding to selected frequencies for unregulated conditions at each damage location can then be interpolated between the nearest two of the eight basic floods. Frequency curves of regulated conditions at each damage center can then be derived from frequency curves of unregulated flows simply by assuming that a given ratio of the base flood will have the same recurrence frequency whether it is modified by regulatory structures or not. This assumption is valid as long as larger unregulated floods always correspond to the larger regulated flows.

g. Derive a stage-frequency curve for the index station at each damage center from water-surface profile studies and flow-frequency curves (as described in Chapter 2) for unregulated conditions for each plan of improvement. These can be used for determining average annual damages for unregulated conditions and for each plan of development and would thus form the primary basis for project selection.

h. Develop a probable maximum flood for each reservoir site, using procedures described in Section 2.03. These will be used as a possible basis for spillway design. Route the probable maximum flood through each reservoir, assuming the most adverse reasonable conditions of initial storage and availability of outlet capacity.

i. If loss of life or major property damage can result from large floods without dam failures, compute a standard project flood as described in Section 2.03 for possible use as a basis of design if economically feasible.

Chapter 4

Water Supply by Reservoirs

CHAPTER 4. WATER SUPPLY BY RESERVOIRS

Section 4.01. Reservoir Characteristics

Water supply for any purpose is usually obtained from groundwater or from surface waters. Groundwater yields and the methods currently in use will be covered in Volume 10, and this section will be limited to discussion of surface water supplies for low-flow regulation or for diversion to areas of use.

In some cases, water supply from surface waters involves only the withdrawal of water as needed from a nearby stream. However, this source can be unreliable, since streamflows can be highly variable and the desired amount might not always be available. An essential requirement of most water supply projects is that the supply be available on a dependable basis. Reservoirs play a major role in fulfilling this requirement. Whatever the ultimate use of water, the main function of a reservoir is to stabilize the flow of water, either by regulating a varying supply in a natural stream or by satisfying a varying demand by the ultimate consumer. Usually some overall loss of water occurs in this process.

In determining the location of a proposed reservoir to satisfy water needs, a number of factors should be considered. The dam should be located so that adequate capacity can be obtained, social and environmental effects of the project will be satisfactory, sediment deposition in the reservoir and scour below the dam will be tolerable, the quality of water in the reservoir will be commensurate with the ultimate use, and the cost of storing and transporting the water to the desired location is acceptable. It is virtually impossible to locate a reservoir site having completely ideal characteristics, and many of these factors will be competitive. However, these factors can be used as general guidelines for evaluating prospective reservoir sites.

When an impounding reservoir is filled, the hydrology of the inundated area and its immediate surroundings is changed in a number of respects. The effects of inflows at the perimeter of the reservoir are translated rapidly to the reservoir outlet, thus effectively speeding the flow of water through the reservoir. Also, large amounts of energy are stored and must be dissipated or utilized at the outlet. The reservoir loses water by evaporation, and this usually exceeds preproject evapotranspiration losses from the lake area. Siltation usually seals the reservoir bottom, but rising and falling water levels may alter the pattern of groundwater storage due to movement into and out of the surrounding reservoir banks. At high stages, water may seep from the reservoir through permeable soils into neighboring catchment areas and so be lost to the area of origin. Finally, sedimentation takes place in the reservoir and scour occurs downstream.

Although this chapter deals primarily with water supply from reservoirs, it should be pointed out that single-purpose reservoirs are now seldom justified. In many countries, good reservoir sites are becoming scarce, and each site must be developed to optimum efficiency or the resource will be partially lost. The available streamflow should be effectively regulated for the joint use of all needs, whenever feasible.

The joint use of storage for more than one purpose creates problems of storage allocation for the various purposes. While retained in reservoir storage, water may provide benefits to recreation, fish, wildlife, hydropower, and esthetics. Properly discharged from the reservoir, similar benefits are achieved downstream. Other benefits that can be derived from the reservoir are those covered in this chapter, including municipal and industrial water supply, agricultural water supply, navigation, and low-flow augmentation.

In most areas, supplemental storage capacity is required for sediment deposition; otherwise, the yield capability of the reservoir may be seriously diminished during the project's economic life. Sediment storage is determined by estimating the average annual sediment yield per square mile of drainage area from observations in the region and multiplying by the drainage area and the economic life of the project. Trap efficiency of the reservoir is evaluated and the distribution of this estimated volume of sediment is determined, using methods to be described in Volume 12. Sediment surveys within the reservoir during actual operation will establish the reliability of these estimates. Storage allocation levels may then be revised if the sediment surveys show a significant difference between what was projected and what was measured. More complete descriptions of the techniques used to determine reservoir sedimentation will be discussed in Volume 12.

A minimum pool at the bottom of active conservation storage is usually established to identify the lower limit of normal reservoir drawdown. The inactive storage below the minimum pool level can be used for recreation, fish and wildlife, hydropower head, sediment deposition reserve, and other purposes. In rare instances, it might be used to relieve water supply emergencies.

Since the primary function of reservoirs is to provide storage, their most important physical characteristic is storage capacity. Capacities of reservoirs on natural sites must usually be determined from topographic surveys. The storage capacity can be computed by planimetering the area enclosed within each elevation contour throughout the full range of elevations within the reservoir site. Areas at frequent elevation intervals are then read from this curve. The increment of storage between any two elevation contours is usually computed by multiplying the average of the areas at the two elevations by the elevation difference. The summation of these increments below any elevation is the storage volume below that level. An alternative to the "average-end-area method" is the determination of the storage capacity by the conic method, which assumes that the volumes are more nearly represented by portions of a cone. This method will be described in detail in Volume 8. In the absence of adequate topographic maps, cross sections of the reservoir area are sometimes surveyed, and the capacity is computed from these vertical cross sections by use of the formula for the volume of a prism.

Reservoir outlets must be located low enough to withdraw water at desired rates with the reservoir stage at minimum pool. These outlets can discharge directly into an aqueduct or into the river. In the latter case, a diversion dam may be required downstream at the main canal intake.

In order to ensure the physical integrity of the project and to protect downstream areas against disastrous failure, a spillway or other overflow facility is required. Hydrologic aspects of spillway design will be discussed in Volume 3.

Section 4.02. Municipal and Industrial Water Use

In the planning and design of reservoirs for water supply, the basic hydrologic problem is to determine how much water a specified reservoir capacity will yield. Yield is the amount of water that can be supplied from the reservoir to a specified location and in a specified time pattern. Safe (or firm) yield is usually defined as the maximum quantity of water that can be guaranteed with some specified degree of confidence during a specific critical period. The critical period is that period in a sequential record that requires the largest volume from storage to provide a specified yield.

The water requirement of a modern city is so great that a community system capable of supplying a sufficient quantity of potable water is a necessity. The first step in the design of a waterworks system is a determination of the quantity of water that will be required, with provision for the estimated requirements of the future. Next, a reliable source of water must be located and finally a distribution system must be provided. Frequently, water at the source is not fit for drinking, and water-purification facilities are ordinarily included as an integral part of the system. Water use varies from city to city, depending on the population, climatic conditions, industrialization, and other factors. In a given city, use varies from season to season and from hour to hour. Planning of a water supply system requires that the probable water use and its variations be estimated as accurately as possible.

Municipal uses of water may be divided into various classes. According to Linsley and Franzini (reference 4.03), domestic use is water used in homes, apartment houses, etc., for drinking, bathing, lawn and garden sprinkling, and sanitary purposes. Commercial and industrial use is water used by commercial establishments and industries. Public use is water required in parks, civic buildings, schools, hospitals, churches, street washing, etc. Water that leaks from the system, unauthorized connections, and other unaccounted-for water is classified as loss and waste.

The average daily use of water for municipal and industrial purposes is influenced by many factors. More water is used in warm, dry climates than in humid climates for bathing, lawn watering, air conditioning, etc. In extremely cold climates water may be wasted at faucets to prevent freezing of pipes. Water use is also influenced by the economic status of the users. The per capita use of water in slum areas is much less than that in high-class, residential districts. Manufacturing plants often require large amounts of water; however, some industries develop their own water supply and place little or no demand on a municipal system. The actual amount depends on the extent of the manufacturing and the types of industry. Zoning of the city affects the location of industries and may help in estimating future industrial demands. Commercial districts also include office buildings, warehouses, and stores; but the per capita demand in such areas is not high.

About 80 percent of industrial water is for cooling and need not be of high quality, but water used for process purposes must be of good quality. In some cases, industrial water must have a lower content of dissolved salts than can be permitted in drinking water. The location of industry is often much influenced by the availability of water supply. If water costs are high, less water is used and industries will often develop their own supply to obtain cheaper water. In this respect, the installation of water meters in some communities has reduced water use by as much as 40 percent. The size of the city being served is a factor affecting water use. Per capita use tends to be higher in large cities than in small towns. The difference results from greater industrial use, more parks, greater commercial use, and, perhaps, more loss and waste in the larger cities. All of these factors, plus estimated population projections, should be considered in designing a waterworks system.

The use of water in a community varies almost continually. In midwinter the average daily use is usually about 20 percent lower than the daily average for the year, while in summer it may be 20 to 30 percent above the daily average for the year. Seasonal industries such as canneries may cause wide variation in water demand during the year. It has been observed that for most communities the maximum daily use will be about 180 percent of the average daily use throughout the year. Within any day, large variations can be as low as 25 percent to as high as 200 percent of the average for portions of the day. A final factor that must be considered in variations in water use is fire fighting. The annual volume of water used for fire fighting is small; but during fires the rate of use may be quite high, and required flows in residential areas may be as high as 200 ℓ/sec, depending on population density. The daily and hourly variations in water use are not usually considered in reservoir design, since most communities use distribution reservoirs (standpipes, etc.) to regulate for these variations. However, in cases where distribution reservoirs are not used or where their capacities are not large enough to supply the maximum demand, variations should be considered in design of the main supply reservoir and aqueduct.

Section 4.03. Agricultural Water Use

Only about one-third of the earth's surface receives enough precipitation in a normal year to mature food crops, and much of this area is unsuited for agriculture. Accordingly, the need for agricultural water supply is primarily for irrigation. Irrigation can be defined as the application of water to soil to supplement deficient rainfall in order to provide moisture for plant growth. In the United States, about 46 percent of all the water used is for irrigation. Irrigation is a consumptive use; that is, most of the water is transpired or evaporated and is essentially lost to further use.

In planning an irrigation project a number of factors must be considered. The first step would be to establish the capability of the land to produce crops that provide adequate returns on the investment in irrigation works. This involves determining whether the land is arable (land which, when properly prepared for agriculture, will have a sufficient yield to justify its development) and irrigable.

If the area is suitable for irrigation, the next step would be to determine the water requirements. The amount of water required to raise a crop depends on the kind of crop and the climate. The plants that are the most important sources of food and fiber need relatively large amounts of water. The most important climatic characteristic governing water need is the length of the growing season. Other factors that affect water requirements are the quality of the water, the amount of land to be irrigated, and, of course, the cost of the water to the irrigator.

In estimating the amount of storage that will be required in a reservoir for irrigation, the losses and waste that occur in the irrigation system must be considered. Losses and waste are usually divided into conveyance and irrigation losses and waste. Conveyance losses and waste are those that occur in the conveyance and distribution system prior to the application of water to crops. These are dependent on the design and construction of the system and also on how the system is operated and maintained. Irrigation losses and waste are those that occur due to the slope of the irrigated land, the preparation of the land, soil conditions, the method of irrigation, and the practices of the irrigator.

The percentage of delivered water that is available in the root zone for crop growth is called the irrigation efficiency. From many observations and tests performed in the United States, it appears that average irrigation efficiencies range between 30 and 50 percent. Conveyance losses, primarily due to seepage in conveyance canals, have been observed to range from 13 to 48 percent of the flow in the canal and probably average 30 percent for unlined canals. The conveyance waste, which seems to be dependent to a large extent on the availability of water, has been found to range from 1 to 60 percent. An estimate of 15 percent of the total conveyance flow would not be unreasonable if no data are available for a more reliable estimate.

Usually, most of the conveyance losses and waste return to the stream as well as a portion of the water actually applied to the irrigated lands. If there are requirements for flow downstream of the reservoir, these return flows can be important in determining the amount of water that must be released to meet such requirements.

In most areas the need for irrigation water is seasonal and depends on the growing season, the number of crops per year, and the amount of precipitation. For these reasons the variation of the demand is often high, ranging from no water for some months up to 20 to 30 percent of the annual total for other months. This variation can have a very large effect on the amount of storage required and the time of year when it is available. A more complete discussion of these monthly variations will be included in Volume 8.

Section 4.04. Navigation and Low-Flow Augmentation

In designing a reservoir to supply water for navigation and low-flow augmentation, the objective is significantly different from objectives for the other purposes that have been discussed previously in this chapter. The objective is to supplement flows at one or more points downstream from the reservoir. For navigation, these flows aid in maintaining the necessary depth of water and alleviate silting problems in the navigation channel. Low-flow augmentation serves a number of purposes including recreation, fish and wildlife, ice control, pollution abatement, and run-of-river power projects. Under certain conditions, low-flow augmentation provides water for the other purposes discussed in this chapter. For instance, if the intake for a municipal and industrial water supply is at some point downstream of the reservoir, the objective may be to supplement low flows at that point.

There are no absolute criteria for navigability and, in the final analysis, economic criteria control. The physical factors that affect the cost of waterborne transport are depth of channel, width and alignment of channel, locking time, current velocity, and terminal facilities. Commercial inland water transport is, for the most part, accomplished by barge tows consisting of 1 to 10 barges pushed by a shallow-draft tug. The cost of a trip between any two terminals is the sum of the fuel costs and wages, fixed charges, and other operating expenses depending on the time of transit. Reservoirs aid in reducing these costs by providing the proper depth of water in the navigation channel, or by providing a slack-water pool in lock and dam projects. Storage reservoirs can rarely be justified economically for navigation purposes alone and are usually planned as multipurpose projects. Improvement of navigation by use of reservoirs is possible when flood flows can be stored for release during low-flow seasons.

The ideal reservoir operation for navigation or low-flow augmentation would involve releases so timed as to supply the deficiencies in natural flow without waste. This is possible only if the reservoir is at the head of a relatively short control reach. As the distance from the reservoir to the reach is increased, releases must be increased to allow for uncertainties in estimating intermediate runoff and for evaporation and seepage enroute to the reach to be served. Moreover, the releases must be made sufficiently far in advance of the need to allow for travel time to the reach, and in sufficient quantity so, after reduction by channel storage, the delivered flows are adequate. The water requirement for these releases is considerably greater than the difference between actual and required flows. Climate can also affect reservoir operation for low-flow regulation. Depending on the purpose to be served, the releases may be required only at certain times of the year or may vary from month to month. For pollution abatement, the important factors are the quality of the water to be supplemented, the quality of the water in the reservoir, and the quality standard to be attained. Also, the level of the intakes from which releases will be made can be a very significant factor in pollution abatement, since the quality can vary from one level to another in the reservoir. Long-term variations can occur due to increased contamination downstream of a reservoir. This should be considered in determining the required storage in the reservoir.

Section 4.05. Estimation of Water Yield

An essential requirement of the design of any reservoir for water supply is the determination of the yield that can be expected from a specified storage capacity or the storage capacity required to supply a specified demand. Briefly, the problem of determining storage-yield relations might be described as the application of various theoretical and empirical methods to hydrologic data in order to determine the regulating effects of a reservoir project. Although these discussions are intended to relate to single reservoirs, many of the principles are generally applicable to multi-reservoir systems. However, the techniques outlined in Chapter 7 for analysis of a multireservoir system are, as a rule, considerably more complex than those described herein.

If demands for water are relatively simple or if approximate results are sufficient, as in the case of many preliminary studies, a simplified method is often used to save time and effort. However, it should be emphasized that the objective of the simplified methods is to obtain a good estimate of the results that could be achieved by detailed sequential routing studies.

The storage required to produce a given yield with no shortage can be estimated from a sequential mass curve. The technique is often referred to as the Rippl Method. The mass curve is constructed by accumulating the inflows to the reservoirs throughout the period of record and plotting the cumulative inflow as ordinate versus the sequential time as abscissa on arithmetic paper as shown in fig. 4.01. The desired yield rate can be represented by a straight line with a slope equal to the desired yield rate in

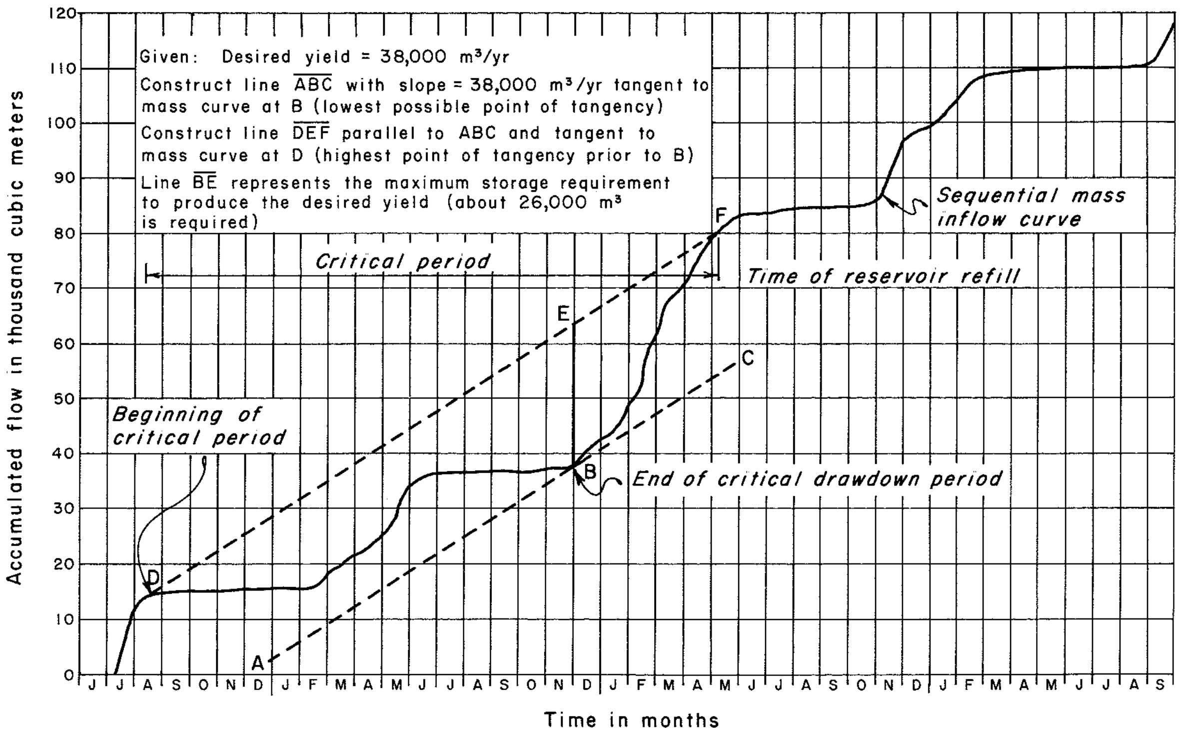


Fig. 4.01. Storage determination using sequential mass curve

unit corresponding to the flow units. Lines are constructed parallel to the desired yield line and tangent to the mass curve at each low point (line $\overline{ABC}$) and at the preceding tangent point that gives the highest tangent (line $\overline{DEF}$). The vertical distance between these two lines (line $\overline{BE}$) represents the storage required to provide the desired yield during the time period between the two tangent points (points D and B). The maximum difference in the period of record is often adopted as the required storage.

Several nonsequential methods can be used for developing a relation for storage yield versus shortage frequency. The application of this procedure is limited, however, to water supply demands that are uniform in time. These methods involve the development of probability relations for varying durations of streamflow. The general procedure is to select a series of extreme low-flow events for a particular duration each year and arrange them in order of magnitude for the period of record. The frequency of each independent minimum-flow rate can then be computed by the methods to be described in Volume 3. If this process is repeated for several different durations, nonsequential mass curves (curves of runoff volume versus duration) can then be constructed for various recurrence intervals. This is done by plotting runoff volume as ordinate against duration as abscissa for a specific return period. In fig. 4.02 for instance, a nonsequential mass curve has been constructed for a 2 percent chance of shortage. To determine the storage requirement, a straight line with a slope equivalent to the required gross yield is plotted tangent to the mass curve. The absolute value of the negative vertical intercept represents the required storage. This procedure is not very reliable for critical durations longer than a year.

An important disadvantage of these simplified types of storage-yield analysis is the inability to evaluate evaporation losses accurately. This may not be critical in humid areas where net evaporation (lake evaporation minus preproject evapotranspiration) is relatively small, but can cause very large errors in studies for arid regions. More important, these procedures are severely limited because they do not permit consideration of seasonal variations in requirements, system nonlinearities, conflicting and complementing service requirements, and several other factors.

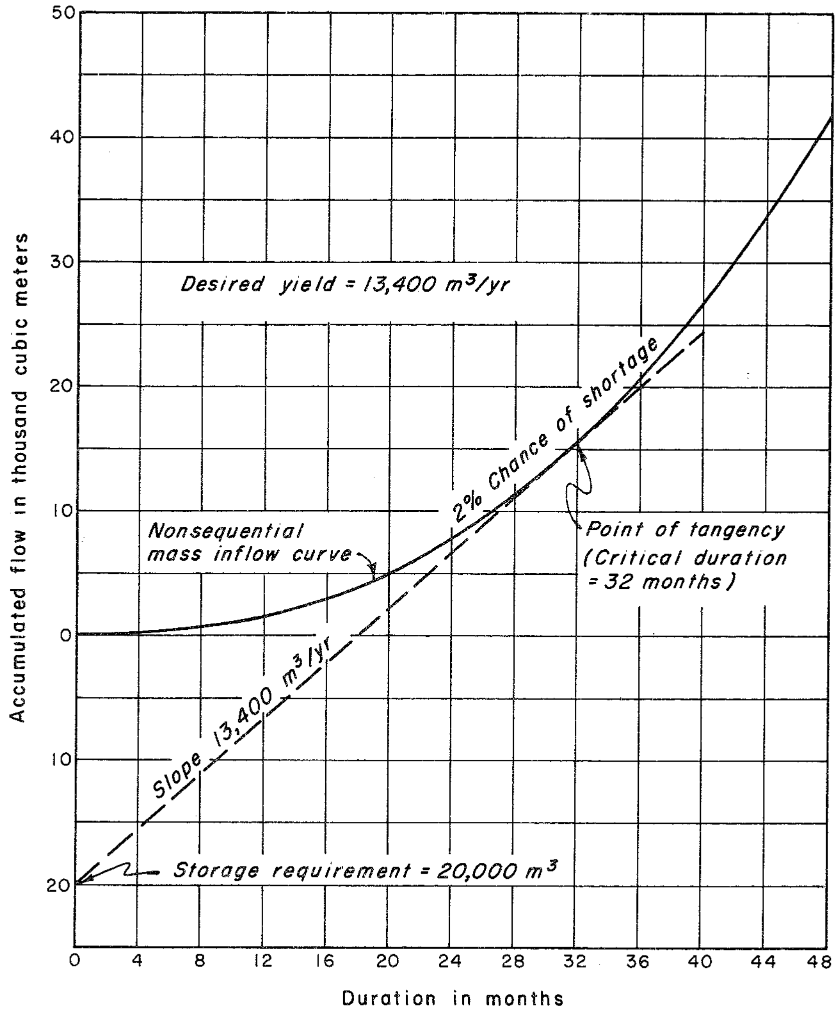


Fig. 4.02. Storage determination using nonsequential mass curve

Section 4.06. Effects of Water Deficiencies

Absolute guarantees of water yield are usually not practical, and the designer should therefore provide estimates of shortages that could reasonably develop in supplying the established demands with available storage. If nonsequential procedures have been used, information on future shortages is limited to the probability or frequency of occurrence, and the duration or severity of shortages will not be known. In using the Rippl Method, no shortages are allowed during the period of analysis, and therefore information is not obtained on the shortages that might be expected in the future. Only in the detailed sequential analysis procedure is adequate information on expected future shortages obtainable.

The amount and duration of shortage that can be tolerated in serving various project purposes can greatly influence the amount of storage required to produce a firm yield. These tolerances vary a great deal for different project purposes and should be analyzed carefully in reservoir design.

One method that has been used to quantify shortages is the shortage index. This index is developed by summing the squares of the shortage ratios for a 100-year period. The shortage ratio is determined by dividing the magnitude of each annual shortage by the annual yield requirement. The shortage index reflects the observation that social and economic effects of shortages are about proportional to the square of the degree of shortage. The advantage of its use is that the social and economic effects of shortages can be evaluated from the index in a simple manner after the hydrologic analysis is complete. Volume 8 will contain a more complete discussion of the shortage index and its use.

Shortages are generally considered to be intolerable for purposes such as drinking water. However, some reduction in the quantity of municipal and industrial water required can be tolerated without serious economic effects by reducing some of the less important uses of water such as lawn watering, car washing, etc. Shortages greater than 10 percent usually cause serious hardship. Most designs of reservoir storage for municipal and industrial water supply are based on supplying the firm yield during the most critical drought of record, with some reserve storage for use in the event of unprecedented droughts.

For irrigation water supply, shortages are usually acceptable under some conditions. Often the desired quantity can be reduced considerably during the less critical parts of the growing season without great crop loss. Also, if there is a reliable forecast of a drought, the irrigator may be able to switch to a crop having less water requirements. Shortages of 10 percent usually have negligible economic effect, whereas shortages as large as 50 percent are usually disastrous.

In designing a reservoir to supply water for navigation or low-flow augmentation, the amount and duration of shortages are usually much more important than the frequency of the shortages. Small shortages might only require rescheduling of deep-draft vessels, whereas large shortages might stop traffic altogether. The same thing is true for such purposes as fish and wildlife where one large shortage during the spawning season, for example, could have serious economic effects for years to come.

Each project purpose should be analyzed carefully to determine what the effects of shortages will be. In many cases, this will be the criterion that determines the ultimate amount of reservoir storage needed for water supply and low-flow regulation.

Section 4.07. Operation Considerations in Water Supply Projects

Many operation considerations affect the service provided by a reservoir for any specific purpose. In addition, many operation requirements are not directly related to any project purpose; these include emergency operations for project safety purposes, operations for mosquito abatement, special operations for eradication of undesirable fish, routine maintenance operations, operations responsive to legal injunctions, and others.

Generally more important are those restrictions that are imposed on one function in order to ensure minimum necessary service for another function. Operation rule curves for flood control or for power generation are examples of this. When minimum services for two functions cannot both be served, relative priorities of service must be implemented. This can be done by allocating storage space to each function and permitting use of that space for that function alone when needed or by using rule curves that depend on the time of year and amount of water in storage.

Allocation of storage space to reservoir conservation functions is an inefficient process and may result in serious hardships and difficult decisions when a high-priority function can no longer be served while a low-priority function still has a reserve of water. On the other hand, if each function is limited to a specified use whenever reservoir storage is at or below a particular rule curve and if a schedule of service reductions is implemented when the reservoir is dangerously low, the overall accomplishment can be maximized.

In addition to regulations governing the emergency spillway operations, which are not directly relevant to this chapter, operation rules usually consist of minimum pool level specification, delineation of a somewhat higher pool level below which services are severely restricted, operation rule curves for power and other individual purposes, and maximum pool levels maintained for flood operations. All of these operation curves can vary seasonally, and it is possible that additional factors such as inflow prediction can be included in the operation rules.

Detailed methods used in formulating the various operation rules will be discussed in Volumes 7, 8, and 9.

Section 4.08. General Study Procedure

After alternative plans for one or more water supply reservoirs have been established, the following steps can be followed in performing hydrologic studies required for each plan:

a. Obtain all available daily and monthly streamflow records that can be used to estimate historical flows at each reservoir and diversion or control point. Compute monthly flows and adjust as necessary for future conditions at each pertinent location. Detailed procedures for doing this will be discussed in Volume 2.

b. Obtain area-elevation data on each reservoir site to be studied and compute storage capacity curves. Determine maximum practical reservoir stage from physiographic and cultural limitations.

c. Estimate monthly evapotranspiration losses from each site and monthly lake evaporation that is likely to occur if the reservoir is built.

d. Determine seasonal patterns of demands and total annual requirements for all project purposes, if applicable, as a function of future time. Synthesize stochastic variations in demands, if significant.

e. Establish a tentative plan of operation, considering flood control and reservoir sedimentation as well as conservation requirements and perform an operation study based on runoff during the critical period of record. The computer program described in Appendix 3 can be used for this purpose.

f. Revise the plan of operation, including sizes of various facilities, as necessary to improve accomplishments and perform a new operation study. Repeat this process until a near-optimum plan of development is obtained.

g. Depending on the degree of refinement justified in the particular study, test this plan of development using the entire period of estimated historical inflows and as many sequences of synthetic streamflows and demands as might be appropriate. Methods for developing synthetic flow and demand sequences will be discussed in Volume 2.

h. Modify the plan of development so as to balance yields and shortages for maximum overall accomplishment of all project objectives.

Chapter 5

Hydroelectric Power Development

CHAPTER 5. HYDROELECTRIC POWER DEVELOPMENT

Section 5.01. Introduction

The primary stimulus for hydroelectric power development as a factor in the overall development of a nation's water resources has been that of revenue production. However, in addition to producing revenue that has traditionally been a major factor in recovering the investments in water resources development, the development of hydroelectric power generating facilities has provided a source of relatively low-cost power that is essential for the stimulation of economic growth and modern social well-being. Because the revenue from hydroelectric power generation is relatively reliable and because it is usually more than adequate to recover the allocated costs associated with the power development, the economic burden imposed by nonrevenue producing beneficial water uses can frequently be reduced. This fact makes hydroelectric power an important partner in multipurpose water resources development. In a developing nation, hydroelectric power may be the key to important social and economic advances as well as the economic foundation upon which an orderly and beneficial water resources development plan can be based.

Besides economic factors, the feasibility of a particular proposed hydroelectric development is dependent upon the need for electric power, the availability of a transmission system to take the power from the point of generation to the points of use, the availability of water from streamflow and storage to produce power in accordance with the capacity and energy demands in the power market area, and the coordination of the power operations of the project with the operations that are necessary to ensure that the other purposes of the project are properly served. Each of these factors must be investigated to ensure that the project is both feasible and desirable and to minimize the possibility that unforeseen conflicts will develop between power and other water uses during the project life.

The ability of a project to supply power is measured in terms of two parameters: capacity and energy. Capacity, commonly measured in kilowatts, is the maximum rate at which work can be done; and energy, often measured in kilowatt-hours, is the amount of work done. Both parameters are important and the operation of a hydroelectric project is sensitive to changes in the demand for either capacity or energy. Experience has indicated that it is very unlikely that the power demands will remain unchanged during the project life. Furthermore, the relative priority of various other water uses can change during the project life, and there are often legal, institutional, social, or environmental factors that might affect the future use of water at a particular project. Consequently, the feasibility studies for a proposed project must not be limited to conditions that are only representative of the current time or the relatively near future. Instead, the studies must include considerations of future conditions that might create irreconcilable conflicts unless appropriate remedial measures are provided for during project formulation.

In the remaining sections of this chapter the hydrologic analyses associated with the planning, design, and operation of hydroelectric projects and systems will be discussed. Other investigations that influence or affect the hydrologic studies will be discussed to the extent that their outcome must be understood by the hydrologic engineer.

Section 5.02. Types of Hydroelectric Development

Power developments, for purposes of this discussion, can be classifiel in two ways--with respect to the type of load served and with respect to the type of site development proposed. The two categories related to the type of load served are baseload plants and peaking plants.

Baseload plants are projects that generate hydroelectric power to meet the baseload demand. The baseload demand is the demand that exists 100 percent of the time. The baseload can readily be seen on a load duration curve such as the annual load duration curve shown in fig. 5.01. This curve shows the percent of time during a given year that a given capacity demand is equaled or exceeded. The area under this curve represents the total energy required to meet the load during the year. Usually the baseload demand is met by thermal generating facilities. However, in cases where there is a relatively abundant supply of water that is available with a high degree of reliability and where fuel is relatively scarce, hydroelectric projects may be developed to meet the baseload demands. These projects would then operate at or near full capacity for 24 hours per day for long periods of time. This type of development is not feasible where there is a large seasonal variation in streamflow unless the baseflow is relatively high or unless there is a provision for a large volume of power storage in the project.

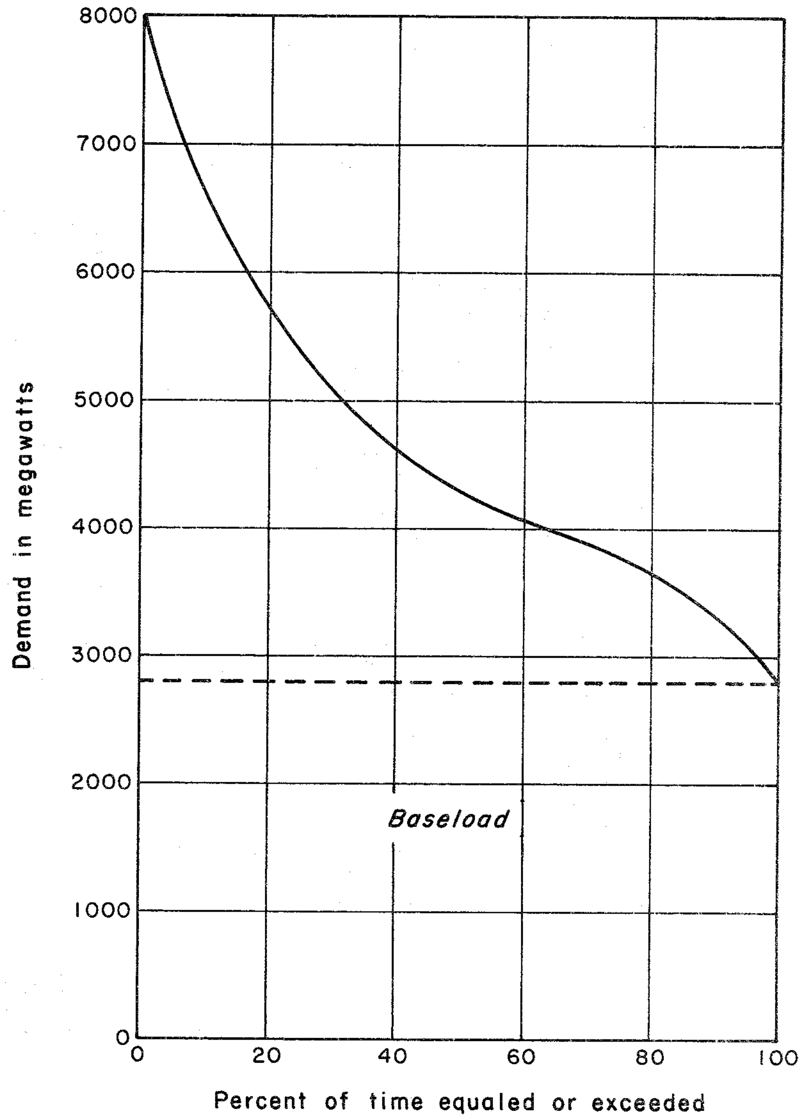


Fig. 5.01. Typical annual load duration curve

Peaking plants are projects that generate hydroelectric power to supplement baseload generation during periods of peak power demands. The peak power demands are the demands that exist primarily during the daylight hours. The time of occurrence and magnitude of peak power demands are shown on a load curve in fig. 5.02; this curve shows the time variation in power demands for a typical week. Depending upon the quantity of water available and the demand, a peaking plant may generate from as much as 18 hours a day to as little as no generation at all. Peaking plants must supply sufficient capacity to satisfy the peak capacity demands of a system and sufficient energy to make the capacity usable on the load, that is, energy or water

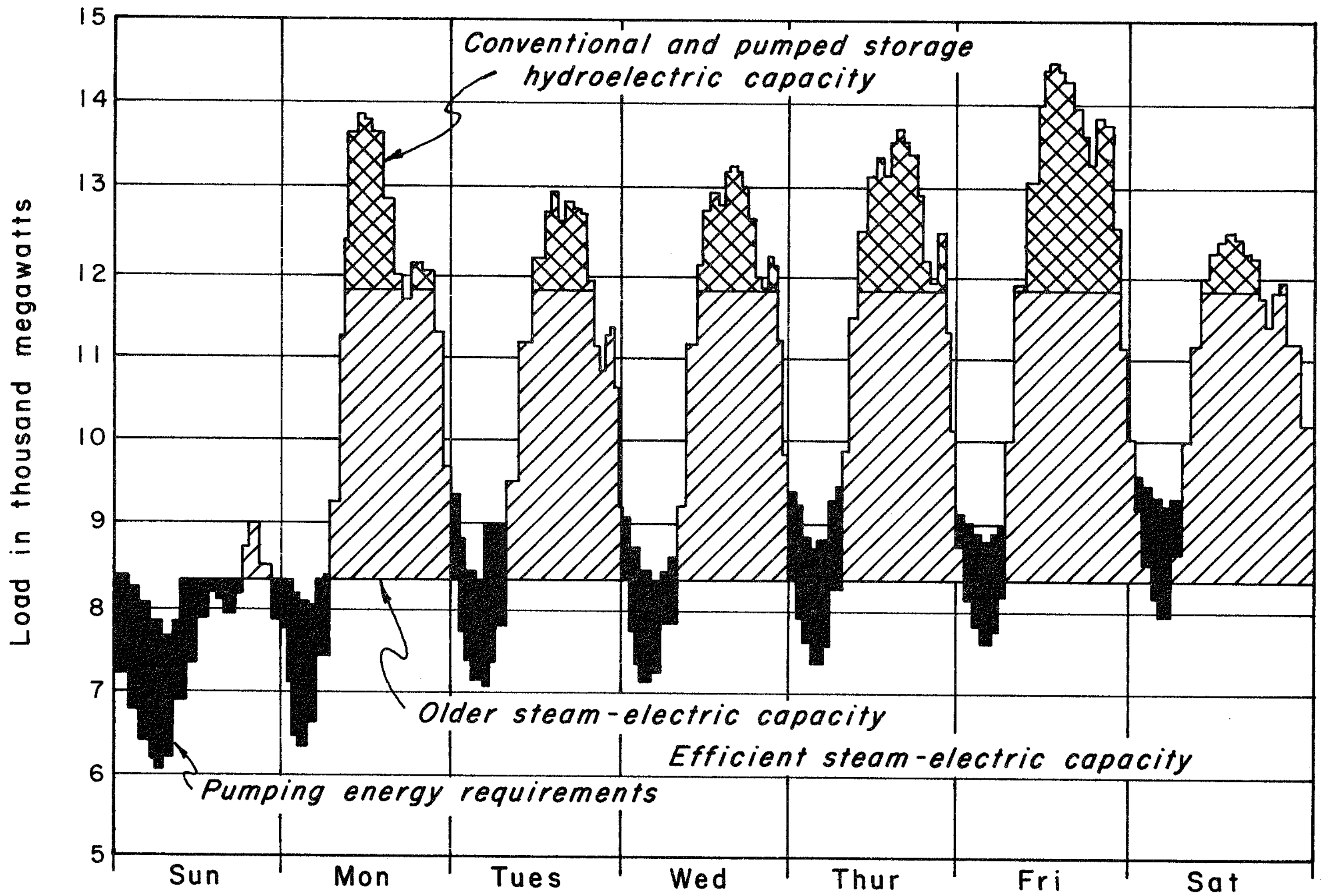


Fig. 5.02. Weekly load curve of a large electric utility system

should be sufficient to supply peaking support for as long and as often as the capacity is needed.

In general, a peaking hydroelectric plant is desirable in a system that has thermal generation facilities to meet the baseload demands. The hydroelectric generating facilities are particularly adaptable to the peaking operation because their loading can be changed rapidly. Also, the factors that make seasonal variations in streamflow a major problem in baseload operation are usually quite easily overcome in a peaking plant if some storage can be provided.

With respect to types of site development, there are three major classifications of hydroelectric projects: storage, run-of-river, and pumped storage. There are also combinations of projects that might be considered as separate classifications, but for purposes of discussing hydrologic analysis it is necessary to define only these three types.

Storage plants are projects that usually have heads in the medium to high range (greater than 25 m) and that have provisions for storing relatively large volumes of water during periods of high streamflow in order to provide water for power generation during periods of deficient streamflow. Considerable storage capacity may be required because the period of deficient flow is quite frequently more than a year long and, in some instances, may be several years long. Since use of the stored water entails drawdown of the power storage, it is desirable that the other water uses associated with the development of a storage plant be such that frequent and severe drawdowns are permissible during dry periods.

Peaking operation, which is quite frequently associated with storage projects, requires large and sometimes rapid fluctuations in releases of water through the generating units; and it is often necessary to provide facilities to reregulate the power releases if fluctuations of water levels below the project are not tolerable. Because storage projects are conducive to multipurpose use and because the power output from a storage plant is a function of the guaranteed output during a multiyear dry period, it is usually necessary to make detailed, complex routing studies to determine the storage requirements, installed capacity and firm energy, and an operating plan. Although these are basically hydrologic studies, they require assumptions and criteria that go far beyond what is normally considered to be hydrology and may require guidance of technical specialists in the fields of power marketing, electric transmission, and hydraulic, mechanical, and electrical machinery.

Run-of-river plants are projects that have little or no power storage and, therefore, must generate power from streamflow as it occurs with little or no benefit from at-site regulation. The projects may be either peaking projects or baseload projects. However, in order for a baseload run-of-river project to be feasible, the stream must have a relatively high base flow. Run-of-river projects generally have productive heads in the low to medium range (5 to 30 m) and are quite frequently associated with navigation developments or other multipurpose developments with limitations on reservoir drawdowns. Because of the absence or near-absence of storage in run-of-river projects, there is usually very little operational flexibility in these projects; and it is necessary that all water uses be compatible. The existence of one or more storage projects in the upstream portion of a river basin may make a run-of-river project in the lower portion of the basin feasible where it would not otherwise be feasible. In this situation, the storage projects provide a regulated outflow that is predictable and usable, while the natural streamflow might be neither.

Run-of-river projects used for peaking operations usually have provisions for a small amount of storage--often called pondage. This pondage is required in order to detain the streamflow during off-peak periods in daily or weekly cycles for use in generating power during peak demand periods. If the cycle of peaking operation is a single day, the pondage requirements are based on the flow volume needed to sustain generation at or near installed capacity for 12 hours. If more storage capacity is available and large fluctuations in the reservoir surface are permissible, a weekly cycle of peaking operation may be considered. Because industrial and commercial consumption of power is significantly lower on weekends than on week days, an "off-peak" period is created from Friday evening until Monday morning. Since generation from the hydroelectric peaking plants is not required during this period, water can be stored in the pondage for use during the 5-day peak-load period.

Because of the relatively low heads associated with run-of-river projects, the tailwater fluctuations are usually quite important--particularly in peaking operations. Although the hydrologic investigations for run-of-river projects are usually not quite as complex as those for storage projects, there are some difficult analyses, such as determination of pondage requirements, that may require extensive study.

Pumped storage plants are projects that depend on pumped water as a partial or total source of water for generating electric energy. This type of project derives its usefulness from the fact that the demand for power is generally low at night and on weekends; therefore, pumping energy at a very low cost will be available from "idle" thermal generating facilities. If there is a need for peaking capacity and if the value of peaking generation sufficiently exceeds the cost of pumping energy (at least 1.5 to 1.0, because about 3 kwhr of pumping are necessary to deliver enough water to provide 2 kwhr of generation), pumped storage might be feasible.

In general, pumped storage projects consist of a high-level forebay where pumped water is stored until it is needed for generation and a low-level afterbay where the power releases are regulated, if necessary, and from which the water is pumped. The pumping and generating are done by generating units composed of reversible pump-turbines and generator-motors located along a tunnel or penstock connecting the forebay and afterbay. The water is pumped from the afterbay to the forebay when the normal power demand is low and released from the forebay to the afterbay to generate power when the demand is high. The feasibility of pumped storage developments is dependent upon the need for relatively large amounts of peaking capacity, the availability of pumping energy at a guaranteed favorable cost, and a load with an off-peak period long enough to permit the required amount of pumping.

There are three types of pumped storage development: diversion, off-channel, and in-channel. The diversion type of development does not recirculate the water between the forebay and afterbay, as described above, because it usually consists of pumping in one basin to a forebay on or near the divide between that basin and an adjacent basin. The water is released through generating units into an afterbay located in the adjacent basin;

thus there is no recirculation of water. The potential advantages of this type of development are that it may be possible to pump against a head that is very small in relation to the head for generating, provided a source of water for pumping can be located at an elevation that is not too far below the forebay. This scheme has the disadvantage that separate pump-motor and turbine-generator units are required, whereas a single reversible unit is used in the other two types of pumped storage development.

The off-channel type of pumped storage development is most feasible when a forebay site exists on a hill or bluff above a stream where an afterbay can be constructed (or above the reservoir of a conventional project). The head differential should be large (greater than 100 m), and the forebay site should be relatively close to the proposed afterbay (less than about 2 km), in order to avoid excessive head loss in the water passages and to reduce construction costs. The forebay site should be impervious or should be geologically suitable for application of an impervious membrane. There must be a site for a powerhouse adjacent to the afterbay, and the geologic conditions must be satisfactory for tunneling to provide water passages. The water supply necessary to support this type of development is not large after the initial supply has been provided. Since the system primarily recirculates the water, it is necessary to provide water only to replace losses due to evaporation and leakage. The off-channel type of development, like the run-of-river project, operates on a daily or weekly cycle. Studies are necessary to determine the forebay storage requirements and size, the pumping energy requirements, the energy generation potential, and the operation plan.

In the in-channel type of pumped storage development the reservoir of a conventional power project is used as a forebay, and some or all of the generating units are of the reversible type. The afterbay could be a reregulation reservoir downstream from the main dam, the reservoir from a downstream project, or a reservoir provided solely to serve as an afterbay. The feasibility of this type of development is increased if either of the former situations exists because the cost of the afterbay is shared with other purposes. However, use of a reregulation reservoir for an afterbay in an in-channel pumped storage scheme frequently increases the storage requirements in the reregulation reservoir. The primary advantage of the in-channel type of development is that pumping is not always required to support the generation from the reversible units as is the case in other pumped storage schemes. In an in-channel pumped storage project the water required to support the portion of the installation that exceeds what would be available in a conventional development is pumped back to the reservoir in its entirety only during the critical period when the entire streamflow and storage are required to support the conventional installation. During the less severe dry periods only part of the water used by the reversible units is pumped into the reservoir, and during periods of high streamflow none of the water is pumped back into the reservoir. This type of pumped storage development is most valuable when there is a large difference between the streamflow quantities in low-flow periods and the average streamflow quantities, because the reversible installation can add substantial installed capacity and firm energy with attendant pumping costs that are far less than what would be incurred with either of the other types of pumped storage development.

Section 5.03. Assessment and Evaluations of Need for Hydroelectric Power

The need for electric capacity and energy in a given region is a function of many factors such as living habits and work schedules of the people served, amount and type of industrial development, and climatic extremes. These factors affect both the magnitude of the need and the types of generating facilities that can be used to meet the needs. The need for power is established by a power market study or survey. The feasibility of a particular hydroelectric project or system is determined by consideration of the needs as established by the survey, availability of transmission facilities, and the economics of the proposed project or projects.

Although forecasts of potential power requirements within a region to be served by a project are not, strictly speaking, hydrologic determinations, they are essential to the development of plans for power facilities and to the determination of project feasibility and justification. The power market survey is a means of evaluating the present and potential market for electrical power in a region. It will account for effects upon energy use and capacity requirements due to such factors as geographic location, natural resources, industrial development, new power uses, changes in economic status, prospective population changes, and national and local objectives relating to the social and environmental well-being of the populace. In the developing countries, the market study must also consider anticipated economic developments, governmental objectives, and the impact that additional electric power might have on the rate and ultimate stage of economic development. Present and future possibilities of supplying the potential market from alternative sources, the availability of surplus power from nearby developments, the possibility of establishing thermal plants that might produce power at competitive rates, and possible future interconnections with existing or planned power grids are other factors that are considered in power market surveys.

The survey must provide a realistic estimate of the power requirements to be met by the project and must show the anticipated rate of load growth from initial operation of the project to the end of its economic life. The survey also provides information regarding the characteristics of the anticipated demands for power. These characteristics, which must be considered in hydrologic evaluations of hydroelectric potential, include the seasonal variation of energy requirements (preferably on a monthly basis), the seasonal variation of capacity requirements (also preferably on a monthly basis), and the range of usable plant factors for hydroelectric projects under both adverse and average or normal flow conditions. The results of a power market survey might be furnished to the hydrologic engineer in the form of load duration or load curves (such as figs. 5.01 and 5.02) showing the projected load growth, the portion of the load that can be supplied by existing generating facilities, and the portion that must be supplied by future additions to the generating system. From these curves the characteristics of planned hydroelectric generating facilities can be determined. Since these data are developed from the needs alone without consideration of the potential for supplying these needs, the next step is to study the potential for hydroelectric development, given the constraints established in the study of needs.

Section 5.04. Estimation of Hydroelectric Power Potential

Traditionally, hydroelectric power potential has been determined on the basis of the critical hydroperiod as indicated by the historical record. The critical hydroperiod is defined as the period when the limitations of hydroelectric power supply due to hydrologic conditions are most critical with respect to power demands. Thus, the critical period is a function of the power demand, the streamflow, and the available storage. In preliminary project planning, the estimates of power potential are often based on a number of simplifying assumptions because of the lack of specific information for use in more detailed analyses. Although these estimates and the assumptions upon which they are based are satisfactory for preliminary investigations, they are not suitable for every level of engineering work. Many factors affecting the design and operation of a project are ignored in these computations, and therefore, detailed sequential analyses of at least the critical hydroperiod should be initiated as early as possible, usually when detailed hydrologic data and some approximate physical data concerning the proposed project become available. Because of the availability of computer programs for accomplishing these sequential routings they can be done rapidly and at a relatively low cost.

Volume 8 will contain discussion of the methods for accomplishing sequential routing studies and information concerning computer programs that are available for use in these studies. The following paragraphs are devoted to the estimation of power potential in preliminary studies and the discussion of assumptions required for the estimates.

The manner in which the streamflow at a given site is used to generate power depends upon the storage available at the site, the hydraulic and electrical capacities of the plant, streamflow requirements downstream from the plant, and characteristics of the load to be served. In theory, the hydroelectric power potential at a particular site, based on repetition of historical runoff, can be estimated by identifying the critical hydroperiod, by obtaining estimates of the average head and average streamflow during this critical period, and by using the data in the equation below to calculate the potential energy available from the project:

$$KWHR = 9.817\ QHTE \qquad (5\text{-}1)$$

where:

Q = average streamflow during critical hydroperiod, m^3/sec

H = average head during critical hydroperiod, m

T = number of hours in critical hydroperiod

E = average overall station efficiency expressed as a ratio

KWHR = energy generated during critical hydroperiod, kwhr

If the critical period has been properly determined, this energy (when converted to the proper time period, such as a year, for evaluation with respect to the needs) will be a good estimate of the energy-production potential of the project under adverse streamflow conditions. However, determination of the critical hydroperiod is not always a straightforward task. The length and severity of the period are dependent upon the characteristics of the load to be served, the type of project, the amount of storage or pondage, the sequence of streamflow during the period, and the constraints imposed by operation for other purposes such as irrigation, flood control, and water supply. Furthermore, there is no universally applicable simple method for calculating the average head and average flow after the critical hydroperiod has been identified.

There are shortcut procedures for estimating average head and average flow, but they can be very misleading if the proposed project is required to operate for purposes other than power, or if the project is to function as an integral part of a larger system. In general, the estimation of power potential requires successive approximations. The approximate nature of the required project is deduced from the physical and hydrologic data at the proposed site and from the characteristics of the power demand. Then the critical hydroperiod is identified, based on the assumed type of project, the approximate power storage or pondage, and the characteristics of the power demand. Finally, the average head and average flow are estimated and the energy potential is calculated from equation 5-1. If the calculated energy is adequate to support the type of project needed to supply power to satisfy the demands and if the estimates all appear to be valid after more detailed investigations that consider important nonpower and nonhydrologic factors, the installed capacity of the project can be assumed and the preliminary formulation can be adopted for detailed study; if not, the erroneous assumptions must be identified and corrected, and the project reformulated.

Marketing considerations usually require that the power potential of a project be evaluated in terms of minimum annual energy or annual firm energy. Since the performance of a storage project during a multiannual dry period cannot be completely evaluated by examining the performance during the minimum year alone (because the operation of the project may be dependent upon the state of the reservoir at the beginning of the year), it is necessary to study the entire critical hydroperiod and to extract the information concerning the minimum-power year. Also, in a peaking project the dependable capacity and peaking capability of the project will be important in establishing the value of the project. A thorough investigation of peaking capability in a storage project necessitates examination of the entire critical hydroperiod, because the variation in reservoir elevation usually controls the time variation of peaking capability and its relation to the projected capacity demands. Also, the dependable capacity, which may be an important marketing consideration for a peaking project, may not occur during the year of minimum energy production. Thus, a study of the minimum year alone, even if an appropriate initial condition could be assumed, would not always yield all of the information that is necessary to determine the feasibility of the project.

Determination of the critical hydroperiod is one of the more difficult tasks associated with the estimation of hydroelectric potential. Obviously, streamflow is an important factor; in fact, the tendency is to define the critical hydroperiod solely through examination of hydrologic records. This should be avoided because other factors such as seasonal variation in power demands and storage for power production are also important. Best results will be obtained when all of these factors are considered, particularly when the storage volume is large in relation to the streamflow volume. Determination of the critical hydroperiod is important because the guaranteed or firm power production of a project is based on the production during the critical hydroperiod. Since the guaranteed energy production is usually a major factor in determining the economic justification and financial feasibility of a project, every effort must be made to obtain estimates that will accurately reflect the potential value of the project.

For projects that are limited to a small amount of storage because of either physical limitations at the site or because of operational limitations, the critical period will ordinarily be directly related to the operational cycle that can be supported by the available storage or pondage. For example, the week of minimum runoff would usually be critical for a project with weekly pondage, and the day of minimum runoff would be critical for a project with only daily pondage. However, because marketing considerations usually require estimates of minimum annual energy production, it is usually necessary to estimate the energy from the minimum annual streamflow in addition to studying the operation of the project during the critical cycle. Also, projects with relatively small storages or pondage frequently have relatively low heads; and since the reservoir elevation does not fluctuate through a wide range, the minimum head (and therefore the peaking capability and dependable capacity) will often be a function of tailwater elevation rather than reservoir elevation. Since high tailwater elevations are associated with high streamflow rather than low streamflow, it may be necessary to study the time variation of flood flows to determine the peaking capability and dependable capacity of a run-of-river project that is operated for peaking demands. The long-term average runoff at a site depends upon the hydrologic conditions upstream of the site. Operation of storage projects at the site or upstream can reduce high flows and increase low flows, but the long-term average flow should not be appreciably affected. Consequently, the average annual energy could be estimated accurately by using the long-term average flow in equation 5-1.

After the critical hydroperiod has been identified, the average head and average flow during the period must be calculated for use in equation 5-1. The average flow during the critical hydroperiod is significantly affected by storage projects at or above a proposed site, and the energy potential during the critical hydroperiod will be erroneous if the average "natural" flow is not adjusted to reflect the use of storage during this period. If a project serves more than one purpose and if, in serving another purpose, some of the storage or streamflow is not available for power production, the average streamflow should be adjusted to reflect the "loss." Losses such as evaporation, leakage, and station use must also be deducted from the available flow before calculating the potential energy. It is frequently necessary to estimate the average annual energy that is available from a project. This can be estimated by using equation 5-1 with the long-term average streamflow and head rather than the critical hydroperiod averages and with T equal to 8760, the number of hours in a year.

The average head for use in equation 5-1 should be the average productive head during the period under consideration. The average productive head is usually based on pool elevation, tailwater elevation, and head loss values that are considered to be representative of the conditions that will exist during the period under study. For estimating average annual energy, it is frequently assumed that the reservoir elevation is at or slightly below the top of the power pool. During the critical hydroperiod, however, it is anticipated that the reservoir storage would be completely utilized, and consequently, estimation of energy during the critical hydroperiod often is based on the reservoir elevation corresponding to the middle of the active power storage range. However, because of certain combinations of power demands and streamflow, this assumption can be in error by as much as 10 to 15 percent.

The tailwater elevation used to compute the average head should be a representative elevation that reflects average tailwater conditions during a time when power generation actually occurs. For example, in a peaking project that usually generates power at or near installed capacity for a short duration, the tailwater elevation should correspond to the discharge at installed capacity rather than to the average discharge. Likewise, if there are releases that do not pass through the generating units but which significantly affect the tailwater, the tailwater elevation should reflect the combination of power releases and other releases.

Use of a project's available energy to generate power at low plant factors (i.e. during a small percentage of the time) can significantly increase the dependable capacity available from the project. If there is a great demand for peaking power, it will frequently be found that the incremental cost of additional capacity at a plant (without increasing total energy output) is much lower than the cost of constructing the same capacity at alternative thermal-electric stations, because the additional cost is limited to the cost of additional penstocks and generating units. Consequently, design for peaking operation usually improves the economics of hydroelectric projects, and some projects have been designed to operate at minimum annual plant factors as low as 5 percent.

Preliminary estimates of hydroelectric power potential are frequently made by use of equation 5-1 with systematically obtained estimates of average head and average flow. These estimates can be based on studies from other projects with similar characteristics or on the judgment of an experienced engineer. In either instance, however, the validity of the estimates should be checked by detailed sequential routing studies for an appropriate time period, usually the critical hydroperiod or the minimum year, whichever is longer. Methods for systematic preliminary estimates and detailed sequential routing studies will be contained in Volume 8 for single projects and Volume 9 for systems of projects.

The concept of using the historical critical hydroperiod as a basis for determining the firm power available from a project is based on the idea that the project will be able to supply at least the firm power throughout its useful life unless a period more critical than the historical critical hydroperiod occurs in the future. Under this concept, the dependability of the firm power is obviously a function of the length of the historical hydrologic record and the length and relative severity of low-flow periods that have occurred during the historical period. If a historical record is relatively short or happens to have included no really adverse conditions, the power potential may be grossly overestimated. On the other hand, if an unusually severe dry period has occurred during the historical record, the potential of the project might be calculated to be far less than what would actually be realized during the project life.

It would appear that some type of probabilistic evaluation of the severity of a given historical critical hydroperiod would be useful in defining the reliability or dependability of the estimated firm power.

Unfortunately, however, the critical hydroperiod severity cannot be measured in terms of flow volume alone (particularly when the period exceeds a year) because the sequence of flows and the time relation between streamflow availability and power demands are also important. Since the critical hydroperiod is a function of a combination of variables rather than a single variable, the problems of statistical evaluation are much more complicated than in the case of, say, peak discharge frequency. Furthermore, the power marketing agencies are often hesitant to state a degree of reliability that would be acceptable for marketing or contracting purposes. These problems have caused the use of the historical critical hydroperiod to be commonly accepted, despite its obvious shortcomings.

The development of stochastic hydrology and the availability of computer programs for studying the operation of projects during critical periods enable the hydrologic engineer to supplement the information contained in the historical hydrologic record through the evaluation of project operation, using synthetic streamflow sequences that are statistically similar to the historical data. The effects of different sequences can be examined, and operation rules can be formulated to minimize the adverse effects of possible critical combinations that were not exhibited in the historical record.

Section 5.05. Functional Design of Power Facilities

When a proposed project reaches the final planning stages or the design stage, it will be necessary to refine the estimates of hydroelectric power potential obtained in the preliminary planning studies. Unless the preliminary studies have been unusually thorough, it is at this time that the first detailed sequential routing studies will be made. At this time, information may be available concerning the types and sizes of water passages, the types and approximate sizes of generating units, the other water uses and their priorities, details of the proposed operation plan, and other physical and hydrologic factors that might affect the power potential of the project. The detailed sequential routing studies might be repeated several times as the project proceeds from the final planning stage through the various design stages. Any major change in project design or in water use should be evaluated with respect to its effect on the estimated power potential.

In addition to the effect of other factors on power, there is a need to define the effect of power facilities on the overall design of the project. For example, the settings of the turbines will affect the excavation quantities in the vicinity of the powerhouse and will also require examination of foundation conditions, the number and size of generating units and hence the unit spacing will influence monolith widths in the dam if the powerhouse is of the integral type, and the critical head or minimum operating head for the turbines may act as a limit on the drawdown in the reservoir. These and other design problems may require special power studies or may require special evaluation of the results of studies made for other purposes. The hydrologic engineer should be aware of the need for studies to establish design criteria so the studies can be organized in a way that minimizes the number of studies.

The design of the powerhouse and the generating units is not a function of the hydrologic engineer, but the data developed from hydrologic studies are the foundation for the work of structural, mechanical, and electrical engineers and for the turbine and generator manufacturers. The two important design parameters that affect the design of almost all power facilities and that are a direct result of the hydrologic investigations are the design output and the design head. The design output for the generating units is determined from the station installed capacity and the number of generating units. The design head is based on the range of operating heads expected for the project.

By the time the design criteria are required, several analyses of hydroelectric potential have probably been made. As the final planning and initial design proceed, many of the physical dimensions of the project are established. When the physical dimensions are well enough defined, a final selection of hydroelectric installed capacity can be made, based on the nature of the project and the power demands that will be served by the project. After the station installed capacity has been determined, it is necessary to determine the type, number, and size of the generating units.

The type of unit is primarily dependent upon the operating head. For heads above about 250 m the Pelton wheel has been used extensively. For operating heads in the range of 15 to 300 m (and even somewhat higher in recent years) the use of Francis reaction-type turbines has been common. For lower heads (30 m or less) propeller-type turbines such as the Kaplan units are used. In order to develop more economically the power potential at sites with heads in the range of 5 to 12 m, new designs of hydraulic turbines have been developed. These units provide for horizontal or inclined-axis axial flow, and the turbines are either of the bulb or tubular type. In some proposals, the generator is connected to the turbine through a speed increaser that permits reducing the physical size and cost of the generator.

The number and size of generating units are dictated by both economic and operational considerations. In general, the unit cost of an installation decreases as larger capacity units are used in place of more units of a smaller capacity. However, construction problems and transportation difficulties create an upper limit on the size of units. Furthermore, operational flexibility, particularly for peaking operations, is improved when there are several small units instead of one or two large ones. Since there are no "standard" turbine and generator sizes, each generating unit is designed on an individual basis to meet the specifications of the project owner. Although this practice appears to permit the owner to specify whatever is required, it is usually advisable to consult with one or more turbine and generator manufacturers before adopting a size of generating unit.

Hydraulic turbines are usually designed to operate near their best efficiencies when generating the design output at the design head. The criteria for selecting a design head at a given site are not standardized. Usually the design head is specified as either the long-term average head or the average head during the critical hydroperiod. Using the long-term average head as the design head will usually maximize the long-term efficiency and thus guarantee the maximum energy production from the available water. In some cases (particularly in arid and semiarid regions that are characterized by extreme seasonal variations in streamflow), it is desirable to set the design head equal to the average head during the critical hydroperiod. This is generally lower than the long-term average head. The rationale for such a decision is that this design will provide better efficiencies during dry periods when streamflows are very low. Thus, long-term efficiency is sacrificed to improve the efficiency during the time of minimum streamflow and thereby increase the dependable firm energy. This also lowers the minimum operating head, which is a function of the design head, thereby permitting a larger drawdown if other uses are not adversely affected. However, this practice reduces the maximum operating head as well, because it, too, is a function of the design head. If flood-control releases are to be made through the power units and if the flood-control storage occupies a relatively large vertical segment of the reservoir, the design head must not be lowered so far as to make operation of the power units impossible in the upper ranges of flood-control storage. According to a publication of the U. S. Bureau of Reclamation (reference 5.04) some approximate maximum and minimum limits, expressed as percentages of design head, are as follows: 125 to 65 percent range for Francis units, 110 to 90 percent for the fixed-blade units, and 125 to 65 percent for adjustable-blade propeller units.

Section 5.06. Effect of Power on Other Project Purposes

Usually power generation must have a high priority relative to other conservation uses. Consequently, thorough investigations of all aspects of the power operation must be conducted to ensure that the power operations do not create intolerable situations for other authorized or approved water uses. Likewise, the power operations must be coordinated with other higher priority purposes such as flood control and municipal water supply to ensure that the planned power operation will not interfere with the operations for these purposes. The operation rules that are necessary to effect the coordination are usually developed and tested by use of engineering judgment and detailed sequential routing studies as described in the following section. However, it is necessary to define the interactions between power and other project purposes before initiating operation studies.

Power generation is generally compatible with most purposes that require releases of water from a reservoir for needs at a downstream location. On the other hand, power generation usually competes with purposes that require withdrawal of the water directly from the reservoir or that restrict fluctuations in the reservoir level. Flood-control requirements frequently conflict with power operations because flood-control needs may dictate that storage space in a reservoir be evacuated at a time when it would be beneficial to store water for use in meeting future power demands. Furthermore, when extensive flooding is anticipated downstream from a reservoir project, it may be necessary to curtail power releases to accomplish flood-control objectives. On the other hand, it is often possible to pass part or all of the flood-control releases through the generating units, thereby reducing the number of additional outlets needed and significantly increasing the energy production over what would be possible if the flood-control releases were made through conduits or over the spillway. Also, many of the smaller floods can be completely regulated within the power drawdown storage, an operation that is beneficial to power because it provides water for power generation that might otherwise have been spilled. This joint use can reduce the exclusive flood-control storage requirements and also reduce the frequency of use of flood-control facilities.

Water for municipal, industrial, or agricultural use can be passed through the generating units with no harmful effects if the point of withdrawal for the other use is below the point where the power discharge enters the river. Only when the withdrawal for other uses is directly from the reservoir is there a conflict between power and these consumptive uses. When the withdrawal is from the reservoir of a storage project, the inclusion of power as a project purpose may require that special attention be given to intake facilities for the other purposes because of the relatively large drawdown associated with storage projects.

Low-flow augmentation for navigation or for most other purposes can be accomplished by releases through power generating units. In the case of baseload projects, the power release is ideally suited for this type of use. In the case of peaking projects, however, a reregulation structure may be necessary to provide the relatively uniform releases that might be required for navigation or for in-stream recreation. Release of water for quality enhancement can sometimes be accomplished through the generating units. Although the intakes for the turbines are usually located at a relatively low elevation in the reservoir, where dissolved oxygen content might be low, the oxygenation that occurs in the tailrace and in the stream below the project may produce water with an acceptable dissolved oxygen content. Since the water for power generation is usually drawn from the lower levels of the reservoir, it is normally at a relatively low temperature and thus ideal for support or enhancement of a cold-water fishery downstream. If warm waters are needed for in-stream recreation, for fishery requirements, or for any other purpose, a special multilevel intake may be required to obtain water of the desired temperature.

Recreation values at a project with power can be enhanced somewhat by inclusion of power because a much larger reservoir is frequently required, with opportunities for extensive recreational activities of all types. Unfortunately, however, the large drawdowns associated with the big storage projects create special problems with respect to location of permanent recreation facilities and may create "mudflats" that are undesirable from the standpoint of esthetics and public health requirements. The drawdown may also expose boaters, swimmers, and other users to hazardous underwater obstacles unless provisions are made to remove these obstacles to a point well below the maximum anticipated drawdown. Obviously the time of occurrence of extreme drawdown conditions is an important factor in determining the degree of conflict with recreation activities.

Section 5.07. Operation of Water Resource Projects with Power Facilities

As implied in the previous section, the operation requirements for a multipurpose project with a power installation can be very complex. The development of operation rules and guides that provide water for each purpose in the quantities and qualities needed for the purpose and at the time it is needed is a task that taxes the ability and judgment of the most experienced engineer. Although an experienced engineer may be able to formulate a set of operation plans that appears to be adequate, such plans should be thoroughly tested.

As in the case of water supply studies, the usual method for testing an operation plan is to simulate the operation of the project under the plans for the entire period of hydrologic record or for one or more periods that are believed to be representative of the range of hydrologic conditions that might be experienced during the life of the project. The simulation usually takes the form of a sequential routing study such as is used to verify and refine estimates of hydroelectric potential. Ordinarily a set of rules would be formulated from consideration of the various project purposes, their relative priorities, and the known or anticipated interactions among the purposes. This set of rules would be tested in the sequential routing study, and by analyzing the results, the effects of the proposed rules can be determined. If there are undesirable results for any purpose or if the rules appear to be inadequate, a new set of rules is formulated, using the knowledge gained from the results of the first study. The process of testing, evaluating, and reformulating is repeated until a satisfactory set of operation rules is developed. These rules would then be adequate if the conditions that will prevail during the project life are accurately represented by the hydrologic data used in the study, if the priority of uses does not change, and if none of the other factors associated with the assumptions and criteria used in the study are changed. Obviously this will not be the case, and it will be necessary to periodically update the operation rules to reflect new hydrologic information and changes in the operational objectives.

The sequential routing techniques to be described in Volume 8 are used for operation studies, but these studies are usually much more complex than the studies to estimate hydroelectric potential. In the latter studies, assumptions are made to simplify the analysis because data are not always available and because much less is known about the physical dimensions of the project and about the exact nature of some of the operation constraints. Legal, social, environmental, economic, and political constraints that could not possibly have been foreseen in the planning studies are now realities and must be considered if the operation rules are to be usable.

The development of assumptions and criteria for use in the operation studies is a major task. Many of the factors that are important in actual operation cannot be quantified explicitly, and some factors cannot be quantified at all. Yet, in order for the project to accomplish the objectives that the studies indicate are possible, the intangibles must be considered--at least implicitly. In many cases the joint operation for several purposes simultaneously, which seemed to be so agreeable in principle during the planning stages, evolves into a near-impossibility when the realities of operation are taken into account. The key to development of good operation policies for a multipurpose project is the use of a good sequential routing study that simulates all important aspects of the project and its purposes with a high degree of fidelity.

Section 5.08. Power System Considerations

When several projects in a region are to be interconnected or when a system of several projects is planned, special studies of the integrated operation of the projects must be conducted to maximize the benefits of the proposed system. System operation implies that all projects that are considered to be part of a system will be operated in such a way as to meet system demands rather than (or in addition to) individual project demands. In this type of operation, at-site maximum and minimum operation constraints may be used to limit the range of operation of each project in meeting the system demands; and there may also be demands that can only be satisfied by certain projects. The fact that such constraints exist does not preclude an effective system operation for hydroelectric power generation or for any other beneficial water use.

The benefits of system operation are that more usable output can usually be realized than could be realized from the individual components operated independently, the system output is more reliable than any of the individual outputs, there is more operational flexibility for use in the event of unforeseen contingencies, and some components can be justified (economically and otherwise) that would not be justifiable as separate projects. The disadvantages of system operation are that the effects of failure of the system are potentially more disastrous than the failure of one or more components would be and that the rules for operating such a system are more complex and, therefore, more difficult to develop, test, evaluate, and implement.

The gain in output from system operation is due to hydrologic diversity that exists even in relatively small regional areas. Because of this diversity, critical conditions do not occur simultaneously everywhere in the system. If a group of projects is operated independently, each project is limited in the output that can be realized under the critical conditions that it experiences, and the sum of the outputs will be representative of what would be expected if critical conditions existed everywhere simultaneously. In system operations, because of the diversity that usually exists, projects that are not experiencing critical conditions can carry the system while projects that are in a critical condition function at a barely acceptable level. The situation changes as the location of critical conditions changes, and the operation objective is that each project contribute to meeting the system demands to the maximum extent possible, considering the relative severity of the hydrologic conditions at that location.

The increase in reliability is due to the fact that the probability of adverse streamflow conditions over a very large region is less than the probability of an equally adverse condition over each subregion. However, it should be noted that if the widespread streamflow deficiency does occur, the loss due to failure of the system will probably be much greater than the losses at individual projects would have been.

The feasibility of system power operation depends upon the existence of a transmission grid to interconnect the projects. If such a grid exists and if the individual lines are sized to permit supplying relatively large portions of the system power demands from any component in the system, the possibility of system operation should be investigated. In the case of adding a new project to an existing system, the planning problem is changed somewhat because the problem is to study the ability of the new system to meet the greater power demands rather than to define the potential of the individual project. In other words, the effect of adding the project to the system must be evaluated; and the installation will then be based on what is needed to complement the system rather than what would have been needed on an at-site basis. The energy and capacity resulting from the project are reflected in the increase in system energy and capacity rather than on the actual at-site values.

In developing operation plans for a system of hydroelectric projects, consideration must be given to the physical interrelations among the projects as well as to the less tangible aspects of system operation. Operation constraints that reflect the physical limitations such as transmission limitations, channel capacities, and diversion and outlet capacities must be developed. Furthermore, techniques must be developed for guiding operation decisions concerning generation of power or withdrawal of water from one or more of the reservoirs in the system. These techniques must be based on consideration of the many possible states of the various components in the system and the combinations of hydrologic events and system states that might reasonably be expected to occur during the life of the system. These operation guides, called system guide curves or system rule curves, have been developed in the past by sequential analysis of system operation over the period of historic hydrologic record as will be described in Volume 9. However, because of the possibility of nonrepresentativeness of the historical data and because of the possibility of developing rules with a built-in historical bias, consideration has been given in recent years to the use of stochastic hydrologic data in developing system operation rules. The stochastic data could be used in the original development of the rules or in testing rules developed from historical data. In either case, the likelihood of built-in historical bias would be minimized.

Section 5.09. General Study Procedure

The study procedure for planning, design, and operation of hydroelectric developments can be summarized as follows:

a. From an assessment of the need for power generation facilities, obtain information concerning the feasibility and utility of various types of hydroelectric projects. This assessment could be made as part of the overall study for a given project or system, or it could be available from a national, regional, or local power authority.

b. From a review of the physical characteristics of a proposed site and a review of other project purposes, if any, develop an estimate of the approximate amount of space that will be available for either sole- or joint-use power storage. This determination and the needs developed under step "a" will determine whether the project will be a storage, run-of-river, or pumped storage power project and whether it will be operated to supply demands for peaking or for baseload generation.

c. Using information concerning seasonal variation in power demands obtained from the assessment of needs, and knowing the type of project and the approximate storage usable for power production, determine the historical critical hydroperiod by review of the historical hydrologic data.

d. An estimate of potential hydroelectric energy for the assumed critical hydroperiod is made using equation 5-1. If the energy calculated from this equation is for a period other than the basic marketing contract period (usually a calendar year), the potential energy during the critical hydroperiod should be converted to a firm or minimum quantity for the contract period (minimum annual or annual firm in the case of a calendar year).

e. Since the ability of a project to produce hydroelectric energy and peaking capacity is a complex function of the head, the streamflow, the storage, and operation for all other purposes, the energy estimate obtained in step "d" is only an approximation. Although this approximation is useful for planning purposes it should be verified by simulating the operation of the project for all authorized purposes by means of a sequential routing study. This analysis should be conducted in the final planning phases or early design phases. Methods to be described in Volume 8, "Reservoir Yield," are used in performing and analyzing sequential routing studies.

f. From the results of detailed sequential routing studies, the data necessary for design of power generating units and power-related facilities of the project should be developed. The design head and design output of the generating units, approximate powerhouse dimensions, approximate sizes of water passages, and other physical dimensions of the project depend on the power installation.

g. Operation rules for the project must be developed before construction is completed. These rules are developed and verified through sequential routing studies that incorporate all of the factors known to affect the project's operation. For many multipurpose projects, these operation rules are relatively complex and require the use of computerized simulation models to facilitate the computations involved in the sequential routing studies.

h. If the project is to be incorporated into an existing system or if the project is part of a planned system, system operation rules must be developed to define the role of the project in supplying energy and water to satisfy the system demands. These rules are also developed and tested by use of sequential routing studies. Sequential routing studies for planning or operation of hydroelectric power systems are best accomplished through the use of a computer program such as the one described in Appendix 3. Some of the particular considerations involved in system studies will be discussed in Volume 9, "Reservoir System Analysis."

Chapter 6

Multipurpose Reservoirs

CHAPTER 6. MULTIPURPOSE RESERVOIRS

Section 6.01. Hydrologic Planning of Multipurpose Projects

Multipurpose reservoir projects were originally conceived as projects that served more than one purpose independently and that would effect savings through the construction of a single large project instead of two or more smaller projects. As the concept developed, the joint use of water and the joint use of reservoir space were added as multipurpose concepts. Even such competitive uses as flood control and water supply would use the same reservoir space at different times during the year.

The feasibility of multipurpose developments is almost wholly dependent upon the demonstrated ability of a proposed project to serve several purposes simultaneously without creating conditions that would be undesirable or intolerable for one or more purposes. In order to demonstrate that multipurpose operation is feasible, detailed analyses of the effects of various combinations of streamflows, storage levels, and water requirements are required. Unfortunately, detailed analyses of these factors are not usually completed until they are necessary for developing an operation plan, because the analyses are complex and because the simplified methods commonly used in planning studies generally do not permit consideration of the factors that are important in these analyses. However, ignoring the details of multipurpose operation in the planning phase is risky because the operation criteria are the primary factors in determining the feasibility of serving several purposes simultaneously.

One of the factors that make detailed sequential analyses of multipurpose operation difficult during planning studies is that sufficient data on various water demands are either not available or not of comparable quality for all purposes. In order to adequately define the multipurpose operation, the analyses must include information on the magnitude and seasonal variations of each demand, long-term changes in demands, relative priority of each use, and shortage tolerances. Information on magnitude and seasonal variation in demands and on long-term variations in demands is usually more readily available than information on relative priorities among uses and on shortage tolerances. If information on priorities and shortages is not available from the various users, one method for obtaining the information is to make several assumptions concerning the priorities and to perform sequential routing studies for each set of assumptions. By using the results of these studies to determine the consequences of various priorities to potential water users, it may be possible for the potential users to adopt a priority arrangement based on the value of the water for the various demands.

Obtaining the relative priorities for the various uses and knowing the characteristics of the demands are important, but the success of multipurpose operation depends on the formulation of operation rules that ensure that water in the proper quantities and qualities is available for each of the purposes at the proper time and place. Techniques for formulating operation rules are not fixed, but the logical approach involves determining the seasonal variation of flood-control space requirement and the seasonal variation of conservation requirements, formulation of general operation rules that satisfy these requirements, and detailed testing of the operation rules to ascertain the adequacy of the plan for each specific purpose.

The judgment of an experienced hydrologic engineer is invaluable in the initial formulation and subsequent development and testing of operation rules. Although the necessary rules cannot be completely developed until most of the physical dimensions of the project are known, any tendency to discount the importance of operation rules as a planning variable should be resisted because of the important role they often assume in the feasibility of multipurpose projects. As a minimum, the operation rules used in a planning study should be sufficiently refined to assist the engineer in evaluating the suitability of alternative projects in realistically satisfying water demands for various purposes.

Section 6.02. Relative Priorities of Project Functions

As indicated in the previous paragraphs, the use of operation rules based on the relative priorities among the various purposes appears to offer the best type of solution to multipurpose operation problems. The degree of success that can be realized depends on a realistic priority system that accurately reflects the relative value of water from the project for a given purpose at a given time. Unless a realistic priority system is used to develop the operation rules, it will not be possible to follow the rules during the project life because the true priorities may control the operation decisions and prevent the project from supplying the services it was designed to provide.

Priorities among the various water resource purposes vary with locale, with water rights, with the need for various types of water use, with the legal and political considerations, and with social, cultural, and environmental conditions. Although these variations make it impossible to specify a normal or general priority system, it might be useful to identify a set of priorities that would be typical under average conditions. In such a situation, operation for the safety of the structure would have highest priority unless the consequences of failure of the structure are minor (which is seldom the case). Of the functional purposes, flood control must have a high priority, particularly where downstream levees, bridges, or other vital structures are threatened. It is not unusual for conservation operations to cease entirely during periods of flood activity if a significant reduction in flooding can be realized thereby. Among the conservation purposes, municipal and industrial water supply and hydroelectric power generation are often given a high priority, particularly where alternative supplies are not readily available. Navigation and irrigation may receive a somewhat lower priority, and water-quality management and other low-flow augmentation priorities would be somewhat lower yet, because temporary shortages are usually not disastrous. Finally, recreation and esthetic considerations would usually have the lowest priority, although these functions sometimes warrant higher priorities. It should be emphasized again that: there can be marked exceptions in the relative priorities as listed above, there are regional differences in relative needs, and legal and institutional factors may greatly affect priorities.

Section 6.03. Managing Competitive and Complementary Functions

As indicated in Chapters 4 and 5, there are many instances where the joint use of storage in a reservoir or of a release from a reservoir is beneficial for all purposes affected. There are also cases where these joint uses adversely affect one or more purposes. Before operation rules can be formulated, the beneficial (complementary) interactions and the adverse (competitive) interactions must be identified. The time of occurrence of the interactions is often as important as the degree of interaction, particularly if one or more of the water uses has significant variations in water demand. In supplying water from a single reservoir for several purposes with seasonally varying demands, it is not uncommon for the services for purposes that would normally be complementary to become competitive at times because of the differences in the seasonal requirements for the various purposes.

When several purposes are to be served from a single reservoir, it is possible to allocate space within certain regions of the reservoir storage for each of the purposes. This practice derived from projects that served only flood control and one conservation purpose, where it was necessary to reserve a portion of the reservoir storage for storing floodwaters. It is still necessary to have a specific allocation of flood-control storage space (although the storage reservation can be allowed to vary seasonally to reflect the seasonal variation in flood potential) because of the basic conflict between reserving empty storage space for regulating potential floods and filling storage space with water to guard against potential droughts. However, applying this practice of specific storage allocations or reservations where several conservation purposes are competing for storage space should be avoided if optimum overall project accomplishments are desired.

Allocation of specific storage space to several purposes within the conservation pool can result in operation conflicts that might make it impossible or very costly to provide water for the various purposes in the quantities needed and at the time they are needed. The concept of commingled or joint-use conservation storage for all conservation purposes with operation criteria to maximize the complementary effects and minimize the competitive effects is far easier to manage and, if carefully designed, will provide better service for all purposes. Where the concept of joint-use storage is used, the operation criteria can be studied in the planning process in such a way that the relative priorities of the various purposes are taken into account. This enables engineers and planners to carefully evaluate a number of priority systems and operation plans, whereas specific storage allocations would not permit flexibility in operation and can result in legal or institutional disputes during the project life. The operation decisions that result from such disputes are frequently not studied in enough detail (from the engineering point of view), and as a result, the ability of the project to serve some purposes may be seriously affected.

Section 6.04. Operation Techniques

There are five basic divisions of reservoir space that can be used in operating a reservoir for various functions. The category that is highest in the reservoir is that space reserved at any particular time for the control of floods. Whenever water is in this space, it must be released in accordance with flood-control requirements. The next three categories of the remaining space can be designated as conservation space. The top category of conservation space is that which exceeds the amount of storage usable to satisfy the firm conservation demands, which include recreation use of the reservoir. Water in this space can be released as surplus to serve needs or uses that exceed basic requirements. The middle category of conservation space is that needed to store water to supply firm water needs. The bottom category of conservation space can be termed buffer space, and when there is empty space in this category, the firm services are curtailed in order to prevent a more severe shortage later. The bottom category of space in the reservoir is designated as the minimum pool reserved for sedimentation, recreation, power head, and other storage functions.

The boundaries between storage zones may be fixed at a constant level or they may vary seasonally as shown in fig. 6.01. In general, the seasonally varying boundaries offer the potential for a more flexible operation

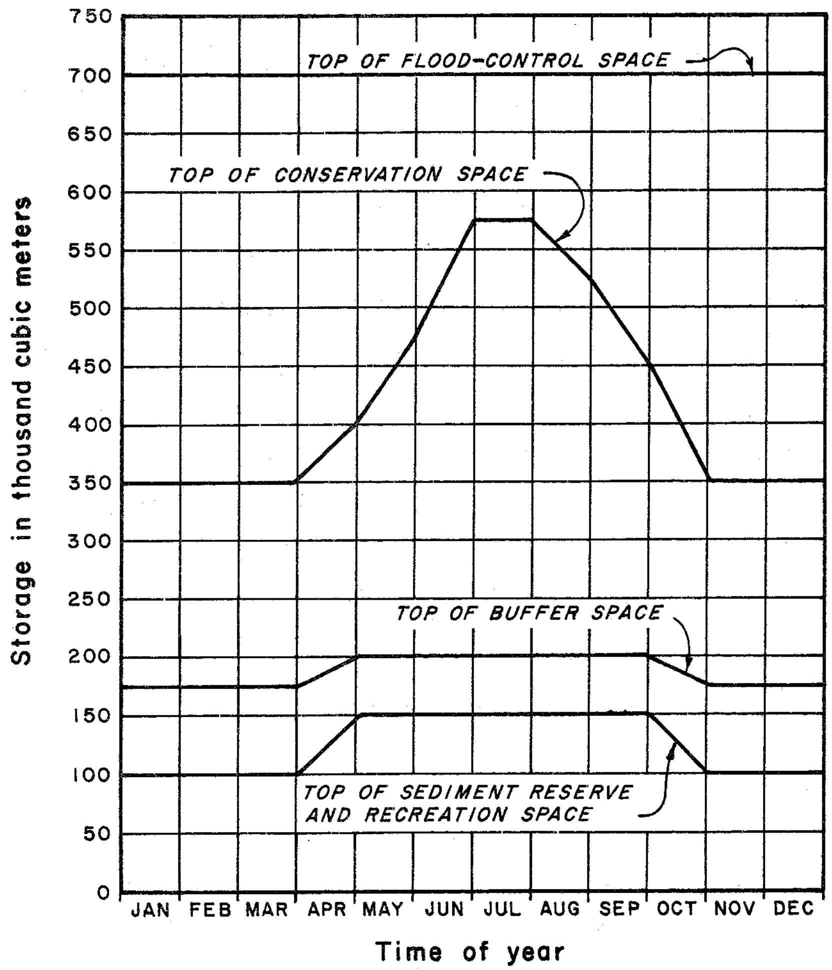


Fig. 6.01. Illustrative example of seasonally varying storage boundaries

plan that can result in higher yields for all purposes. However, the proper location of the seasonal boundaries requires more study than the location of a constant boundary. Furthermore, an additional element of chance is introduced when the boundaries are allowed to vary, because joint use of storage might endanger firm supplies for one or more specific purposes. The location of the seasonally varying boundaries is determined by a process of formulating a set of boundaries and attendant operation rules, testing the scheme by a detailed sequential routing study, evaluating the outcome of the study, changing the rules or boundaries if necessary, and repeating the procedure until a satisfactory operation results.

Expressing demand schedules as a function of the relative availability of water is another means of incorporating flexibility and relative priority in operation rules. For example, the balance between hydro and thermal power generation might well be a continuous function of available storage. As another example, it might be possible to have two or more levels of navigation service or lengths of navigation season with the actual level of service or length of season being dependent upon the availability of water in the reservoir. By regulating the level of supply to the available water in the reservoir, users can plan emergency measures that will enable them to withstand partial reductions in service and thereby avoid complete cessation of service, which might be disastrous. Terms such as desired flow and minimum required flow for, say, navigation can be used to describe levels of service.

There can be as many levels of service as a user desires, but each level requires criteria for determining when the level is to be initiated and when it is to be terminated. The testing and development of the criteria for operating a multipurpose project with several purposes and several levels of service are accomplished by detailed sequential routing studies. Since the development and testing of these criteria are relatively difficult, the number of levels of service should be limited to the minimum number needed to achieve a satisfactory operation plan.

Buffer storages or buffer zones are regions within the conservation storage where operation rules effect a temporary reduction in firm services. The two primary reasons for temporarily reducing services are to ensure service for a high-priority purpose while eliminating or curtailing services for lower-priority purposes, and to change from one level of service for a given purpose to a lower level of service for that same purpose when storage levels are too low to ensure continuation of firm supplies for all purposes. As with the other techniques for implementing multipurpose operation, the amount of buffer storage and the location of the boundaries cannot be determined accurately except by successive approximations and testing by sequential routing studies.

Section 6.05. Construction and Physical Operation

In addition to hydrologic determinations discussed above, a number of important hydrologic determinations are required during project construction and during project operation for ensuring the integrity of the project and its operation.

Of primary concern from a hydrologic standpoint during construction are cofferdam and diversion conduit provisions. If a cofferdam used for dewatering the work area is overtopped, serious delays and additional construction costs can result. In the case of high cofferdams where substantial pondage occurs, it is possible that failure could cause major damage in downstream areas. Cofferdams should be designed on the same principles as are permanent dams, generally on the basis of balancing incremental costs against incremental benefits of all types. This will require flood frequency and hypothetical flood studies, as described in Chapters 2 and 3. Where major damage might result from cofferdam failure, a standard project flood or even a probable maximum flood may be used as a primary basis of design.

Where a major dam embankment may be subject to overtopping during construction, diversion conduit capacity must be sufficient to regulate floods that might occur with substantial probability during the critical construction period. It is not necessary that the regulated releases be nondamaging downstream, but it is vital that the structure remain intact.

Conduits, spillways, and all regulating gates must be functionally adequate to accomplish project objectives. Their sizes, dependability, and speed of operation should be tested using recorded and hypothetical hydrographs and anticipated hydraulic heads to ensure that they will perform properly. The nature of stilling facilities might be dictated by hydrologic considerations, if frequency and duration of high outflows substantially influence their design. The necessity for multilevel intakes for quality control can be assessed by detailed reservoir stratification studies under all combinations of hydrologic and reservoir conditions. Techniques for conducting reservoir stratification studies will be discussed in Volume 11.

The design of power facilities can be greatly influenced by hydrologic considerations, and these are discussed in Chapter 5.

Regardless of the purposes for which a reservoir is constructed, it is imperative that spillway facilities be provided that will ensure the integrity of the project in the event of extreme floods. Whenever the operation rules of a reservoir are substantially changed, spillway facilities should be reviewed to ensure that the change in project operation does not adversely alter the capability to pass extreme floods without endangering the structure. The capability of a spillway to pass extreme floods can be adversely affected by changes in operation rules that actually affect the flood operation itself or by changes that result in higher pool stages during periods of high flood potential. General considerations in the hydrologic design of spillways are discussed in Chapter 3.

A number of situations might require special operation rules. For example, operation rules are needed for the period during which a reservoir is initially filling, for emergency dewatering of a reservoir, for interim operation of one or more components in a system during the period while other components are under construction, and for unanticipated conditions that seem to require deviation from established operating rules. The need for operation rules during the filling period is especially important because many decisions must be based on the filling plan. Among the important factors that are dependent upon the filling schedule are the on-line date for power generating units, the in-service dates for various purposes such as water supply and navigation, and the effective date for legal obligations such as recreation concessions.

One of the last considerations in the hydrologic design of any reservoir, but one of the more important, is the specification of monitoring facilities, including streamflow, rainfall, reservoir stage, and other hydrologic measurements. These facilities serve two basic purposes: to record all operations and to provide information for operation decisions. The former purpose satisfies legal requirements and provides data for future studies. The latter purpose may greatly increase the project effectiveness by enabling the operating agency, through forecasts of hydrologic conditions, to increase operation efficiency. As an impressive example in flood-control applications, the ability to forecast runoff 12 hours in advance where regulated releases are on the order of 25 percent of peak design flood inflow can decrease standby space requirements by as much as

25 percent or more. Hydrologic aspects of monitoring facilities and forecasts will be discussed in Volumes 7 to 9.

Section 6.06. General Study Procedure

As indicated earlier, there is no fixed procedure for developing operation plans for multipurpose projects; however, the general approach that should be common to all cases would include the following steps:

a. Survey the potential water uses to be served by the project in order to determine the magnitude of each demand and the seasonal and long-term variations in the demand schedule.

b. By evaluating the importance of the various uses and the consequences of shortages, and by consulting with the water users, develop a relative priority for each purpose and determine the levels of service that will be necessary to serve each purpose with the required priority. If necessary, make sequential studies illustrating the consequences of various alternative priority systems.

c. Establish the seasonal variation of flood-control space required, using procedures discussed in Chapter 3.

d. Establish the total power, water supply, and low-flow regulation requirements for competitive purposes during each season of the year.

e. Establish the seasonal variation of storage requirement to satisfy these needs, using procedures described in Chapters 4 and 5.

f. Determine the amount of storage needed as a minimum pool for power head, recreation, sedimentation reserve, and other purposes.

g. Using the above information, estimate the size of reservoir and seasonal distribution of space for the various purposes that would satisfy the needs. Determine reservoir characteristics, including flowage, spillway, power plant, and outlet requirements.

h. Test and evaluate the operation of the project through the use of recorded hydrologic data in a sequential routing study to determine the adequacy of the storage estimates and proposed rules with respect to the operation objectives for each purpose. If necessary, make necessary changes and repeat testing, evaluating, and changing until satisfactory operation is obtained.

i. Test proposed operation rules by use of sequential routing studies with stochastic hydrologic data to evaluate the possibility of historical bias in the proposed rules.

j. Determine needs for operation and monitoring equipment required to ensure proper functional operation of the project.

k. As detailed construction plans progress, evaluate cofferdam needs and protective measures needed for integrity of project construction, particularly diversion capacity as a function of dam construction stage and flood threat for each season.

Chapter 7

Water Resource Systems

CHAPTER 7. WATER RESOURCE SYSTEMS

Section 7.01. Introduction

Very few, if any, water resource systems are designed and operated for the most effective and efficient accomplishment of overall objectives. A system usually consists of reservoirs, diversion, power plants, and canal units that are each constructed for specific objectives and that cannot be operated in contradiction to existing agreements and customs. Nevertheless, there is considerable latitude in developing the integrated operation of any water resource system; but the problem is greatly complicated by the legal and social restrictions that ordinarily exist.

Water resource system operation is usually modeled mathematically, rather than by means of physical models. The mathematical representation of a water resource system is extremely complex, and neat mathematical solutions are almost never feasible. Operations research techniques such as linear programming and dynamic programming can be applied to limited portions of a water resource system, but usually are not capable of solving the overall problem of optimizing system outputs. It is usually necessary to simulate the detailed sequential operation of a system, representing the manner in which each element in the system will function under realistic conditions of inputs and requirements on the system. Optimization of system outputs would require a number of such simulations, successively approximating the physical characteristics and operation rules that would yield optimum output.

A factor that greatly complicates the simulation and evaluation of reservoir system outputs is the stochastic nature of the inputs and of the requirements on the system. In the past, it has been customary to evaluate system accomplishments on the assumption that a repetition of historical inputs and requirements (adjusted to future conditions) would adequately represent system values. However, this assumption has been demonstrated to be somewhat hazardous, and it is desirable to test any proposed system operation under a great many sequences of inputs and requirements. This requires a mathematical model that will define the frequency and correlation characteristics of inputs and requirements and that is capable of generating a number of long sequences of these quantities. Techniques for accomplishing this will be discussed in Volume 2.

Section 7.02. System Description

Water resource systems consist of reservoirs, power plants, diversion structures, channels, and conveyance facilities. In order to simulate system operation, the system must be completely described in terms of the location and functional characteristics of each facility.

In the case of reservoirs, the relation of surface area and release capacity to storage content must be described. This, in effect, reflects the storage capacity of the reservoir because release capacity will presumably increase rapidly as storage exceeds reservoir capacity. The top-of-dam elevation must be specified and the ability of the structure to withstand overtopping must be assessed. Characteristics of the control gates on the outlets and spillway must be known in order to determine constraints on operation. The drainage area of the reservoir must be described in order to evaluate inflows that will occur.

In the case of power plants at storage reservoirs, the relation of turbine and generation capacity to head must be determined. In order to compute the head on the plant, the relation of tailwater elevation to outflow must be known. Also, the relation of overall power plant efficiency to head is required. Other characteristics such as turbine leakage and operating efficiency under partial load might also be important.

In the case of diversion structures, maximum diversion capacity must be established. This, of course, is also true for all conveyance units. The nondamaging capacity of all river channels in the system must be estimated.

The water resource system can be described for analysis purposes by listing the features of structures and system features at each control point in turn, progressing in the upstream-to-downstream direction. A typical description is illustrated in the generalized computer program description of Appendix 3.

Section 7.03. System Operation Objectives and Criteria

Regardless of the function or combination of functions for which a water resource system is operated, there is usually a fixed objective for each function. After a project has been constructed, it is operated to provide services that are counted on by the users. In the case of power generation and water supply, the services are usually contracted; and it is essential to provide contracted amounts insofar as possible. Services above the contracted amounts are ordinarily of significantly less value. In the case of services such as flood control and recreation that are not ordinarily covered by contracts, service areas are developed in such a manner as to require the degree of service for which the project was constructed. Shortages in any of the services can be very costly, whereas surpluses are usually of minor value. Accordingly, the objectives of water resource system operation are usually fixed for any particular plan of development. These are expressed in terms of operation rules that specify quantities of water to be released and diverted, quantities of power to be generated, reservoir storages to be maintained, and flood releases to be made. These quantities will normally vary seasonally and with the amount of water in storage in the system. Rule curves for the operation of the system for each function are developed by successive approximations on the basis of performance during a repetition of historical streamflows adjusted to future conditions or on the basis of synthetic streamflows that would represent future runoff potential. The derivation of rule curves for evaluation of system operation will be discussed in detail in Volume 9.

Section 7.04. System Search Techniques

Evaluation of system operation under any specified operation rules and set of input quantities is so complex that it requires a detailed simulation of the operation for long periods of time. This is accomplished by assuming that steady-state conditions prevail for successive short intervals of time. In order to simulate the operation during each interval, the system is searched in an upstream-to-downstream direction. At each pertinent location, requirements for each service are noted, and the reservoirs at and above that location are operated in such a way as to serve those requirements, subject to system constraints such as outlet capacity, channel capacity, reservoir storage capacity, etc. As the computation procedure progresses to downstream locations, the operation commitments made for upstream locations become increasingly constraining. It often becomes necessary to assign priorities among services that conflict. Where power generation causes flows downstream to exceed channel capacity, for example, a determination must be made as to whether to curtail power generation. If there is inadequate water at a diversion to serve both the canal and river requirements, a decision must be made; and this requires preprogramming of such decisions in order to permit automatic computer simulation of the system.

In the system search routine, the operation of each reservoir is subject to change as requirements at successive downstream points are examined. Accordingly, a completely new search of the upstream system is necessary as the requirements at each successive downstream point are examined. As these requirements are satisfied, the new commitments on the operation of upstream units must be recorded.

Section 7.05. Conservation Operation

While the flood-control operation of a reservoir system is sensitive to short-time variations in system input, the operation of a system for conservation (for functions other than flood control) is usually sensitive only to long-period streamflow variations. Accordingly, simulation of the conservation operation of a water resource system is usually based on a relatively long computation interval such as a month. Although the basic computation interval may be long, some aspects of the conservation operation, such as diurnal variations in power generation in a peaking project, might require examination of selected typical or critical periods to define important short-term variations.

Rule curves for the operation of a reservoir system for conservation usually consist of standard power generation and water supply requirements that will be served under normal conditions, a set of storage levels that will provide a target for balancing storage among the various system reservoirs, and maximum and minimum permissible pool levels for each season based on flood control, recreation, and other project requirements. Often some criteria for decreasing services when the system reservoir storage is critically low will be desirable.

In simulating the operation of a reservoir system for conservation, the time of travel of water between points in the system is usually ignored, since it is small in relation to the computation interval and since resulting computation errors do not accumulate. On the other hand, channel losses might be quite important; and it is sometimes necessary to account for such losses in natural river channels and diversion canals.

Section 7.06. Flood-Control Operation

The simulation of the flood-control operation of a water resource system is generally similar to that for conservation operation. However, steady-state conditions cannot be assumed to prevail for long periods of time (such as one month), physical constraints such as outlet capacity are more important, and the time translation and channel storage effects cannot ordinarily be ignored. Consequently, the problem of simulating the flood-control operation of a system can be more complex than for conservation.

The computation interval necessary for satisfactory simulation of flood operations is usually on the order of a few hours or one day at the most. Sometimes intervals as short as 15 or 30 minutes are necessary. It is usually not feasible to simulate for long periods of time, such as the entire period of record, using such a short computation interval; also, it is unnecessary, since most of the flows are of no consequence from a flood-control standpoint. Accordingly, simulation of flood-control operation is usually made only for important flood periods.

If the operation of each reservoir in a system can be based on conditions at or above that reservoir, an upstream-to-downstream search of the system can establish reservoir releases, and these releases can be routed through channel reaches as necessary in order to obtain a realistic simulation. Under such conditions, the computer program described in Appendix 1 is capable of simulating the system operation with a high degree of accuracy. However, this approach is not feasible in the usual case where a reservoir is operated to regulate flows at a remote point downstream.

A procedure has not yet been devised to solve for the combination of releases at upstream reservoirs that will exactly satisfy channel capacity at a downstream control point, taking into account the time translation and channel storage effects, and that will provide continuity in successive time intervals. However, a solution can be made by ignoring the channel storage effects; and it can then be checked accurately, accounting for channel storage effects, as described in the preceding paragraph. This is accomplished in exactly the same manner as is the simulation for conservation operation as described in Section 7.05. The time translation effects can be taken into account by translating the input values in such a manner as to permit a solution of the system operation as though the quantities all occurred simultaneously. The output quantities that are computed simultaneously would then be assigned different times in order to account for the translation time between locations in the river basin. The solution would then be checked by use of the computer program described in Appendix 1, taking into account channel storage effects.

The starting conditions for simulating the flood-control operation of a water resource system for any particular flood period would depend on the operation of the system for conservation purposes prior to that time. Accordingly, usual practice is to simulate the system operation for conservation first, using an appropriate computation interval such as a month, and then to use the state of the system at the beginning of the month during which the flood occurred as the initial conditions for the flood simulation. If the state of the system is changing rapidly during the conservation operation, it might be necessary to perform a short-period operation study for conservation purposes to bridge the gap between the beginning of the month and the start of the flood period.

Section 7.07. System Power Operation

Where a number of power plants in the water resource system serve the same system load, there is usually considerable flexibility in the selection of plants for power generation at any particular time. In order to simulate the operation of the system for power generation, it is necessary to specify the overall system requirement and the minimum amount of energy that must be generated at each plant during each month or other interval of time.

Since the entire system power requirement might possibly be supplied by incidental generation due to releases made for other purposes, it is first necessary to search the entire system to determine generation that would occur with only minimum power requirements at each plant and with all requirements throughout the system for other purposes. If insufficient power is generated to meet the entire system load in this manner, a search will be made for those power reservoirs where storage is at a higher level in relation to the rule curves than at other power reservoirs. The additional power load requirement will then be assigned to those reservoirs in such a manner as to maintain the reservoir storages as nearly as possible in conformance with the rule curves that balance storage among the reservoirs in the most desirable way. This must be done without assigning more power to any plant than it can generate at overload capacity and at the system load factor for that interval. This requires two complete searches of the system, one without system power load and the second with it. A third search is usually made in order to refine the computations on the basis of an accurate value of the average power head during the computation interval. The computer program described in Appendix 3 has been designed to accomplish this system power simulation. The operation of that computer program will be described and illustrated in Volume 9 of this report.

Section 7.08. Determination of Firm Yield

It is frequently desired to determine the maximum firm yield of power generation or water supply at a specified location that can be supplied by a specified system of reservoirs. Ordinarily, it is not possible to make a direct solution; and a number of iterations, each consisting of a complete system simulation for long periods of time, are required. One way of accomplishing this is by successive approximations. This would consist simply of modifying the target yield after each iteration and determining whether a surplus or deficit remains. If a surplus remains, the target yield is increased for the next trial; and if a shortage occurs, the target yield is decreased. A large increment of yield adjustment is first used, and the increment is decreased whenever surplus changes to shortage or vice versa.

If the yield is defined as the supply that can be maintained throughout the simulation period without shortages, then the process of converging on the maximum yield can be expedited. This is done by maintaining a record in the computer of the minimum reserve storage (if no shortage has yet occurred) or of the amount of shortage (if one does occur) in relation to the total requirement since the last time that all reservoirs were full. The surplus or shortage that existed at the end of any computation interval would be expressed as a ratio of the supply since the reservoirs were last full, and the minimum surplus ratio (if no shortage occurs) or maximum shortage ratio (if a shortage does occur) that occurs during the entire simulation period would be used to adjust the target yield for the next iteration. This is a rather crude procedure, principally because it is possible that not all reservoirs will fill during reasonably wet periods; and this would introduce iteration errors (it would call for too small an adjustment). However, the next iteration would detect these errors. A procedure for accomplishing this type of firm yield determination is included in the computer program described in Appendix 3.

Section 7.09. Derivation of Operation Criteria

A plan of development for a water resource system consists not only of the physical structures and their functional characteristics but also of the criteria by which the system will be operated. In order to compare alternative plans of development, it is necessary that each plan be operated optimally. The derivation of optimal operation criteria for a water resource system is probably more difficult than the derivation of optimum configuration and unit sizes because any small change in operation rules can affect many functions in the system for long periods of time and in very subtle ways.

Operation criteria generally consist of release schedules at reservoirs, diversion schedules at control points, and minimum flows in the river at control points, in conjunction with reservoir balancing levels that define the target storage contribution among the various reservoirs in the system. All of these can vary seasonally, and target flows can vary stochastically. Once the unit sizes and target flows are established for a particular plan of development, a system of balancing levels must be developed. The system response to a change in these balancing levels is a complicated function of many system, input, and requirements characteristics. For this reason, development of a set of balancing levels is an iteration process, and a complete system simulation must be done for each iteration.

In the early stages of deriving balancing levels, it usually is best to simulate system operation only for the most critical periods of historical streamflows. The final solution should be checked by simulation for long periods of time. The balancing levels defining the flood-control space are first tentatively established on the basis of minimum requirements for firm flood control that will provide the desired degree of protection. Preliminary estimates of other levels can be established on the basis of reserving the most storage in the smaller reservoirs, in those reservoirs with the least amount of runoff, and in those reservoirs that supply operation services not producible by other reservoirs.

After a preliminary set of balancing levels is established, they should be defined approximately in terms of a minimum number of coefficients. The general shape and spacing of levels at a typical reservoir might be defined by use of four or five variables, along with rules for computing the levels from those variables. Variations in levels among reservoirs should be defined by one or two variables, if possible, in order to reduce the amount of work required for optimization to an acceptable quantity.

Optimization of a set of balancing levels for operation rule curves can then be accomplished by successive approximations, using a complete system simulation computation for critical drought periods and using a gradient technique for adjusting the operation-curve coefficients. A routine for accomplishing this is under development in The Hydrologic Engineering Center and will be included as a part of the computer program described in Appendix 3.

Section 7.10. General Study Procedure

There is no completely satisfactory general approach to developing an optimum plan of improvement for a complex water resource system. Ordinarily many services are arbitrarily fixed and act as constraints on system operation for other services. In many cases, all but one service is fixed and the system is planned to optimize the output for one remaining service such as power generation. It should also be recognized that most systems have developed over a long period of time and that many services are in fact fixed, as are many system features.

Nevertheless, a rather idealized general study procedure that can be used as a goal for practical studies is as follows:

a. As in project studies described earlier, prepare regional and river-system topographic maps showing locations of hydrologic stations, existing and contemplated projects, service and damage areas, and pertinent drainage boundaries. Obtain all precipitation, snowpack, and runoff data pertinent to the project studies. Obtain physical and operation data on existing projects. Construct a normal seasonal isohyetal map for the river basin concerned.

b. For each location where flood protection is to be provided, estimate approximately the nondamage flow capacity that exists or could be ensured with minor channel and levee improvements. Estimate also the amount of storage (in addition to existing storage) that would be needed to provide a reasonable degree of protection, using procedures described in Chapter 3. Distribute this storage in a reasonable way among contemplated reservoirs in order to obtain a first approximation of a plan for flood control. Include approximate rule curves for releasing some or all of this storage for other uses during the nonflood season where appropriate.

c. Determine approximately for each tributary, where appropriate, the total water needed each month for all conservation purposes and attendant losses, and, using procedures described in Chapter 4, estimate the storage needed on each principal tributary for conservation services. Formulate a basic plan of development including detailed specification of all reservoir, canal, channel, and power plant features and operation rules; all flow requirements; benefit functions for all conservation services; and stage-damage functions for all flood damage index locations. Although this part of plan formulation is not entirely a hydrologic engineering function, a satisfactory first approximation requires good knowledge of runoff characteristics, hydraulic structure characteristics and limitations, overall hydroelectric power characteristics, and engineering feasibility and costs of various types of structures, relocations, etc.

d. Using the general procedures outlined in Chapters 2 and 3, develop flood frequencies, stage-discharge relations, and hypothetical flood hydrographs for unregulated conditions and for the preliminary plan of development for flood control. It may be desirable to do this for various seasons of the year in order to evaluate seasonal variation of flood-control space. Evaluate the flood-control adequacy of the plan of development, using procedures described in Section 7.06, and modify it as necessary to improve the overall net benefits for flood control while preserving basic protection where essential. Each modification must be followed by a new evaluation of net benefits for flood control. (Benefits evaluation routines are contained in the computer program described in Appendix 1.) Each iteration is costly and time-consuming; consequently, only a few iterations are feasible, and considerable thought must be given to each plan modification.

e. Using the computer program described in Appendix 3, simulate the conservation operation of the system for all sequences of record that span drought periods that might be critical for design. If recorded values are not available, synthetic generated sequences can be used, and methods for doing this will be described in Volume 2. Modify the system design as considered necessary for improving system accomplishments and simulate again, repeating this process until a near-optimum design is obtained. Test this design by simulating operation for the entire period of record and, if feasible, for 10 or 20 synthetic sequences whose length corresponds to the economic life of the proposed system.

f. Where a system is designed for construction over a long period of time to satisfy increasing needs, the above procedure should be used for each stage of development. Then a simulation of the system operation for conservation over the entire staging sequence should be made for 10 or 20 synthetic sequences of hydrologic imputs and system requirements, in order to test the design against many types of droughts occurring at various times during the period of operation. When synthetic sequences are used, shortages will occur; and losses due to such shortages must be subtracted from the overall benefits obtained.

g. Compute probable maximum floods for all reservoir sites for possible use in spillway design, and route these floods through the reservoirs as discussed in Chapter 3. Where loss of life or major property damage is possible, compute standard project floods for possible design use for flood-control features.

Selected Bibliography

SELECTED BIBLIOGRAPHY

Chapter 1

1.01. American Society of Civil Engineers, "Hydrology Handbook," Manuals of Engineering Practice No. 28, New York, 1949.

1.02. California Department of Water Resources, "Manual of Hydrology," Sacramento, Calif., 1961.

1.03. Chow, Ven Te, ed., "Handbook of Applied Hydrology," McGraw-Hill, New York, 1964.

1.04. Davis, C. V. et al., "Handbook of Applied Hydraulics," 3d ed., McGraw-Hill, New York, 1969.

1.05. Eckstein, Otto, "Water-Resource Development: The Economics of Project Evaluation," Harvard University Press, Cambridge, Mass., 1958.

1.06. Federal Council for Science and Technology, Ad Hoc Panel on Hydrology, "Scientific Hydrology," Washington, D. C., June 1962.

1.07. Linsley, Ray K. et al., "Hydrology for Engineers," McGraw-Hill, New York, 1958.

1.08. U. S. Bureau of Reclamation, "Flood Hydrology," Bureau of Reclamation Manual, U. S. Department of the Interior, Washington, D. C., 1947, rev. 1951.

1.09. U. S. Geological Survey, "Manual of Hydrology," (in 3 parts), Water-Supply Papers 1541, 1542, and 1543, U. S. Department of Interior, Washington, D. C., 1960.

1.10. U. S. Soil Conservation Service, Hydrology, Sec. 4 of "Engineering Handbook," U. S. Department of Agriculture, Washington, D. C., 1956, Supplement A, 1957.

Chapter 2

2.01. Beard, Leo R., "Statistical Methods in Hydrology," U. S. Army Engineer District, Corps of Engineers, Sacramento, Calif., Jan 1962.

2.02. Chow, Ven Te, "Open-Channel Hydraulics," McGraw-Hill, New York, 1959.

2.03. Henderson, F. M., "Open Channel Flow," Macmillan, New York, 1966.

2.04. U. S. Army, Office, Chief of Engineers, "Interior Drainage of Leveed Urban Areas: Hydrology," Engineering Manual 1110-2-1410, Washington, D. C., May 1965.

Chapter 3

3.01. Beard, Leo R., "Flood Control Operation of Reservoirs," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 89, No. HY1, pp 1-23, New York, Jan 1963.

3.02. Tennessee Valley Authority, "Floods and Flood Control," Technical Report 26, Washington, D. C., 1961.

3.03. U. S. Bureau of Reclamation, "Design of Small Dams," U. S. Department of Interior, Washington, D. C., 1960.

3.04. U. S. Army, Office, Chief of Engineers, "Reservoir Regulation," Engineering Manual 1110-2-3600, Washington, D. C., May 1959.

Chapter 4

4.01. Beard, Leo R., "Methods for Determination of Safe Yield and Compensation Water from Storage," Seventh International Water Supply Congress, Barcelona, Spain, 1966.

4.02. Fair, G. M. et al., "Water and Wastewater Engineering; Volume 1, Water Supply and Wastewater Removal," John Wiley, New York, 1966.

4.03. Linsley, Ray K. and Franzini, Joseph B., "Water-Resources Engineering," McGraw-Hill, New York, 1964.

4.04. U. S. Army Engineer District, Corps of Engineers, The Hydrologic Engineering Center, "Reservoir Storage-Yield Procedures," (preliminary), Sacramento, Calif., May 1967.

Chapter 5

5.01. Federal Power Commission, "Hydroelectric Power Evaluation," Washington, D. C., 1968.

5.02. Inter-Agency Committee on Water Resources, "Glossary of Important Power and Rate Terms, Abbreviations, and Units of Measurement," Federal Power Commission, Washington, D. C., 1965.

5.03. United Nations, "Manual of Standards and Criteria for Planning Water Resource Projects," Water Resources Series No. 26, New York, 1964.

5.04. U. S. Bureau of Reclamation, "Selecting Hydraulic Reaction Turbines," U. S. Department of Interior, Washington, D. C., 1966.

Chapter 6

6.01. Kurtilla, J. V. and Eckstein, Otto, "Multiple Purpose River

Development: Studies in Applied Economic Analysis," Johns Hopkins Press, Baltimore, Md., 1958.

Chapter 7

7.01. Fiering, Myron B. and Hufschmidt, Maynard M., "Simulation Techniques for Design of Water-Resource Systems," Harvard University Press, Cambridge, Mass., 1966.

7.02. Maass, A. et al., "Design of Water-Resource Systems," Harvard University Press, Cambridge, Mass., 1962.

7.03. United Nations, "Multiple-Purpose River Basin Development; Part I, Manual of River Basin Planning," Flood Control Series No. 7, New York, 1955.

Appendix 1

HEC-1
Flood Hydrograph Package

HEC-1 FLOOD HYDROGRAPH PACKAGE

COMPUTER PROGRAM 723-X6-L2010

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, U. S. ARMY
609 Second Street
Davis, California 95616

FOREWORD

This is the first revision of the March 1969 publication of this program. New routines include principally the ability to compute simultaneously a number of floods of various sizes for each of several plans of development and average annual damages of various types at all pertinent locations for each plan. The program has been segmented for ease of adapting to medium-size computers, and several minor improvements have been made. Metric units can now be used. The special Colorado River routine has been removed; otherwise the program will work on existing data decks as previously described if one blank card is added at the end of the job specification cards.

HEC-1 - FLOOD HYDROGRAPH PACKAGE

THE HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L2010

CONTENTS

ADDENDA

EXHIBITS

HEC-1 - FLOOD HYDROGRAPH PACKAGE

1. THE HEC PACKAGE LIBRARY

a. This is the first in a series of computer packages designed for comprehensive computation in a large area of hydrologic engineering with minimum interruption of core computation and maximum flexibility and ease of operational control. While the packages are intended primarily to increase effectiveness within The Hydrologic Engineering Center, they should also be useful to other offices having access to large computers. Each package will contain routines available in a variety of smaller programs, which will be maintained for use in smaller computers. In addition, many automatic features and sequential operations are included in the packages. Each package will be written in FORTRAN IV and designed to be contained in 32,000 words of core, insofar as possible, so that they can be used in virtually any major computer. It is intended that binary translations would be maintained on disk at installations where frequent use would warrant, thus permitting efficient use for very simple operations as well as for extremely complex ones. Computation procedures used are intended to be the best and most detailed available to and accepted by the profession, although generalization has required some simplification and inclusion of a choice of techniques where appropriate.

b. Up-to-date information and copies of source statement cards can be obtained from The Hydrologic Engineering Center upon request by Government and cooperating agencies. While the Government is not responsible for the results obtained when using these programs, assistance in resolving any malfunctioning of the programs will be furnished by the Center to the extent that time and funds are available. It is desired that any user of the programs who finds an inadequacy or desirable addition or modification notify The Hydrologic Engineering Center.

2. THE FLOOD HYDROGRAPH PACKAGE

All ordinary flood hydrograph computations associated with a single recorded or hypothetical storm, including routing through channels and reservoirs where outflow is a function of storage and inflow, can be accomplished with this package. Routines include rainfall-snowfall-snowpack-snowmelt determinations, computation of basin precipitation from station values, computation of unit hydrographs and of hydrographs, routing by reservoir, storage-lag, multiple-storage, straddle-stagger, Tatum and Muskingum methods, and complete stream system hydrograph routing and combining. These can all be combined in a single job, if desired. Best-fit unit hydrograph, loss-rate snowmelt and base freezing temperatures, and best-fit routing coefficients can be derived automatically, given known inputs and outflows. Each derivation is a single job, the results of which need not be, but ordinarily would be, examined before use in subsequent computations.

A comprehensive stream system design flood computation procedure is included by which about five base floods are computed simultaneously, each representing average rainfall severity corresponding to a specified area size. An interpolated hydrograph is automatically established for each concentration point, based on the size of the area tributary to that point. This routine is useful in storm drainage computations as well as for river basin computations.

A routine for evaluating reservoir and channel development plans for one or more locations includes the computation of average annual damages at each damage center for each plan of development as well as for existing conditions. This involves simultaneously computing about eight system floods for each plan, covering the entire range of floods that significantly contribute to damages. System floods may be either multiples of the runoff from a single representative storm or the runoff from multiples of a typical storm. Flow-damage curves for each type of damage and flood peak frequency curves for existing conditions must be specified for each damage center. Unit hydrograph coefficients, loss coefficients, degree of imperviousness, and routing coefficients for each plan must also be specified in advance.

Automatic plot routines are provided to illustrate results of computation on the printout . Many jobs can be done in rapid sequence on a single run. Examples of input and output, and a source program listing are given in exhibits 1, 2 and 4, respectively.

3. METHODS OF COMPUTATION

a. Basin total precipitation is computed from station precipitation as follows:

$$PRCPA = \frac{\Sigma(PRCPN \cdot WTN)}{\Sigma(ANAPN \cdot WTN)} ANAP \qquad (1)$$

where:

PRCPA = Basin-mean total precipitation
PRCPN = Station total precipitation
WTN = Station relative weight
ANAPN = Station normal precipitation
ANAP = Basin-mean normal precipitation

Where normal precipitation is not used, dummy values of 1 should be supplied as input. Short-period station-average precipitation is next computed as follows:

$$PRCP = \frac{\Sigma(PRCPR \cdot WTR)}{\Sigma WTR} \qquad (2)$$

where:

PRCP = Station-average interval precipitation
PRCPR = Station interval precipitation
WTR = Station relative weight

Station-average interval precipitation is then prorated to total the PRCPA value obtained in equation 1.

b. Where snowfall or snowmelt is considered, there is provision for separate computation by (up to 10) 1000-foot elevation zones. Temperatures used are intended to represent the temperatures at the bottom of the lowest elevation zone, and are reduced in computation by the number of degrees (TLAPS) specified per thousand feet of elevation. The base temperature used in melt equations is specified (as FRZTP), since variations from 32° F might be warranted, considering fluctuations of temperature within each computation interval and other factors. Snowmelt is ordinarily computed by use of equation 3. If the energy budget method is desired, snowmelt is computed by use of equation 4 if precipitation is occurring or equation 5 if no precipitation is occurring.

$$SNWMT = COEF\ (TEMPR-FRZTP) \qquad (3)$$

$$SNWMT = COEF\ (.09+(.029+.00504WIND+.007PRCP)\ (TEMPR-FRZTP)) \qquad (4)$$

$$SNWMT = COEF\ (.002SOL(1-ALBDO)+(.0011WIND+.0145)\ (TEMPR-FRZTP)+.0039WIND(DEWPT-FRZTP) \qquad (5)$$

where:

SNWMT = Melt in inches per day in 1000-foot elevation zone
TEMPR = Air temperature in degrees F at middle of zone
FRZTP = Freezing temperature in degrees F
COEF = Melt coefficient
PRCP = Rainfall in inches per day

SOL = Solar radiation in langleys per day

ALBDO = Albedo of snow, $.75/D^{.2}$, constrained above .4

WIND = Wind speed in miles per hour, 50 feet above snow

DEWPT = Dew point in degrees F

D = Days since last snowfall

Determination of whether precipitation falls as rain or snow in any zone is made by comparing the zone temperature with a value 2° F higher than the snowmelt base temperature (FRZTP + 2.). Snowmelt is subtracted and snowfall is added to the snowpack in each zone.

c. If the unit hydrograph is not provided, it is computed by the Clark Method to conform to specified Snyder or Clark coefficients with a time-area curve supplied, or with a synthetic time-area curve based on the following:

$$AI = T^{1.5}/.707 \quad (0<T<.5) \tag{6}$$

$$1\text{-}AI = (1-T)^{1.5}/.707 \quad (.5<T<1) \tag{7}$$

where:

AI = Area as a ratio to total basin area

T = Time as ratio to time of concentration

After converting the time-area curve to the given time of concentration (tc) and unit volume, and interpolating to the desired time interval, the unit hydrograph is computed as follows:

$$Q(2) = CA \cdot I + CB \cdot Q(1) \tag{8}$$

$$QUNGR = .5\ (Q(1) + Q(2)) \tag{9}$$

$$CA = TRHR/(R + .5\ TRHR) \tag{10}$$

$$CB = 1 - CA \tag{11}$$

where:

Q(2) = Instantaneous flow at end of period

Q(1) = Instantaneous flow at start of period

I = Incremental area during period (converted to cfs per inch of runoff)

QUNGR = Unit hydrograph ordinate

TRHR = Tabulation interval in hours

R = Basin storage coefficient in hours

The unit hydrograph is terminated when its volume exceeds .995 inches or 100 ordinates, whichever occurs first. If a unit hydrograph that conforms to specified Snyder coefficients is desired, it is established by successive approximations of the corresponding Clark coefficients.

d. Basin precipitation can be supplied as quantities in inches for each interval or as ratios to a given storm total. It can also be computed automatically for standard project storm precipitation using criteria in EM-1110-2-1411, and for probable maximum precipitation using criteria in HMS Report 33 and a storm pattern similar to the standard project storm pattern. The largest day of precipitation is preceded by the second largest and followed by the third largest. Six-hour storm amounts within each day are similarly distributed. A transposition coefficient can be supplied or will be computed using the following:

$$TRSPC = 1 - .3008/(SAREA)^{.17718}$$

where:

TRSPC = Coefficient to obtain basin precipitation from storm precipitation
SAREA = Drainage area in square miles

e. Loss rates can be computed using initial and uniform losses or by the following functions of rainfall intensity and accumulated loss (ground wetness):

$$AK = STRKR/RTIOL^{.1(CUML)} \quad (12)$$

$$DLTK = .2\ DLTKR\ \left[1-(CUML/DLTKR)\right]^{2} \geq 0 \quad (13)$$

$$ALOSS = (AK + DLTK)\ PRCP^{ERAIN} \quad (14)$$

where:

- ALOSS = Loss in inches per hour
- AK = Basic loss coefficient
- STRKR = Basic loss index for start of storm
- DLTK = Incremental loss coefficient
- DLTKR = Incremental loss index
- RTIOL = Ratio of loss coefficient to that when 10 inches more of accumulated loss occurs
- CUML = Accumulated loss in inches
- PRCP = Precipitation in inches per hour

The loss rate function is illustrated in exhibit 5.

In the case of rain losses in a snowmelt flood DLTK is zero, AK is arbitrarily increased 1 percent per day to reflect the change to warmer weather, and equations 12 and 13 are not used.

f. Base flow consists only of an exponential recession flow from preceding runoff computed as follows:

$$Q(2) = Q(1)/RTIOR^{.1} \qquad (15)$$

where:

Q(1) = Flow at start of interval
Q(2) = Flow at end of interval
RTIOR = Ratio of recession flow to that 10 intervals later

g. The hydrograph, if not supplied directly, is computed by the unit hydrograph technique, adding computed runoff to base flow. When this total is below a recession threshold flow (QRCSN), it is not permitted to recede faster than the base flow recession rate (equation 15).

h. Procedures for routing are described in EM 1110-2-1408, "Routing of Floods Through River Channels", in ES-171 Technical Bulletin No. 22 (Multiple Storage), and in Handbook of Applied Hydrology, by Ven Te Chow. These are briefly described as follows:

(1) Modified Puls. Outflow is a function of storage and therefore of storage indication (S+Q/2), which is determined from equation 16.

$$STRI(2) = STRI(1) + QH - Q(1) \qquad (16)$$

where:

STRI(2) = Storage indication (S+Q/2) at end of interval
STRI(1) = Storage indication (S+Q/2) at start of interval
QH = Average inflow for interval
Q(1) = Outflow at start of interval

(2) Muskingum. Outflow is a funciton of prism and wedge storage, which are functions of inflow and outflow, determined as follows:

$$Q(2) = (CA - CB)I(1)+(1-CA)Q(1)+CB\cdot I(2) \qquad (17)$$

$$CA = 2(TRHR)/(2AMSKK(1-X) + TRHR) \qquad (18)$$

$$CB = (TRHR-2AMSKKX)/(2AMSKK(1-X) + TRHR) \qquad (19)$$

where:

Q(2) = Outflow at end of interval
Q(1) = Outflow at start of interval
I(1) = Inflow at start of interval
I(2) = Inflow at end of interval
TRHR = Routing interval
AMSKK = Muskingum's K
X = Muskingum's X

(3) Straddle-stagger. Successive inflows numbering NSTDL (at least 2) are averaged and the average is lagged LG intervals beyond middle of range over which flows were averaged. In order to have outflows on correct timing, 1/2 time interval is added by program to specified value of LG if straddle (NSTDL) is an even number. Tatum routing can be effected by specifying NSTPS (number of reaches) as number of Tatum steps, 2 for NSTDL and zero for LG.

(4) Multiple Storage. Multiple storage routing using the time-of-storage coefficient (TSK expressed in hours) is accomplished by routing the hydrograph NSTPS successive times using the following equation:

$$Q(2) = \frac{(QH-Q(1))\ TRHR}{TSK \cdot Q(1)^{-.2} + TRHR/2} + Q(1) \qquad (20)$$

where:

Q(2) = Outflow at end of interval
Q(1) = Outflow at start of interval
QH = Average inflow
TRHR = Routing interval in hours

All routing procedures include the assumption that flow has been steady prior to the beginning of each hydrograph at the flow rate of its first ordinate.

i. Derivation of unit hydrograph and loss rate coefficients or routing coefficients is accomplished by assigning +1 to the variable IDERV and -1 to the coefficients to be derived. Observed runoff must be supplied, and in the case of routing optimization, a pattern hydrograph for intermediate runoff (between given inflow and outflow) must also be supplied. This hydrograph is automatically multiplied by a ratio to equal the difference between inflow and outflow volumes. Coefficients are derived by successive approximations, using the subroutine described in Appendix I for continuous variables. Discrete variables are optimized by testing successive values, starting with 1, and selecting the first optimum that appears (the value preceding the one that causes the objective function to worsen). The criterion for optimizing reconstitution is to minimize the weighted root-mean-square errors between computed and observed flows. In order to improve the reproduction of peak flows, errors associated with high flows are weighted heavier than those associated with low flows. Each error square is multiplied by $(Q+\bar{Q})/(2\bar{Q})$. Also, if a reproduction is not satisfactory, considerable improvement can be made in a second run by a routine that artificially changes 1 or 2 flows in each flood temporarily to force a better reproduction without impairing the validity of the results. For example, a portion of a reconstituted hydrograph that is too low can be fitted better by increasing a key flow by about double the discrepancy. Since the reconstituted hydrograph is derived from the known unit hydrograph and loss rate functions, the only test of validity is its comparison with the observed hydrograph. A volume check is included in hydrograph reconsitution that assures approximate correspondence in volume between the observed and computed hydrographs.

j. A hydrograph balance routine is included to convert any pattern hydrograph to one having specified volumes within given durations. Two arrays of flows are carried. The first consists of the pattern hydrograph and the second of the adjusted hydrograph. Starting with the shortest duration specified, the period of maximum flow of the pattern hydrograph is determined,

and the sum of all flows within each period that have not already been used in shorter-duration computation is computed. Adjusted flows within that period are subtracted from the specified volume for that duration. Then all unadjusted flows within that duration are multiplied by the ratio required to obtain the incremental volume needed. Since the changed shape of hydrograph can change the location of maximum amounts, this process is repeated up to 10 times until all volumes are within 1 percent, using the derived hydrograph as the new pattern hydrograph each time.

k. Stream system design flood computation can account for decreasing amounts of basin-average precipitation with increased basin size. This feature is useful for river system or storm drain system design. Up to 5 basin-average amounts (or ratios to normal precipitation) can be used to compute base floods. Each base flood corresponds to the design amount for a specified size of basin (index area or transposition area). At each successive location in a stream system, the actual area tributary to that location is used to interpolate logarithmically between base floods as follows:

$$Q = Q_A \log \frac{X}{B} / \log \frac{A}{B} + Q_B \log \frac{X}{A} / \log \frac{B}{A} \qquad (21)$$

where:

Q = Instantaneous flow of design hydrograph
X = Tributary area for stream location
A = Next smaller index area
B = Next larger index
Q_A = Instantaneous flow of base flood corresponding to A
Q_B = Instantaneous flow of base flood corresponding to B

l. In order to assure consistency in runoff volumes, the rainfall and snowmelt excess for the base flood corresponding to each successively larger index area includes a proportional amount of the excess for the base flood corresponding to the next smaller index area. Excess is computed for each base flood only for the incremental index area. This incremental excess is multiplied by the incremental index area, and the product is added to the product of the excess and index area for the previously computed base flood (which corresponds to the next smaller index area). The sum is then divided by the index area.

m. A base flood hydrograph for an "upsteam" location is the contribution of that location to the design flood downstream where the actual tributary area equals the index area for that base flood. A base flood for a "downstream" location (where the actual tributary area is larger than the particular base flood index area) is larger than the design flood for that location and is computed only for interpolation purposes. It is possible that interpolated design hydrographs above and below a confluence will be inconsistent. The upstream hydrographs should (and always do) add to more than the design hydrograph below the confluence. However, if one of the tributary design hydrographs is larger than the downstream interpolated hydrograph (because of the interpolation), a provision assures that the actually computed design hydrograph below the tributary is at least as large as the largest tributary design hydrograph.

4. DESCRIPTION OF INPUT

a. As in all HEC programs, input is entered whenever possible in ten 8-column fields per card, except that the first column of each card is retained for card identification and ordinarily not read by the computer. Thus the first item of data on each card occupies 7 columns (2-8). Numbers should be right-justified. Whole numbers can be without decimal points, and all integer numbers (identified by variable names starting with letters I through N) must be without decimal points. Letters, commas, etc., cannot be used except in title cards and column 1 of each card. The first title card of each job must have an A in column 1 in order to identify the start of the job to the computer. In certain cases where a job is rejected, the computer can then waste cards until it finds the start of the next job.

b. Input data requirements are summarized in exhibits 6 and 7, and examples are shown in exhibit 1. Cards A to E1 are job control and job data cards that are not repeated in the same job. Cards F to S are hydrograph specification and associated data cards and are repeated as required for each hydrograph needed. Cards T to U_3 are routing specification and associated data cards and are repeated as required for each routing needed. Cards V to V_2 are frequency-flow-damage relationships and are repeated as required for each damage category and each plan.

c. The stream system combining operation must be controlled by input. Since a hydrograph is first required, the program will read a hydrograph specification and associated cards. Subsequent operations are controlled by the variable NEXT, which calls for routing specification and associated cards if +1, hydrograph specification and associated cards if -1, and end of run if 0. Combining operation is effected by a positive value of NCOMB equal to the number of hydrographs to be combined. This can be called on either the hydrograph or routing specificiation cards and will operate before the next specification cards are read. The order of computing hydrographs is vital in certain respects, since the latest established hydrographs remaining in storage are the ones to be combined. Hydrographs are removed from storage when they are combined. In order to assure effective use of core and proper combining, the following rules should be followed:

(1) Always start hydrograph computations at the remaining points farthest upstream (in terms of the number of intervening combining points) from the stream system mouth.

(2) Once a hydrograph at or above any combining point is computed, all hydrographs at or above that combining point must be computed before any others.

(3) As soon as all hydrographs are computed at or above any point, they must be combined and routed to the next downstream point before proceeding with further hydrograph computation.

5. OUTPUT

Output is illustrated in exhibit 2.

6. DEFINITION OF TERMS

Terms used in coding this program are defined in exhibit 3.

7. HARDWARE REQUIREMENTS

The program as dimensioned herein requires 32,000 words of core storage in the CDC6600 computer with dimension limits shown herein. No tape drive units are used. The dimension limits shown herein (particularly the 4800 quantity) are not adequate for all operations, but are generally adequate and permit use of the program in the GE-425 computer. A plot subroutine version is available for use on terminals having only 120 characters per line on the printer (particularly the GE-225).

8. OPERATING INSTRUCTIONS

Standard FORTRAN IV operating instructions apply. The number of hydrograph ordinates, the number of plans and ratios of hydrographs that can be accommodated is determined by dimension size. In order to guard against over-running the dimensions, the dimension limits defined at the start of the main program must correspond to those contained in the dimension statements. Standard values are:

Variable	Size	Definition
KUHCO	100	Number of unit hydrograph ordinates
KO	150	Number of ordinates per hydrograph
KH	270	Number of hydrographs in memory
KQH	4800	Total number of ordiantes in memory
KN	50	Nonrecording precip stations in region
KP	11	Recording precip stations in region
KHN	25	Nonrecording precip stations for sub-basin
KHR	9	Recording precip stations for sub-basin
KNH	120	Hydrograph locations

The limit, KH, must equal or exceed KHGR*NSTM and KHGR*NPLAN*NRTIO, and the variable KQH must equal or exceed KHGR*NPLAN*NRTIO*NO and also KHGR*NSTM*NQ, where KHGR is the number of locations for which hydrographs can be stored in memory at one time (before combining at any location), usually less than 5 or 6. The number of locations for which hydrographs must be stored in memory at one time can be controlled by careful planning of the computation sequence. Each time that a hydrograph is computed for a sub-basin, it requires separate memory space. Routed hydrographs use the same memory space over again. When hydrographs are combined, the memory space for all hydrographs except one is released for further use.

OPTIMIZATION SUBROUTINE

1. Subroutine OPTIM determines the optimum values of a set of continuous variables that will result in a minimum value of an objective function. The feasible range of each variable cannot include zero and must be large relative to its absolute value (because 1-percent increments are used to determine trends). The basic method used is the univariate gradient method described in the paper by Leo R. Beard, "Optimization Techniques in Hydrologic Engineering."

2. The three variables in the argument are:

a. A floating point variable dimensioned to 3, which is the criterion for optimization to be minimized (if a maximum criterion is desired, its reciprocal can be used).

b. A fixed point variable, which is the number of parameters to be varied to obtain optimum.

c. A floating point variable dimensioned to 10, which is the respective values of each parameter. These should be as independent of each other as possible in their effects on the criterion (objective) function.

3. Variables in common are:

a. IFREZ, dimensioned to 10, which prevents its corresponding parameter from changing when IFREZ is positive.

b. ITRNS, which controls the entry point to the subroutine.

c. M, which is the subscript of the parameter.

d. NC, which is the subscript of the criterion function.

e. IDGST, which causes diagnostic print-out when positive.

f. M1, which is the subscript of the parameter previously changed.

g. NC2, which is the upper limit of the do-loop that estimates the next optimum value of a parameter.

4. Use of this subroutine is as follows:

a. Define initial values of all variables in the argument. Define IFREZ and IDGST as zero or 1. A value of -1 must be set for ITRNS. Call the subroutine.

b. Compute the criterion. Call the subroutine.

c. If ITRNS equals zero and NC2 equals 1, constrain the variable with subscript M to the acceptable range and transfer to recompute the criterion function. If ITRNS equals zero and NC2 exceeds 1, transfer to recompute the criterion function. If ITRNS equals 1, print out results.

DEFINITIONS

SUBROUTINE OPTIM

CORMN	- Maximum correction in negative direction
CORMX	- Maximum correction in positive direction
CORR	- Correction in percent
CRITN(NC)	- Criterion function
DIF2	- Second difference in criterion function
DSERI	- Difference in criterion function between 1st and 2nd trial
DSER2	- Difference in criterion function between 2nd and 3rd trial
FIN	- Indicator when positive indicates end of optimization
GAIN(M)	- Reduction in criterion function in last correction
GANMX	- Maximum reduction of criterion function in last correction of any variable
IDGST	- Indicator when positive calls for diagnostic print-out
IFREZ(M)	- Indicator when positive prevents change of variable
ITRNS	- Indicator controlling operation between main program and subroutine
L	- Temporary variable
M	- Variable subscript
MX	- Variable subscript
M1	- Subscript of preceding variable
NADJ	- Number of adjustments of variable to prevent divergence
NC	- Computation number
NCYCL	- Cycle number
NC1	- Lower limit of computation loop
NC2	- Upper limit of computation loop
NVAR	- Number of variables
TEMP1	- Adjusted value of preceding variable
TEMP2	- Unadjusted value of working variable
TEST	- Minimum value of criterion function attained
VAR(M)	- Variable

PLOTTING SUBROUTINE

1. Subroutine graph is especially designed for the flood hydrograph package to provide a plot of selected output on the printer automatically. Items to be plotted are pre-selected in the program and are controlled by the programmed variable NV as follows:

NV	Items	Spaces
1	Hydrograph that was read in, computed as a ratio to another, combined, interpolated or balanced	1-121
2	Inflow for routing*	1-101
	Routed outflow*	1-101
3	Computed runoff from rainfall	1-101
	Excess#	121-81
	Rainfall#	121-81
4	Reconstituted runoff from rain and snowmelt*	1-101
	Observed runoff*	1-101
	Temperature	61-101
	Precipitation	121-81
5	Reconstituted runoff from rainfall*	1-101
	Observed runoff*	1-101
	Excess#	121-81
	Rainfall#	121-81
6	Computed runoff from rain and snowmelt	1-101
	Temperature	61-101
	Total excess#	121-81
	Rain plus snowmelt#	121-81
7	Reservoir inflow*	1-101
	Routed outflow*	1-101
	Storage	61-101
8	Observed inflow for routing*	1-101
	Observed outflow to be reconstituted*	1-101
	Routed outflow*	1-101

* Scales identical in each group
\# Scales identical in each group

2. The grid consists of 121 printer spaces initially defined in both PLOT and SAVE arrays as a period in every tenth space starting with 1 and as a blank in all remaining spaces. The range of each variable is determined by searching all values to be plotted and by specifying zero as a lower limit in some cases. Where more than one item must be plotted on the same scale for comparison, the span (ISPAN) of all items except the last is specified as zero, which causes a search of all of such items for range and then selects a common scale for all. The scale is selected so that the interval for each 10 spaces is the product of any number of tens or tenths with 1, 2, 4, or 5.

3. The location of each point to be plotted is computed as an interpolated integer from the magnitude of the variable and the selected scale and is used as the subscript of PLOT, which is defined in turn as the symbol (AX) to be plotted. After all variables are entered into the PLOT array for a given interval, the PLOT array is printed and then equated to the SAVE array to regain the blank grid. Each printed line is numbered serially for identification.

DEFINITIONS

SUBROUTINE GRAPH

ALTRE - Letter E
ALTRI - Letter I
ALTRO - Letter O
ALTRP - Letter P
ALTRS - Letter S
ALTRT - Letter T
AMAX - Maximum value of variable
AMIN - Minimum value of variable
ASTRK - Asterisk
AX - Plotting symbol
BLANK - Blank space
I - Column subscript
IFMT - Format indicator
ISCAL - Scale indicator
ISPAN - Span of scale for variable to be plotted
ISTAQ - Station number
ISTEP - Indicator of direction of plotting increment
ISTRT - Column location of start of scale
ITEMP - Temporary variable
ITMP - Temporary variable
ITP - Temporary variable
J - Subscript of variable
K - Interval subscript
L - Temporary subscript
LX - Column number for plot
NQ - Number of flow ordinates
NS - Scale number
NV - Number of variables (index)
PER - Period symbol
PLOT - Symbol for each column
PRCP - Precipitation or substituted quantity
Q - Computed flow or substituted quantity
QO - Observed flow or substituted quantity
RATIO - Ratio by which scale is multiplied
SAVE - Array to save plotting lines and spaces
SCALE - Scale title
STEP - Increment of variable corresponding to 10 plotting spaces
STP - Increment of variable corresponding to 1 plotting space
STR - Storage or substituted variable
STRT - Column where scale starts
TEMP - Temporary variable
TMP - Temporary variable

UNIT HYDROGRAPH AND LOSS RATE FUNCTIONS

1. Purpose and Scope. Partial automation of hydrograph analysis for flood-control studies through the use of electronic computers has necessitated the use of certain mathematical functions and associated parameters. The nature of some functions and parameters used in HEC-1 is described in this appendix to supplement information contained in EM 1110-2-1405, reference 1.

2. Effects of "Lumped" Basin Quantities.

a. Functions described herein are based in part on the fact that hydrologic quantities concerned in hydrograph analysis are averaged or "lumped" for computation purposes. Rainfall on a basin is expressed as a set of basin-average amounts for successive equal intervals of time, and their application neglects variations within each time interval and any random variations within the basin. Similarly, variations in snowpack and in loss-rate characteristics of the soils are simplified. Time intervals and basin sizes must, therefore, be limited so that neglecting these variations will not seriously affect computed runoff. However, the limitation imposed on the size of the basin can be somewhat relaxed by the use of loss-rate functions that reflect areal rainfall distribution and variations of soils, vegetation and other pertinent factors within a basin.

b. No feasible means of accounting for all of the effects of random variations in the areal distribution of rainfall and snowmelt have been devised. Accordingly, the maximum subarea size feasible for hydrograph analysis is limited by the degree of random rainfall variation. This limitation can be relatively minor in areas of general storms where rainfall is highly correlated from point to point. On the other hand, it can be highly restrictive where rainfall is erratic as in thunderstorms.

c. Infiltration losses are more seriously affected by random areal variations of rainfall than is the unit hydrograph. Furthermore, areal variations of soils and vegetation also affect losses. Both factors tend to cause increased losses with increased basin-mean rainfall. This is illustrated in the following simplified examples, where two halves (A and B) of a basin have different rainfall in the one case and different infiltration rates in the other. The portion of rain in these examples that is not lost is termed excess.

I Uniform infiltration, varying rain

Period	Half A			Half B			Basin Average		
	Rain	Loss (1)	Excess	Rain	Loss (1)	Excess	Rain	Loss	Excess
1	.10	.10	.00	.20	.20	.00	.15	.15	.00
2	.20	.20	.00	.40	.40	.00	.30	.30	.00
3	.30	.30	.00	.60	.40	.20	.45	.35	.10
4	.40	.40	.00	.80	.40	.40	.60	.40	.20
5	.50	.40	.10	1.00	.40	.60	.75	.40	.35

II Uniform rain, varying infiltration

Period	Half A			Half B			Basin Average		
	Rain	Loss (2)	Excess	Rain	Loss (1)	Excess	Rain	Loss	Excess
1	.10	.10	.00	.10	.10	.00	.10	.10	.00
2	.20	.20	.00	.20	.20	.00	.20	.20	.00
3	.30	.20	.10	.30	.30	.00	.30	.25	.05
4	.40	.20	.20	.40	.40	.00	.40	.30	.10
5	.50	.20	.30	.50	.40	.10	.50	.30	.20

(1) Loss is equal to rainfall up to maximum of .4

(2) Loss is equal to rainfall up to maximum of .2

It will be noted that, although certain conditions in each portion of the basin are the same (loss capacity in the first case and rain in the second), the basin-mean (lumped) loss rate is not a linear function of basin-mean precipitation. Virtually all drainage basins are highly heterogeneous, and consequently losses for a given ground wetness must surely be curvilinear functions of basin-mean rainfall. This type of relation has been detected in many hydrograph reconstitutions for complex storms. A convenient function is as follows:

$$L = kP^{E} \qquad (1)$$

where:

L = Loss rate in inches per hour

P = Rainfall rate in inches per hour

k = Constant dependent on wetness of the ground

E = Exponent between 0 and 1, depending on the variation of factors within the basin

d. In equation 1, loss is a simple ratio of rainfall intensity when E is 1.0, and loss is independent of rainfall intensity when E is zero (the usual assumption). A full range of intermediate values of E has been observed, but the derived value in each case can be greatly affected by inaccuracies or inadequacies in rainfall data. In view of the unreliability of derived values, a value of 0.7 for E (or some other regional average) is frequently used for purposes of uniformity in comparing values of k for different storms and different basins.

e. The following relationship, which takes into account the fact that losses decrease with increasing ground wetness (which is illustrated by the straight-line portion of the curve on plate 4) is used in HEC computer programs:

$$k_i = \frac{k_o}{A^{(.1\Sigma L_i)}} \qquad (2)$$

where:

k_i = Current value of loss coefficient k

k_o = Starting value of k

A = Ratio of k to its value after 10 inches more loss has taken place

ΣL_i = Current accumulated loss in inches

3. <u>Base Flow Considerations</u>.

a. Traditionally, the unit hydrograph is intended to represent surface runoff. Subsurface runoff and other forms of "base flow" are usually considered separately, often without a rigorous analysis. Such flows are a function of subsurface storage and are not linear functions of rainfall.

b. In an effort to minimize the subjective judgment in hydrograph analysis, computer programs developed in The Hydrologic Engineering Center include all components of streamflow in the direct derivation of the unit hydrograph except the following, which are calculated separately:

(1) Recession flow from antecedent runoff that would occur in the absence of the current storm.

(2) Recession flow from the current runoff computed from the unit hydrograph (after the end of the current storm).

c. Both of these quantities are computed as identical exponential decay functions (receding straight lines on semilog paper) defined as the ratio (B) of flow at a given time to flow 10 tabulation intervals later. Thus, the recession flow at the end of any period is computed from the recession flow at the start of that period as follows:

$$Q_i = Q_{i-1}/B^{.1} \tag{3}$$

Recession of antecedent flow computed in this manner is added to runoff computed from the unit hydrograph, and total flow is computed in this manner after it has receded below a threshold flow, Q_R. The threshold flow, Q_R and B are obtained by plotting observed recession curves on semilog paper, selecting Q_R as the upper limit of the portion that is sensibly a straight line and B as the ratio (always greater than 1.0) of flow 10 intervals apart on that straight line. Since this recession is considered to be characteristic of a basin, these values should be the same for different flood hydrographs at the same location.

4. Unit Hydrograph Computation.

a. The unit hydrograph is used to transform rainfall excess occurring at a specified time over the basin to runoff that occurs later at a stream concentration point. In doing this, it accounts for a time delay and the effects of storage above and beneath the earth's surface. The shape of the unit hydrograph depends on the duration of unit rainfall excess, and therefore, the concept of the instantaneous unit hydrograph used by C. O. Clark in describing the "Clark Method" in reference 2 is used to define a unique unit hydrograph for the point of concentration. This is theoretically the hydrograph that would result from 1 inch of rainfall excess occurring over the basin in a specified areal pattern and in zero time.

b. The instantaneous unit hydrograph is based on a relation of time versus contributing excess for the specified areal pattern of rainfall excess and stream pattern. Usually this relation is taken as a curve of distance measured along the stream channel from the point of concentration versus area contributing within that distance. The development of such a relation, showing time in percent of total travel time is illustrated in plates 1 and 2. It is possible to refine the curve by considering the variation of velocity from stream reach to stream reach and specified contributions of excess (as ratio to basin-mean contribution) in different portions of the basin. The time variable is the travel time that occurs without storage effects, and the longest travel time for any path in the basin is called the time of concentration, T_c. Since a unit hydrograph represents runoff from one inch of average excess on the basin, its computation is based on the time-area curve expressed in units of square-mile-inches (time-excess curve). The time-excess curve is tabulated (column 2 of table 1) as the difference during each time interval, in units corresponding to the ordinates of plate 2. Times are read from plate 2 at percentage points corresponding to actual time divided by the time of concentration T_c. The time-excess curve is converted to an instantaneous unit hydrograph as shown in table 1 as follows:

$$x = \Delta t/(R+.5\Delta t) \tag{4}$$

$$o_i = xI_i + (1-x)o_{i-1} \tag{5}$$

$$O_i = 645\ o_i/\Delta t \tag{6}$$

where:

- x = Routing coefficient
- Δt = Tabulation interval in hours
- R = Storage coefficient in hours
- I_i = Increment of unit excess in sq. mi.-inches on the time-excess curve during period i
- o_i = Ordinate in sq. mi.-inches of the instantaneous unit hydrograph at the end of period i
- O_i = Ordinate in cfs of the instantaneous unit hydrograph at the end of period i

c. The instantaneous unit hydrograph is then converted to a unit hydrograph of duration Δt by simply averaging two instantaneous unit hydrographs spaced an interval Δt apart as follows:

$$Q_i = .5(O_i+O_{i-1}) \tag{7}$$

d. The complete procedure is as follows:

(1) Draw lines (iso-chrones) which subdivide the basin into a chosen number of parts as illustrated on plate 1. These iso-chrones are constructed so that the travel time along a watercourse is the same from one iso-chrone to another. For simplicity, they are usually drawn equal distances apart from the concentration point to the uppermost head of the basin. The number of iso-chrones used is usually chosen so that a convenient scale may be used and a reasonably good definition of the time versus area relation obtained.

(2) Measure areas within each subdivision (plate 1). If nonuniform pattern of rainfall excess is assumed, multiply each area by the average excess within that subdivision.

(3) Plot the curve of time versus accumulated area (or excess) as shown on plate 2 and tabulate increments between points one tabulation interval apart.

(4) Route the inflow (column 2 of table 1) from step 3, to the point of concentration (column 3 of table 1) using equations (4) and (5).

(5) Multiply the routed outflow by a constant so that the total volume equals the unit-hydrograph volume corresponding to one inch of runoff, using equation (6).

(6) Average the ordinates of the routed hydrograph with those of an identical hydrograph one tabulation interval earlier (equation 7). The result is the unit hydrograph from unit rainfall excess of duration equal to the tabulation interval.

e. Aside from the advantage that the "Clark" unit-hydrograph procedure described herein provides a means of direct computation for electronic computer applications, other advantages derive from the fact that a time-area curve is used. It provides a means of adjusting objectively for changes in drainage patterns resulting from construction of reservoirs, channels and diversions without requiring that the basin be subdivided into many subareas. This is accomplished simply by constructing a time-area curve (with modified time of concentration) that corresponds to new travel times through reaches and reservoirs.

5. Derivation of Coefficients.

a. Although unit hydrograph coefficients T_c and R are given physical significance in reference 2, uncertainties of the concepts and of recorded data usually preclude their reliable determination in a simple fashion (without detailed reconstitution studies). The constants T_c and R are not rigid, but through the analysis of several different storms on the same basin, different values might be obtained for different storms. For example, the time of concentration for a storm centered over the head of the basin should be longer than one centered over the foot of the basin.

b. If sufficient discharge and rainfall records are available, values of T_c and R can be estimated from observed events. The variable T_c may be estimated as the time from the end of heavy rainfall excess to the point of contraflexure on the recession limb of the flood hydrograph. Likewise, the variable R may be estimated by dividing the discharge at the point of contraflexure by the rate of change of flow at that point on the hydrograph. This is illustrated on plate 3. However, the shapes of hydrographs reflect many irregularities of rainfall and stream patterns, and estimates obtained in this manner are usually satisfactory only for first approximations.

c. Where rainfall (and/or snowmelt) and runoff data are available, it is best to derive the unit hydrograph and loss coefficients by successive approximations by applying trial unit hydrographs to the rainfall excess computed from trial loss functions. The computation is demonstrated in table 2 and plates 3 and 4. The duration of unit rainfall excess and tabulation interval must be shorter than the time of concentration and preferably shorter than one-third of the time of concentration. Storms selected for study should be of duration several times the tabulation interval in order to provide representative basin coverage of rainfall.

d. Hydrograph reconstitution by successive approximations should yield best estimates of loss and unit-hydrograph coefficients. Where loss coefficients are to be compared for different storms or basins, some of the coefficients should be kept the same for all reconstitutions, particularly values of E in equation (1) and A in equation (2).

6. Synthetic Unit Hydrographs.

a. Synthetic unit hydrographs can be derived for ungaged areas by use of regional correlation relationships developed from studies of unit hydrographs derived for streams where data are available. These are usually developed using regression techniques and residual map analysis as described in reference 3.

b. Since changes in the two unit-hydrograph coefficients, T_c and R, produce similar changes on the unit hydrograph, about equally good hydrograph reconstitutions can be obtained by decreasing one and increasing the other. Thus, results obtained are not ordinarily as dependable for individual values as for their sum. For this reason, ordinary practice for regional studies consists of adopting an average ratio of R/T_c for the entire region and correlating only the sum, $R + T_c$, with basin characteristics such as drainage area size, average stream length, slopes, etc.

REFERENCES

1. Corps of Engineers, U.S. Army, Engineering and Design, Flood-Hydrograph Analyses and Computations, EM 1110-2-1405, 31 August 1959.

2. Clark, C.O., "Storage and the Unit Hydrograph", Trans. ASCE, 1945.

3. Beard, Leo R., "Statistical Methods in Hydrology", January 1962, US Army Corps of Engineers.

TABLE I

Unit Graph Computation
Clark Method

THOMES CREEK AT PASKENTA, CALIFORNIA

DRAINAGE AREA = 190 SQUARE MILES
TIME OF CONCENTRATION (Tc) = 8.0 HOURS (See Plate 3)
ATTENUATION VALUE (R) = 5.5 HOURS (See Plate 3)
TIME INTERVAL (Δt) = 2.0 HOURS

EQUATIONS (Subscript i refers to current period)

$$X = \Delta t / (R + .5\Delta t) = 0.308$$

$$o_i = X I_i + (1 - X) o_{i-1}$$

$$O_i = o_i 645 / \Delta t$$

$$Q_i = .5(O_{i-1} + O_i)$$

TIME *hr* *(1)*	INFLOW (PLATE 2) I_i *sq. mi.-in* *(2)*	INSTANTANEOUS UNIT GRAPH o_i *sq. mi.-in* *(3)*	INSTANTANEOUS UNIT GRAPH O_i *cfs* *(4)*	2-HOUR UNIT GRAPH Q_i *cfs* *(5)*
0	0	0	0	0
2	14	4.32	1,393	700
4	44	16.54	5,334	3,360
6	53	27.78	8,959	7,150
8	79	43.54	14,042	11,500
10	0	30.13	9,717	11,880
12		20.85	6,724	8,220
14		14.43	4,654	5,690
16		9.99	3,222	3,940
18		6.91	2,228	2,720
20		4.78	1,542	1,890
22		3.31	1,067	1,300
24		2.29	739	900
26		1.58	510	630
28		1.09	352	430
30		0.75	242	300
32		0.52	168	200
34		0.36	116	140
36		0.25	81	100
38		0.17	55	70
40		0.12	39	50
42		0.08	26	30
44		0.06	19	20
46		0.04	13	20

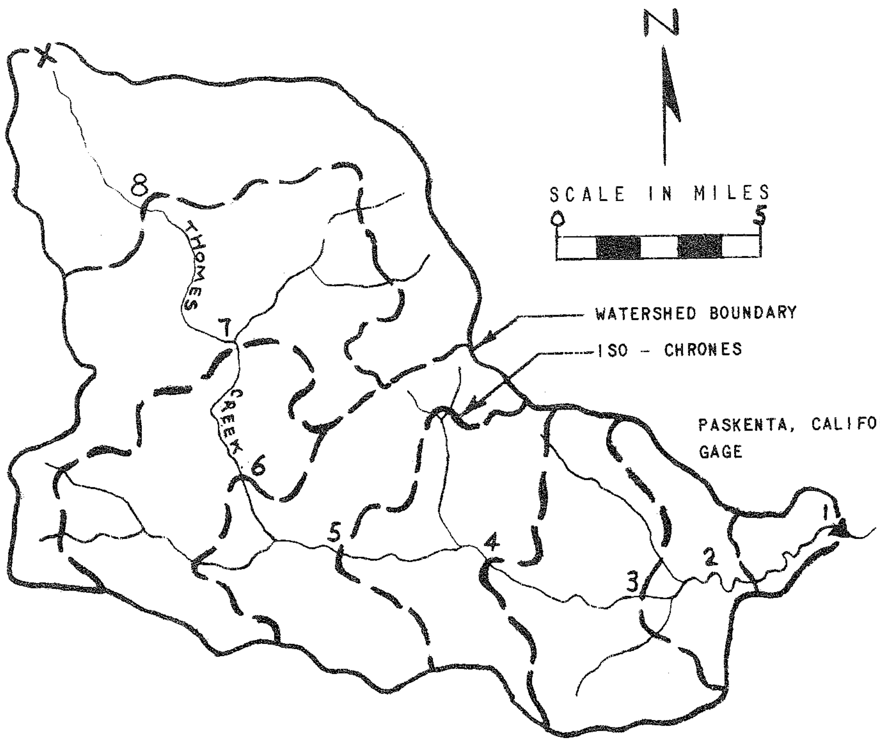
TABLE 2

THOMES CREEK AT PASKENTA, CALIFORNIA
FLOOD HYDROGRAPH COMPUTATION
31 JANUARY - 2 FEBRUARY 1963

DRAINAGE AREA = 190 SQUARE MILES
RECESSION FLOW BELOW 4,000 cfs = $0.95(Q_{i-1})$

DATE	TIME	PERIOD RAIN	RAIN RATE	K VALUE	LOSS RATE $L=KP^{.7}$	PERIOD LOSS	ACCUM-ULATED LOSS	RAIN EXCESS Col 3-Col 7	UNIT GRAPH TABLE 1	RUNOFF	ANTECEDENT BASE FLOW $0.95(Q_{i-1})$	FLOOD HYDROGRAPH Col 11 + Col 12
Day/Mo/Year	*hour*	*inches*	*in/hr*	*Plate 4*	*in/hr*	*inches*	*inches*	*inches*	*cfs*	*cfs*	*cfs*	*cfs*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
	INITIAL						.50				1,320	1,320
31 JAN 63	0600	.24	.12	.65	.12	.24	.74	0	0	0	1,250	1,250
	0800	.70	.35	.53	.25	.50	1.24	.20	700	140	1,190	1,330
	1000	1.68	.84	.41	.36	.72	1.96	.96	3,360	1,340	1,130	2,470
	1200	.78	.39	.36	.19	.38	2.34	.40	7,150	4,940	1,070	6,010
	1400	.06	.03	.34	.03	.06	2.40	0	11,500	10,510	1,020	11,530
	1600	.04	.02	.34	.02	.04	2.44	0	11,880	16,280	970	17,250
	1800	.82	.41	.34	.18	.36	2.80	.46	8,220	17,970	920	18,890
	2000	.58	.29	.33	.14	.28	3.08	.30	5,690	15,540	870	16,410
	2200	.24	.12	.32	.07	.14	3.22	.10	3,940	13,900	830	14,730
	2400	.02	.01	.31	.01	.02	3.24	0	2,720	14,370	790	15,160
1 FEB 63	0200	0	0	.31	0	0	3.24	0	1,890	14,200	750	14,950
	0400	0	0	.31	0	0	3.24	0	1,300	11,660	710	12,370
	0600	.26	.13	.31	.07	.14	3.38	.12	900	8,540	670	9,210
	0800	.24	.12	.30	.07	.14	3.52	.10	630	6,320	640	6,960
	1000	.36	.18	.30	.09	.18	3.70	.18	430	5,370	610	5,980
	1200	0	0						300	5,500	580	6,080
	1400	0	0						200	5,800	550	6,350
	1600	0	0						140	5,580	520	6,100
	1800	0	0						100	4,570	490	5,060
	2000	0	0						70	3,160	470	4,810*
	2200	0	0						50			4,570*
	2400	0	0						30			4,340*
2 FEB 63	0200	0	0						20			4,120*
	0400	0	0						20			
												$(0.95)(Q_{i-1})$

*RUNOFF + ANTECEDENT BASE FLOW IS LESS THAN 4,000 cfs SO ANTECEDENT RECESSION FLOW IS COMPUTED FOR HYDROGRAPH.



TRAVEL TIME FROM "X" TO GAGE IS 8.0 HOURS FOR THE 32 MILES

MAP AREA NUMBER	PLANIMETER VALUES FROM MAP INCREMENTAL units	ACCUMULATED units	ACCUMULATED AREA (sq.mi.) (Col 3) * (58.8)	TRAVEL TIME IN PERCENT $\sum[(1/8)*(100)]$
1	2	3	4	5
1	0.08	0.08	5	12.5
2	0.15	0.23	14	25.0
3	0.40	0.63	37	37.5
4	0.36	0.99	58	50.0
5	0.45	1.44	85	62.5
6	0.45	1.89	111	75.0
7	0.66	2.55	150	87.5
8	0.68	3.23	190	100.0
TOTAL	3.23			

Sq.mi./Planimeter unit = 190/3.23 = 58.8

DRAINAGE AREA = 190 SQUARE MILES

THOMES CREEK AT PASKENTA, CALIFORNIA
WATERSHED MAP

COMPUTATION
OF
THE TIME-AREA RELATION

PREPARED BY: CEA DATE: 21 OCTOBER 1968

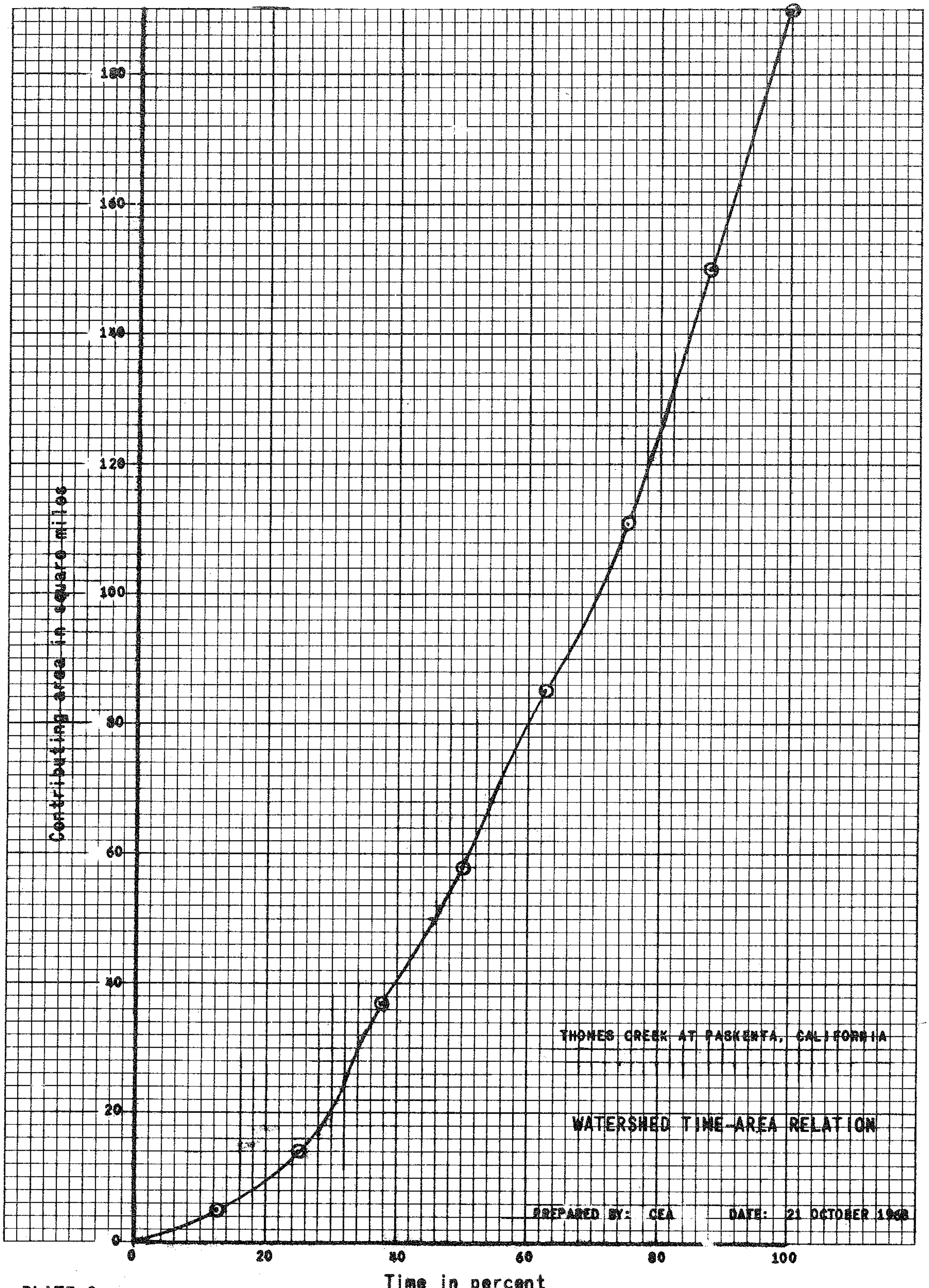
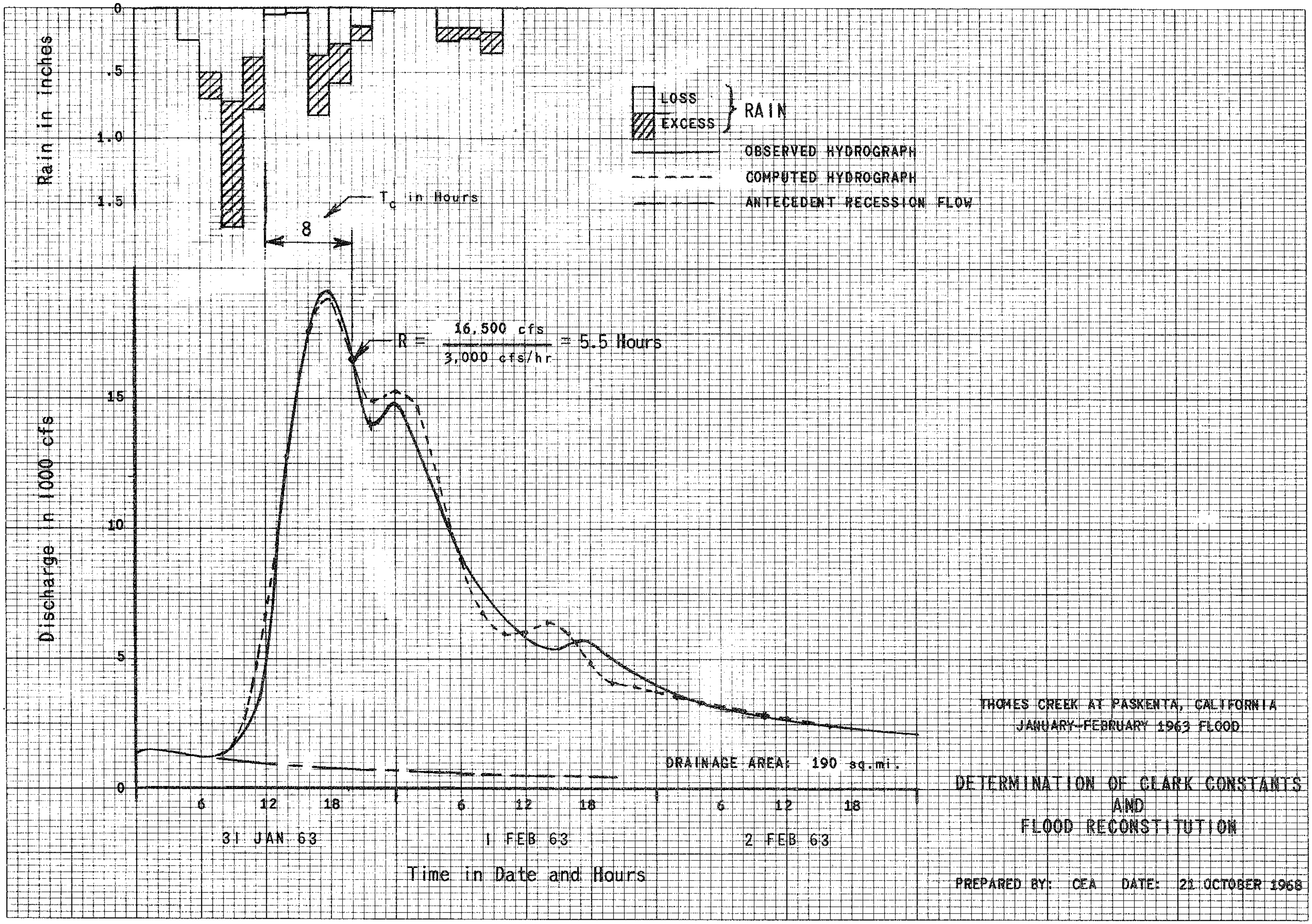
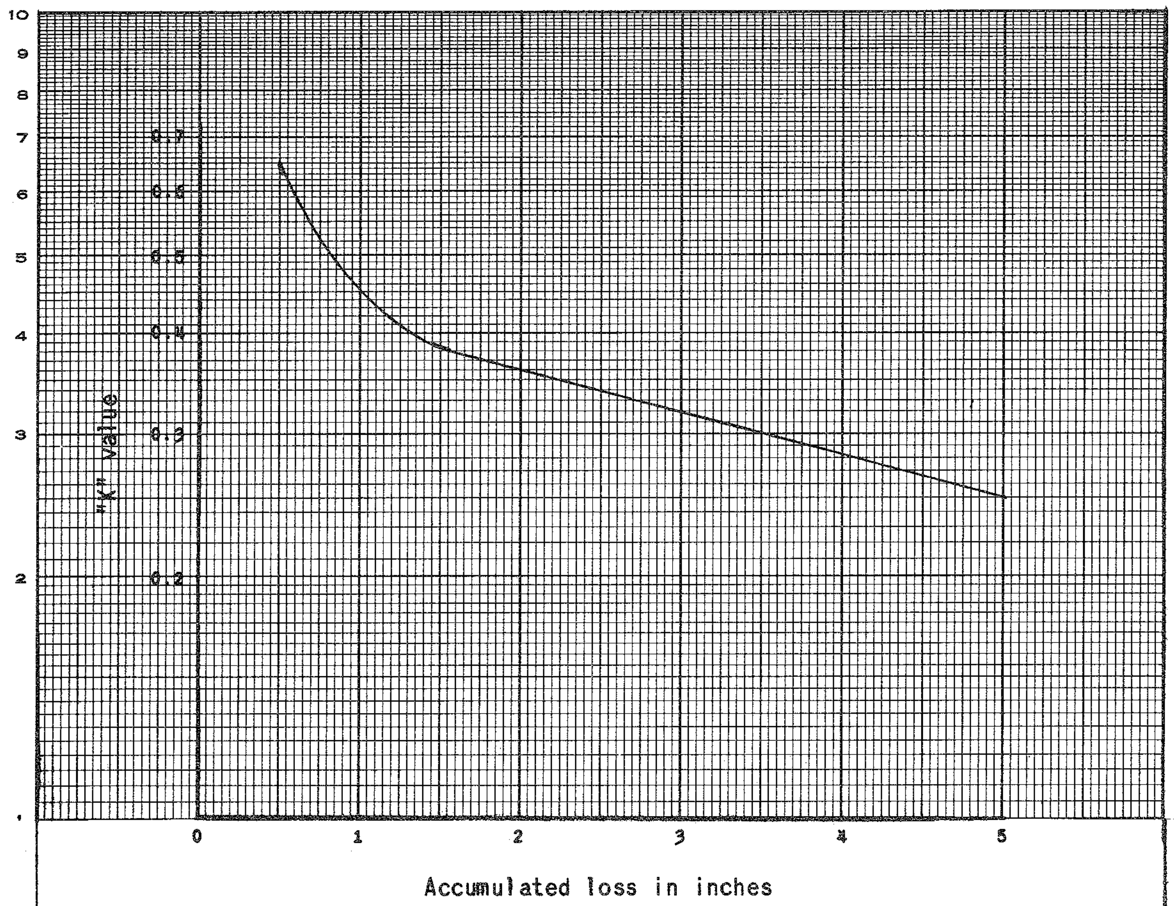


PLATE 2 ADDENDUM III


Rain in inches
0
.5
1.0
1.5
LOSS
EXCESS
RAIN
OBSERVED HYDROGRAPH
COMPUTED HYDROGRAPH
ANTECEDENT RECESSION FLOW
T_c in Hours
8
R = 16,500 cfs / 3,000 cfs/hr = 5.5 Hours
Discharge in 1000 cfs
15
10
5
0
6
12
18
31 JAN 63
1 FEB 63
2 FEB 63
Time in Date and Hours
DRAINAGE AREA: 190 sq.mi.
THOMES CREEK AT PASKENTA, CALIFORNIA
JANUARY-FEBRUARY 1963 FLOOD
DETERMINATION OF CLARK CONSTANTS
AND
FLOOD RECONSTITUTION
PREPARED BY: CEA DATE: 21 OCTOBER 1968



LOSS RATE FUNCTION:

$$L = KP^E$$

WHERE:

L = LOSS RATE IN INCHES PER HOUR
K = VALUE FROM CURVE
P = RAINFALL IN INCHES PER HOUR
E = CONSTANT FOR WATERSHED AREA

THOMES CREEK AT PASKENTA, CALIFORNIA
WATERSHED LOSS CHARACTERISTIC

DETERMINATION
OF
"K" VALUES

PREPARED BY: CEA DATE: 21 OCTOBER 1968

PLATE 4 ADDENDUM III

SAMPLE INPUT

```
A                         TEST NO. 1
A                   FLOOD HYDROGRAPH PACKAGE
A            BASIN PRECIPITATION AND HYDROGRAPH RECONSTITUTION W/O SNOW
B      2             67     11      2              1      1
B
C   1400    1400   1800   1500   1500   1500   1500   1500   1600   1900
C   2000    2000   2400   2500   2600   2700   3200   4300   5400   6200
C   8300    9800  11300  14000  18600  27100  27400  29200  34500  43100
C  43000   41800  38200  34000  32200  32800  30500  28400  26300  24700
C  23000   21000  19000  17600  16300  15300  14400  13400  12400  11400
C  10500    9600   8800   8000   7500   7000   6500   6200   5800   5500
C   5400    5700   5500   5400   5000   4800   4600
1     29    1.20     30   1.50     35     .5
D      1    1.36  18.52
D      2    1.88  16.19
D      3    1.01  15.65
D      4    2.18  18.47
D      5     .90  20.17
D      6    1.89  18.82
D      7    2.23  16.98
D      8    3.36  23.57
D      9    2.20  17.32
D     10    2.05  11.59
D     11    1.67  17.17
E      1
1    .02       0      0      0      0    .14    .06      0    .10    .04
1    .06     .01      0    .01      0      0      0      0    .01    .11
1    .19     .03    .04    .02    .05    .17    .08    .03      0    .07
1    .02     .03      0      0    .01      0
1      0
1      0
1      0
E      4
1      0       0      0    .04    .02    .03    .14    .06    .05    .01
1      0       0    .02    .01    .02      0    .16    .13    .04      0
1    .08     .03    .06    .19    .06    .01    .01      0      0    .11
1    .01       0      0      0      0      0
1      0
1      0
1      0
```


EXHIBIT 1

F	100	0		11	2	0	0	0	0	0
F										
G									10000	1.75
G	1600	0								
1	1	1	2	1	3	1	4	1	5	1
1	6	1	7	1	8	1	9	1	10	1
1	11	1								
2	1	1	4	1						
N	5696									
O	18									
P	-1	-1	0	-1			.7	0	-1	-1

A	TEST NO. 2									
A	FLOOD HYDROGRAPH PACKAGE									
A	SNOWMELT RECONSTITUTION BY ENERGY BUDGET METHOD									
B	24		122			1	1			
B										
C	9390	8840	8280	8180	8180	8020	7780	7580	7530	7950
C	9230	10700	11600	12900	14900	17500	19800	22200	22100	22400
C	24800	28900	31700	34000	33200	30400	27800	25900	24400	22700
C	21000	19700	18800	18100	17600	17200	17200	19200	23000	26200
C	28000	27600	25600	23600	22400	23200	26800	32700	39500	47200
C	53400	57400	60000	61400	60600	59400	54800	51300	50400	48800
C	47200	46900	47900	48800	46500	42700	39300	33800	28900	26600
C	27100	28100	27600	25400	23400	22600	22800	24600	24400	22000
C	21200	21200	20300	18900	17100	17400	17100	15700	14900	14200
C	13300	12200	11300	12500	13800	13400	12400	11800	11100	10500
C	10000	9660	9300	9150	8800	8400	8120	7740	7330	7040
C	6400	6130	5710	5650	5440	5100	4880	4680	4500	4400
C	4440	4480								
1	21	2.0	36	.15	52	1.5	61	.1	64	2.
F	1	0	122	0	0	0	0	0	0	
F				1						
G									10000	1.4
G	10000		3							
H	.02	.00	.00	.04	.02	.00	.02	.01	.00	.00
H	.00	.00	.00	.00	.00	.19	.32	.00	.00	.00
H	.00	.08	.04	.41	.01	.00	.03	.01	.05	.02
H	.00	.10	.15	.20	.08	.02	.12	.19	.10	.10
H	.02	.02	.06	.00	.00	.00	.00	.00	.00	.04
H	.01	.00	.04	.17	.03	.13	.04	.02	.00	.00
H	.01	.14	.08	.10	.05	.04	.04	.00	.00	.01
H	.07	.01	.00	.00	.03	.32	.63	.05	.00	.04
H	.31	.02	.00	.05	.23	.00	.00	.00	.00	.00
H	.01	.05	.29	.50	.02	.05	.03	.00	.00	.00
H	.01	.33	.01	.04	.14	.01	.00	.00	.00	.00
H	.03	.04	.00	.00	.00	.00	.00	.03	.13	.10
H	.00	.04								
I	41	40	45	48	42	39	44	47	52	52
I	51	51	55	57	57	54	53	53	57	60
I	60	55	53	51	51	54	51	51	49	47
I	50	51	44	44	52	55	57	58	58	56

 EXHIBIT 1

I	52	49	47	55	54	66	72	69	71	71
I	69	68	69	69	66	64	66	68	66	69
I	74	71	67	66	69	59	56	63	69	74
I	75	65	62	67	69	66	56	62	67	70
I	66	58	61	64	68	61	64	71	72	66
I	59	62	61	58	63	66	66	65	69	75
I	73	78	76	77	71	69	71	71	73	76
I	78	79	78	77	79	77	76	76	76	77
I	74	74								
J	28	28	31	35	24	23	32	31	34	34
J	27	31	36	34	35	45	39	36	38	41
J	40	42	39	41	40	43	42	39	39	38
J	35	42	35	40	42	43	48	51	48	44
J	31	35	41	39	42	44	43	46	49	53
J	50	48	52	56	50	52	53	44	42	46
J	50	55	53	54	53	37	42	46	51	53
J	55	37	43	48	50	57	50	51	52	58
J	51	47	46	54	46	40	49	42	44	38
J	41	47	52	54	54	57	50	52	55	61
J	59	60	54	56	57	50	49	50	53	56
J	59	57	49	50	52	49	46	56	59	61
J	51	50								
K	8.6	6.8	9.8	12.0	13.2	3.8	7.9	7.0	2.8	13.6
K	16.4	6.9	5.8	4.3	5.5	7.1	6.2	4.9	3.5	3.9
K	9.4	10.1	12.8	8.9	7.8	5.5	9.0	7.1	5.0	8.7
K	10.6	9.3	10.4	9.0	6.6	7.1	7.0	6.6	8.9	9.0
K	9.3	7.1	9.4	6.3	7.2	4.5	3.2	5.1	4.7	5.4
K	8.5	3.8	7.9	8.6	5.3	5.8	12.9	8.0	6.3	9.8
K	11.6	10.3	3.6	3.6	11.5	11.5	6.8	5.0	5.2	5.2
K	6.8	10.0	6.0	5.8	8.8	8.8	7.0	5.0	3.0	4.5
K	8.5	4.2	5.0	4.0	8.2	6.2	7.0	5.5	8.2	11.5
K	6.8	6.8	8.8	3.5	4.0	5.6	8.2	5.7	4.9	5.0
K	8.1	11.8	5.0	6.9	6.0	6.6	4.0	6.2	5.1	5.0
K	5.9	4.8	5.8	5.6	4.3	7.1	3.9	6.5	9.3	5.6
K	4.7	7.0								
L	397.9	556.5	469.9	446.1	466.3	521.9	312.5	484.1	585.0	562.2
L	513.4	557.0	576.9	600.4	538.0	315.7	352.0	595.0	556.6	568.2
L	569.2	504.7	451.2	266.9	546.0	420.7	579.9	486.5	531.0	531.1
L	394.0	380.3	371.9	155.7	551.7	414.5	532.7	404.3	499.7	269.8
L	610.0	554.7	722.9	684.9	734.0	732.5	728.4	668.8	516.2	158.2

L	772.6	709.6	531.1	302.3	752.7	471.9	559.2	789.7	751.1	753.4
L	657.2	315.3	698.8	454.2	141.3	601.3	501.8	592.4	732.7	698.5
L	202	570	531	617	212.7	108.0	107.7	717	693	124
L	538	794	628	633	589	587	467	700	771	576
L	684	490	435	445	667	244	593.3	725.0	788.6	760.4
L	687.0	600.5	603.1	495.9	658.3	719.6	723.9	737.5	727.6	724.8
L	361.6	691.8	753.6	753.0	728.4	748.9	727.1	749.1	705.0	716.3
L	742.2	719.5								
M	0	0	7	13	18	20	21	23	27	36
N	0	0	100	700	2800	2900	2300	1400	400	100
O	0	0	18	20	21	23	25	27	32	36
P	-1	-1	-1	-1	-1	-1	-1	-1	0	-1

A	TEST NO. 3									
A	FLOOD HYDROGRAPH PACKAGE									
A	TEST OF SPFE, PMS AND ROUTING AND COMBINING ROUTINES									
B	2		60							
B	3									
F	1									1
F										
G			29.50	0.867	100	0.50	0.15	0	0	1.00
G	0						100			
3	89.0	100.0	107.0	118.0						
P	7.67	2.92								
U	2		2	1	-1					-1
U										
2	0	10000	25000	40000	55000	70000	85000	100000	250000	
3	100	100	1000	5000	10000	20000	30000	40000	50000	
F	2		45				11		2	1
F										
G	19.95								1770	1.49
G	1860			.8			177			
H	0	.001	.002	.001	.001	.003	.009	.005	.006	.012
H	.021	.031	.051	.055	.045	.046	.040	.034	.040	.049
H	.056	.066	.079	.0135	.045	.022	.009	.009	.014	.013
H	.002	.005	.014	.008	.001	.000	.005	.007	.013	.021
H	.010	.005	.004	.003	.002					
P	3.68	2.94		1.02			.7		1.02	4.0
Q	0	3	8	17	23	33	50	66	79	94
Q	100									
U	4	3	0			0				-1
U	2	100	.2							
F	3									1
F										
G		14.0		0.867	100	1.00	.20	0	0	1.00
G	0	2.1					100			
P	7.67	2.92								
U	4	1					3.2	.2	2	1
U		20	.1							
U	5		2							-1
U	3									
F	5	1							2	0
F										

NOTE: Schematic diagram and input data sequence are shown on page 13 of this exhibit.

G					200					
G							200			
S	0									
S	0									170
S	1180	2190	2370	1550	780	390	195	525	2040	4480
S	8440	18500	39900	58600	58600	40800	22300	11600	5960	3000
S	1490	690	175	20	8					
S										

```
A                                          TEST NO. 4A
A                                     FLOOD HYDROGRAPH PACKAGE
A                              STREAMFLOW OPTIMIZATION-PLATE 3 EM 1110-2-1408
B      12              15                                  1
B
C    2000    7000   11700   16500   24000   29100   28400   23800   19400   15300
C   11200    8200    6400    5200    4600
1
F       1       1                                                               1
F
G                                     100
G
S    2200   14500   28400   31800   29700   25300   20400   16300   12600    9300
S    6700    5000    4100    3600    2400
U       2      -1                                      -1      -1
U                               0
1    2000    7000   11700   16500   24000   29100   28400   23800   19400   15300
1   11200    8200    6400    5200    4600
```

 EXHIBIT I

```
A                                      TEST 6
                                FLOOD HYDROGRAPH PACKAGE
A                                  BALANCED HYDROGRAPH
B       2               72
B
F       1       1
F                        1
G                                        1000
G
S   42000   40000   41000   45000   54000   69000   95000  131000  163000  170000
S  158000  148000  133000  118000  107000   99000   92000   90000   86000   85000
S   88000   99000  128000  149000  173000  189000  208000  230000  254000  277000
S  300000  326000  361000  402000  428000  440000  431000  411000  395000  353000
S  322000  296000  281000  268000  254000  238000  224000  210000  199000  189000
S  180000  172000  164000  158000  151000  145000  139000  134000  130000  126000
S  122000  118000  114000  111000  107000  104000  100000   97000   94000   91000
S   87000   84000
T       1  310000       3  873000       6 1650000      12 3000000      36 6300000
```

A					TEST NO. 7					
A					FLOOD HYDROGRAPH PACKAGE					
A					SYSTEM INTERPOLATION ROUTINE					
B	2		96						5	
B	4									
I	1000	9.08	3000	8.93	5000	8.70	7000	8.57	9000	8.43
F	4865		96							1
F										
G				1	3503				3000	1.30
G	1200						3503			
H	.0000	.0000	.0000	.0014	.0015	.0048	.0092	.0048	.0048	.0063
H	.0131	.0141	.0189	.0237	.0189	.0141	.0092	.0048	.0029	.0015
H	.0029	.0000	.0000	.0000	.0087	.0175	.0175	.0175	.0039	.0087
H	.0000	.0000	.0140	.0000	.0097	.0184	.0000	.0000	.0310	.0000
H	.0000	.0209	.0179	.0155	.0155	.0058	.0131	.0155	.0063	.0097
H	.0087	.0126	.0175	.0146	.0121	.0141	.0141	.0136	.0126	.0155
H	.0170	.0233	.0209	.0276	.0340	.0660	.0209	.0184	.0170	.0155
H	.0146	.0126	.0073	.0107	.0049	.0073	.0034	.0024	.0000	.0000
H	.0107	.0000	.0107	.0310	.0048	.0281	.0141	.0048	.0039	.0087
H	.0000	.0000	.0000	.0000	.0000	.0000				
P	12.3	8.6		.4		2.2	.7			4
U	4890	24								-1
U	.2									
F	4885		-96							1
F										
G				1	1750				700	1.34
G	280						1750			
P	6.6	4.6		.33		2.2	.7			4
U	4890	12								-1
U	2									
F	4890		-96						3	
F										
G				1	3296				1000	1.34
G	400						3296			
P	13.2	9.2		.39		2.2	.7			4

NOTE: Schematic diagram and input data sequence are shown on page 14 of this exhibit.

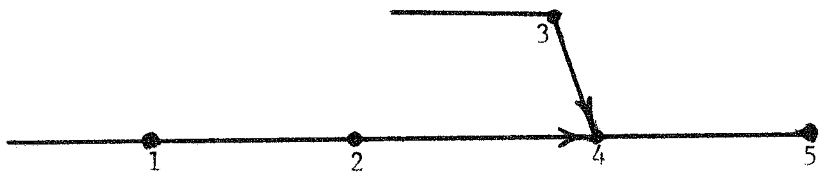
TEST 8
FLOOD HYDROGRAPH PACKAGE
MULTIPLE FLOOD TEST

A										
B	3		100							2
B	3									
2	8	.5	.6	.7	.8	.95	1.1	1.3	1.6	
F	-1		24							1
F										
G				1	2851				13300	1.17
G	3990			1					-1	
H	.09	.09	.17	.17	.35	.35	.13	.13	.28	.28
H	.58	.58	.94	1.40	.45	.45	.05	.05	.09	.09
H	.19	.19	.07	.07						
N	1514									
O	46									
P	66.1	66.1		.20			.50		.20	3.00
U	-3	1	6							-1
U	12					-1				
F	-2		24							1
F										
G				1	2851				5240	1.37
G	1570			1						
H	.09	.09	.17	.17	.35	.35	.13	.13	.28	.28
H	.58	.58	.94	1.40	.45	.45	.05	.05	.09	.09
H	.19	.19	.07	.07						
N	507									
O	45									
P	26.2	26.2		.20			.50		.20	3.00
U	-3	1	4						2	-1
U	9					-2				
F	-3		24						2	1
F										
G				1	2851				5240	1.38
G	1570			1					-2	
H	.09	.09	.17	.17	.35	.35	.13	.13	.28	.28
H	.58	.58	.94	1.40	.45	.45	.05	.05	.09	.09
H	.19	.19	.07	.07						
N	395									
O	48									
P	28.1	28.1		.20			.50		.20	3.0

NOTE: Schematic diagram and input data sequence are shown on page 15 of this exhibit.

U	-4	1	4							-1
U	9					-1				
F	-4		24						2	1
F										
G				1	2851				3650	1.23
G	1090								-1	
H	.09	.09	.17	.17	.35	.35	.13	.13	.28	.28
H	.58	.58	.94	1.40	.45	.45	.05	.05	.09	.09
H	.19	.19	.07	.07						
N	435									
O	42									
P	44.4	44.4		.20			.50		.20	3.0
U	5			-1						1
U										
U	5			1	-1					0
U					3					
2	0	11400	152000							
3	0	27600	27600							
V	-5	.20	.14	.10	.06	.04	.03	.02	.01	
1	8	34500	38000	43000	47000	53000	59000	70000	91000	
2	110.9	5.	40.	115.	215.	370.	580.	1030.	2600.	
2	44.4	2.	16.	46.	86.	148.	232.	412.	1040.	
2	66.5	3.	24.	69.	129.	222.	348.	618.	1440.	

EXHIBIT 1

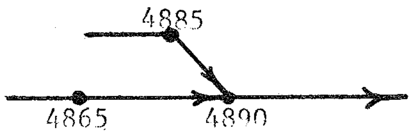


Schematic Diagram for Test No. 3

Input Data Sequence

	Operation	Input Cards	Key Indicators
1.	Compute probable maximum flood at 1	A, B, F, G, G3, P	NCOMB = 0 NEXT = 1
2.	Route hydrograph from 1 to 2 by storage-lag method	U, U2, U3	NCOMB = 0 NEXT = -1
3.	Compute hydrograph for local area between 1 and 2 and combine with routed hydrograph from 1	F, G, H, P, U	NCOMB = 2 NEXT = 1
4.	Route combined hydrograph at 2 to 4 by Tatum method	U	NCOMB = 0 NEXT = -1
5.	Compute standard project flood at 3	F, G, P	NCOMB = 0 NEXT = 1
6.	Route hydrograph at 3 to 4 by Muskingum method and combine with hydrograph previously routed from 2 to 4 (local runoff negligible)	U	NCOMB = 2 NEXT = 1
7.	Route combined hydrograph at 4 to 5 by straddle-stagger method	U	NCOMB = 0 NEXT = -1
8.	Read in local flow between 4 and 5 and combine with routed hydrograph from 4	F, G, S	NCOMB = 2 NEXT = 0

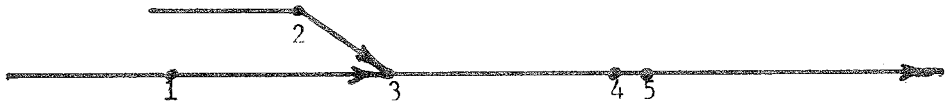
EXHIBIT 1



Schematic Diagram for Test No. 7

Input Data Sequence

Operation	Input Cards	Key Indicators
1. Compute hydrograph at 4865 by interpolation between closest 2 of 5 system floods	A, B, F, G, H, P	NSTM = 5 NCOMB = 0 NEXT = 1
2. Route 5 system floods from 4865 to 4890 and interpolate to obtain routed hydrograph	U	NCOMB = 0 NEXT = -1
3. Compute hydrograph at 4885 by interpolation between closest 2 of 5 system floods	F, G, P	NP = -96 NCOMB = 0 NEXT = 1
4. Route 5 system floods from 4885 to 4890 and interpolate to obtain routed hydrograph	U	NCOMB = 0 NEXT = -1
5. Compute local hydrograph for area below 4865 and 4885 and above 4890 by interpolation between closest 2 of 5 system floods and combine with routed hydrographs	F, G, P	NP = -96 NCOMB = 3 NEXT = 0



Schematic Diagram for Test No. 8

Input Data Sequence

Operation	Input Cards	Key Indicators
1. Compute hydrograph at 1	A, B, B2, F, G, H, P	NPLAN = 2 NRTIO = 8 NCOMB = 0 NEXT = 1 NDMG = 0
2. Route hydrograph at 1 to 3	U	NCOMB = 0 NEXT = -1 NDMG = 0
3. Compute hydrograph at 2	F, G, H, P	NCOMB = 0 NEXT = 1 NDMG = 0
4. Route hydrograph at 2 to 3 and combine with hydrograph routed from 1	U	NCOMB = 2 NEXT = -1 NDMG = 0
5. Compute hydrograph for local area below 1 and 2 and above 3 and combine with routed hydrographs	F, G, H, P	NCOMB = 2 NEXT = 1 NDMG = 0
6. Route combined hydrographs at 3 to 4	U	NCOMB = 0 NEXT = -1 NDMG = 0
7. Compute hydrograph for local area below 3 & above 4 and combine with routed hydrograph from 3	F, G, H, P	NCOMB = 2 NEXT = 1 NDMG = 0
8. For Plan 1 (no development), no reservoir routing	U	IRES = -1 NCOMB = 0 NEXT = 1 NDMG = 0

Operation	Input Cards	Key Indicators
9. For Plan 2 (proposed reservoir), route combined hydrographs at 4 through reservoir 5	U, U2, U3	IRES = 1 NCOMB = 0 NEXT = 0 NDMG = 3
10. Compute average annual damages for each plan	V2	

TEST NO. 1
FLOOD HYDROGRAPH PACKAGE
BASIN PRECIPITATION AND HYDROGRAPH RECONSTITUTION W/O SNOW

NHR	NMIN	NQ	NSTAN	NSTAR	ISNOW	IDERV	IPLOT	NSTM	NPLAN
2	-0	67	11	2	-0	1	1	-0	-0

IPRNT	METRC	IDGST	IDAYX	IHRX	IMINX
-0	-0	-0	-0	-0	-0

IQ	RQ	IQ	RQ	IQ	RQ	IQ	RQ	IQ	RQ
29	1.20	30	1.50	35	.50	-0	-.00	-0	-.00

NON-RECORDING PRECIP

STA	STORM	NAP
1	1.36	18.52
2	1.88	16.19
3	1.01	15.65
4	2.18	18.47
5	.90	20.17
6	1.89	18.82
7	2.23	16.98
8	3.36	23.57
9	2.20	17.32
10	2.05	11.59
11	1.67	17.17

RECORDING PRECIP

1									
.02	.00	.00	.00	.00	.14	.06	.00	.10	.04
.06	.01	.00	.01	.00	.00	.00	.00	.01	.11
.19	.03	.04	.02	.05	.17	.08	.03	.00	.07
.02	.03	.00	.00	.01	.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00			
4									
.00	.00	.00	.04	.02	.03	.14	.06	.05	.01
.00	.00	.02	.01	.02	.00	.16	.13	.04	.00

.08	.03	.06	.19	.06	.01	.01	.00	.00	.11
.01	.00	.00	.00	.00	.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00
.00	-.00	-.00	-.00	-.00	-.00	-.00			

ISTAQ	IHDGR	NP	NSTN	NSTR	NUHGQ	NCLRK	LOCAL	NCOMB	NEXT
100	0	-0	11	2	0	0	0	0	0

IPNT	NDMG	IBAL	INRGY
-0	-0	-0	-0

STORM	SPFE	PMS	TRSPC	TRSDA	STRTL	CNSTL	RTIMP	QRCSN	RTIOR
-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	10000.0	1.75

STRTQ	ALSMX	TLAPS	RATIO	TP	CP	TAREA
1600.	.00	-.00	-.00	-.00	-.00	-.00

PRECIP STA WT

NON RECORDING PRECIP

1	1.00	2	1.00	3	1.00	4	1.00	5	1.00
6	1.00	7	1.00	8	1.00	9	1.00	10	1.00
11	1.00								

RECORDING PRECIP

1	1.00	4	1.00

SNOW=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
AREA=	5696.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0	-.0
NAP=	18.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00	-.00

AREA= 5696.0 NAP= 18.00

INPUT DATA

TC	R	COEF	STRKR	STRKS	RTIOK	ERAIN	FRZTP	DLTKR	RTIOL
-1.00	-1.00	.00	-1.00	-.00	-.00	.70	.00	-1.00	-1.00

INITIAL ESTIMATES

TC+R	R/(TC+R)	COEF	STRKR	STRKS	RTIOK	ERAIN	FRZTP	DLTKR	RTIOL
37.74	.50	.00	.20	-.00	-.00	.70	.00	.50	2.00

DERIVED VARIABLES

16.83	.60	.00	.27	-.00	-.00	.70	.00	1.10	3.42

INFILTRATION INDEX = .081

STRKR FOR RTIOL OF 3. = .28

OPTIMIZATION RESULTS

TC	R	COEF	STRKR	STRKS	RTIOK	ERAIN	FRZTP	DLTKR	RTIOL
13.55	20.12	.00	.28	-.00	-.00	.70	.00	1.16	3.42

UNIT HYDROGRAPH 57 END-OF-PERIOD ORDINATES, LAG= 13.29 HOURS, CP= .47 VOL= 1.00

6978.	26055.	52870.	82880.	109278.	126416.	139928.	123278.	111601.	101031.
91462.	82799.	74957.	67857.	61430.	55611.	50344.	45576.	41259.	37351.
33813.	30611.	27711.	25087.	22711.	20560.	18612.	16849.	15253.	13809.
12501.	11317.	10245.	9275.	8396.	7601.	6881.	6229.	5639.	5105.
4622.	4184.	3788.	3429.	3104.	2810.	2544.	2303.	2085.	1887.
1709.	1547.	1400.	1268.	1148.	1039.	940.			

TIME	RAIN	EXCS	END-OF-PERIOD FLOW COMP Q	OBS Q
1	.01	.00	1513.	1400.
2	.00	.00	1431.	1400.
3	.00	.00	1353.	1800.
4	.03	.00	1279.	1500.
5	.01	.00	1209.	1500.
6	.12	.00	1144.	1500.
7	.14	.00	1099.	1500.
8	.04	.00	1088.	1500.
9	.11	.01	1158.	1600.
10	.03	.00	1341.	1900.
11	.04	.00	1582.	2000.
12	.01	.00	1829.	2000.
13	.01	.00	2016.	2400.
14	.01	.00	2098.	2500.

15	.01	.00	2067.	2600.
16	.00	.00	1954.	2700.
17	.11	.03	1970.	3200.
18	.09	.02	2496.	4300.
19	.03	.00	3516.	5400.
20	.08	.02	4950.	6200.
21	.19	.09	7202.	8300.
22	.04	.01	10366.	9800.
23	.07	.02	13943.	11300.
24	.15	.07	17889.	14000.
25	.08	.03	22141.	18600.
26	.13	.06	26563.	27100.
27	.05	.02	30818.	27400.
28	.02	.00	34257.	29200.
29	.00	.00	36705.	34500.
30	.13	.06	38207.	43100.
31	.02	.00	38741.	43000.
32	.02	.00	38413.	41800.
33	.00	.00	37461.	38200.
34	.00	.00	36061.	34000.
35	.01	.00	34309.	32200.
36	.00	.00	32083.	32800.
37	.00	.00	29378.	30500.
38	.00	.00	26631.	28400.
39	.00	.00	24122.	26300.
40	.00	.00	21845.	24700.
41	.00	.00	19783.	23000.
42	.00	.00	17915.	21000.
43	.00	.00	16225.	19000.
44	.00	.00	14694.	17600.
45	.00	.00	13308.	16300.
46	.00	.00	12052.	15300.
47	.00	.00	10916.	14400.
48	.00	.00	10322.	13400.
49	.00	.00	9760.	12400.
50	.00	.00	9229.	11400.
51	.00	.00	8726.	10500.
52	.00	.00	8252.	9600.
53	.00	.00	7802.	8800.
54	.00	.00	7378.	8000.

55	.00	.00	6976.	7500.
56	.00	.00	6597.	7000.
57	.00	.00	6238.	6500.
58	.00	.00	5898.	6200.
59	.00	.00	5577.	5800.
60	.00	.00	5274.	5500.
61	.00	.00	4987.	5400.
62	.00	.00	4715.	5700.
63	.00	.00	4459.	5500.
64	.00	.00	4216.	5400.
65	.00	.00	3986.	5000.
66	.00	.00	3769.	4800.
67	.00	.00	3564.	4600.
SUM	1.83	.44	826846.	879700.

NOTE: Sample plotting is shown on page 42 of this exhibit.

```
                              TEST NO. 2
                        FLOOD HYDROGRAPH PACKAGE
                SNOWMELT RECONSTITUTION BY ENERGY BUDGET METHOD

     NHR     NMIN       NQ    NSTAN    NSTAR    ISNOW    IDERV    IPLOT     NSTM    NPLAN
      24       -0      122       -0       -0        1        1       -0       -0       -0

   IPRNT    METRC    IDGST    IDAYX     IHRX    IMINX
      -0       -0       -0       -0       -0       -0

      IQ       RQ       IQ       RQ       IQ       RQ       IQ       RQ       IQ       RQ
      21     2.00       36      .15       52     1.50       61      .10       64     2.00

   ISTAQ    IHDGR       NP     NSTN     NSTR    NUHGQ    NCLRK    LOCAL    NCOMB     NEXT
       1        0      122        0        0        0        0        0        0       -0

    IPNT     NDMG     IBAL    INRGY
      -0       -0       -0        1

   STORM     SPFE      PMS    TRSPC    TRSDA    STRTL    CNSTL    RTIMP    QPCSN    RTIOR
    -.00     -.00     -.00     -.00     -.00     -.00     -.00     -.00  10000.0     1.40

   STRTQ    ALSMX    TLAPS    RATIO       TP       CP    TAREA
  10000.     -.00     3.00     -.00     -.00     -.00     -.00

   SNOW=       .0       .0      7.0     13.0     18.0     20.0     21.0     23.0     27.0     36.0

   AREA=       .0       .0    100.0    700.0   2800.0   2900.0   2300.0   1400.0    400.0    100.0

    NAP=      .00      .00    18.00    20.00    21.00    23.00    25.00    27.00    32.00    36.00

 AREA= 10700.0      NAP=   23.64

 INPUT DATA

      TC        R     COEF    STRKR    STRKS    RTIOK    ERAIN    FRZTP    DLTKR    RTIOL
   -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00      .00    -1.00

 INITIAL ESTIMATES
```

TC+R	R/(TC+R)	COEF	STRKR	STRKS	RTIOK	ERAIN	FRZTP	DLTKR	RTIOL
4.31	.50	1.00	.20	.20	2.00	.50	32.00	.00	2.00

DERIVED VARIABLES

9.47	.89	.67	.17	.17	1.55	.56	31.78	.00	2.00

INFILTRATION INDEX = .267

OPTIMIZATION RESULTS

TC	R	COEF	STRKR	STRKS	RTIOK	ERAIN	FRZTP	DLTKR	RTIOL
45.51	181.83	.67	.17	.17	1.55	.56	31.78	.00	2.00

UNIT HYDROGRAPH 42 END-OF-PERIOD ORDINATES, LAG= 49.49 HOURS, CP= .22 VOL= 1.00

9621.	26232.	31166.	27307.	23926.	20963.	18368.	16094.	14101.	12355.
10825.	9485.	8311.	7282.	6380.	5590.	4898.	4291.	3760.	3295.
2887.	2529.	2216.	1942.	1701.	1491.	1306.	1144.	1003.	878.
770.	674.	591.	518.	454.	397.	348.	305.	267.	234.
205.	180.								

							END-OF-PERIOD FLOW	
TIME	PRECIP	TEMP	SNOMLT	SNOW EX	RAIN	RAIN EX	COMP Q	OBS Q
1	.02	41.0	.06	.00	.00	-.00	9669.	9390.
2	.00	40.0	.19	.00	.00	-.00	9349.	8840.
3	.00	45.0	.17	.00	.00	-.00	9040.	8280.
4	.04	48.0	.13	.00	.01	.00	8753.	8180.
5	.02	42.0	.06	.00	.00	.00	8485.	8180.
6	.00	39.0	.18	.00	.00	-.00	8211.	8020.
7	.02	44.0	.07	.00	.00	.00	7940.	7780.
8	.01	47.0	.10	.00	.00	.00	7677.	7580.
9	.00	52.0	.29	.00	.00	-.00	7436.	7530.
10	.00	52.0	.33	.01	.00	-.00	7332.	7950.
11	.00	51.0	.32	.01	.00	-.00	7413.	9230.
12	.00	51.0	.33	.02	.00	-.00	7583.	10700.
13	.00	55.0	.41	.04	.00	-.00	8046.	11600.
14	.00	57.0	.46	.07	.00	-.00	9170.	12900.
15	.00	57.0	.45	.06	.00	-.00	10735.	14900.
16	.19	54.0	.30	.06	.15	.03	12499.	17500.
17	.32	53.0	.24	.06	.18	.05	14686.	19800.
18	.00	53.0	.40	.07	.00	-.00	16804.	22200.
19	.00	57.0	.44	.09	.00	-.00	18274.	22100.

20	.00	60.0	.51	.12	.00	-.00	19819.	22400.
21	.00	60.0	.57	.16	.00	-.00	22298.	24800.
22	.08	55.0	.39	.11	.06	.02	25142.	28900.
23	.04	53.0	.34	.09	.02	.01	27018.	31700.
24	.41	51.0	.20	.07	.23	.09	28392.	34000.
25	.01	51.0	.19	.03	.01	.00	29162.	33200.
26	.00	54.0	.34	.07	.00	-.00	28429.	30400.
27	.03	51.0	.20	.04	.02	.00	27195.	27800.
28	.01	51.0	.18	.03	.01	.00	25749.	25900.
29	.05	49.0	.11	.01	.01	.00	23813.	24400.
30	.02	47.0	.08	.00	.00	.00	21615.	22700.
31	.00	50.0	.17	.01	.00	-.00	19464.	21000.
32	.10	51.0	.17	.04	.06	.01	18077.	19700.
33	.15	44.0	.06	.00	.00	.00	17172.	18800.
34	.20	44.0	.07	.00	.00	.00	15773.	18100.
35	.08	52.0	.18	.04	.04	.01	14588.	17600.
36	.02	55.0	.29	.08	.02	.00	14702.	17200.
37	.12	57.0	.36	.14	.11	.03	16572.	17200.
38	.19	58.0	.40	.17	.18	.06	20642.	19200.
39	.10	58.0	.45	.19	.09	.03	25998.	23000.
40	.10	56.0	.37	.15	.08	.03	30590.	26200.
41	.02	52.0	.21	.06	.01	.00	32530.	28000.
42	.02	49.0	.11	.01	.01	.00	31330.	27600.
43	.06	47.0	.08	.00	.00	.00	28424.	25600.
44	.00	55.0	.36	.11	.00	-.00	26338.	23600.
45	.00	54.0	.41	.14	.00	-.00	26666.	22400.
46	.00	66.0	.58	.26	.00	-.00	29563.	23200.
47	.00	72.0	.66	.32	.00	-.00	35020.	26800.
48	.00	69.0	.54	.24	.00	-.00	41027.	32700.
49	.00	71.0	.40	.18	.00	-.00	44718.	39500.
50	.04	71.0	.54	.29	.04	.01	47364.	47200.
51	.01	69.0	.62	.34	.01	.00	51825.	53400.
52	.00	68.0	.47	.24	.00	-.00	56501.	57400.
53	.04	69.0	.59	.34	.04	.02	60140.	60000.
54	.17	69.0	.63	.39	.17	.07	65497.	61400.
55	.03	66.0	.24	.10	.03	.01	69570.	60600.
56	.13	64.0	.20	.09	.13	.03	67862.	59400.
57	.04	66.0	.35	.20	.04	.01	64604.	54800.
58	.02	68.0	.30	.16	.02	.00	63005.	51300.
59	.00	66.0	.30	.16	.00	-.00	61533.	50400.

60	.00	69.0	.34	.19	.00	-.00	60128.	48800.
61	.01	74.0	.51	.33	.01	.00	60752.	47200.
62	.14	71.0	.41	.27	.14	.04	63795.	46900.
63	.08	67.0	.09	.04	.08	.01	64672.	47900.
64	.10	66.0	.07	.03	.10	.01	60614.	48800.
65	.05	69.0	.15	.09	.05	.01	55377.	46500.
66	.04	59.0	.05	.02	.04	.00	50940.	42700.
67	.04	56.0	.02	.00	.03	.00	45943.	39300.
68	.00	63.0	.07	.03	.00	-.00	40820.	33800.
69	.00	69.0	.10	.05	.00	-.00	36893.	28900.
70	.01	74.0	.14	.08	.01	.00	34379.	26600.
71	.07	75.0	.16	.10	.07	.01	33159.	27100.
72	.01	65.0	.10	.06	.01	.00	32354.	28100.
73	.00	62.0	.08	.04	.00	-.00	30752.	27600.
74	.00	67.0	.10	.06	.00	-.00	28721.	25400.
75	.03	69.0	.03	.02	.03	.00	26730.	23400.
76	.32	66.0	.02	.01	.32	.01	24520.	22600.
77	.63	56.0	.02	.00	.50	.00	22196.	22800.
78	.05	62.0	.06	.03	.05	.00	20079.	24600.
79	.00	67.0	.05	.02	.00	-.00	18431.	24400.
80	.04	70.0	.02	.01	.04	.00	16970.	22000.
81	.31	66.0	.02	.01	.31	.01	15584.	21200.
82	.02	58.0	.00	.00	.02	.00	14275.	21200.
83	.00	61.0	.01	.01	.00	-.00	12837.	20300.
84	.05	64.0	.01	.01	.05	.00	11485.	18900.
85	.23	68.0	.03	.02	.23	.01	10549.	17100.
86	.00	61.0	.02	.01	.00	-.00	10200.	17400.
87	.00	64.0	.02	.01	.00	-.00	9862.	17100.
88	.00	71.0	.03	.02	.00	-.00	9536.	15700.
89	.00	72.0	.03	.02	.00	-.00	9220.	14900.
90	.00	66.0	.03	.01	.00	-.00	8915.	14200.
91	.01	59.0	.01	.00	.01	.00	8620.	13300.
92	.05	62.0	.01	.01	.05	.00	8335.	12200.
93	.29	61.0	.01	.01	.29	.01	8059.	11300.
94	.50	58.0	.00	.00	.47	.00	7793.	12500.
95	.02	63.0	.01	.00	.02	.00	7535.	13800.
96	.05	66.0	.02	.01	.05	.00	7285.	13400.
97	.03	66.0	.02	.01	.03	.00	7044.	12400.
98	.00	65.0	.03	.02	.00	-.00	6811.	11800.
99	.00	69.0	.03	.02	.00	-.00	6586.	11100.

100	.00	75.0	.03	.02	.00	-.00	6368.	10500.
101	.01	73.0	.01	.00	.01	.00	6157.	10000.
102	.33	78.0	.01	.01	.33	.00	5954.	9660.
103	.01	76.0	.01	.00	.01	.00	5757.	9300.
104	.04	77.0	.01	.00	.04	.00	5566.	9150.
105	.14	71.0	.00	.00	.14	.00	5382.	8800.
106	.01	69.0	.00	.00	.01	.00	5204.	8400.
107	.00	71.0	.01	.00	.00	-.00	5032.	8120.
108	.00	71.0	.01	.00	.00	-.00	4865.	7740.
109	.00	73.0	.01	.00	.00	-.00	4704.	7330.
110	.00	76.0	.01	.00	.00	-.00	4549.	7040.
111	.03	78.0	.01	.00	.03	.00	4398.	6400.
112	.04	79.0	.01	.00	.04	.00	4253.	6130.
113	.00	78.0	.01	.01	.00	-.00	4112.	5710.
114	.00	77.0	.01	.01	.00	-.00	3976.	5650.
115	.00	79.0	.01	.01	.00	-.00	3844.	5440.
116	.00	77.0	.01	.01	.00	-.00	3717.	5100.
117	.00	76.0	.01	.01	.00	-.00	3594.	4880.
118	.03	76.0	.01	.00	.03	.00	3475.	4680.
119	.13	76.0	.01	.01	.13	.00	3360.	4500.
120	.10	77.0	.01	.00	.10	.00	3249.	4400.
121	.00	74.0	.01	.01	.00	-.00	3141.	4440.
122	.04	74.0	.00	.00	.04	.00	3038.	4480.
SUM	7.00	62.	21.30	7.45	5.70	.64	2677280.	2685210.

```
                           TEST NO. 3
                    FLOOD HYDROGRAPH PACKAGE
       TEST OF SPFE, PMS AND ROUTING AND COMBINING ROUTINES

   NHR    NMIN      NQ   NSTAN   NSTAR   ISNOW   IDERV   IPLOT    NSTM   NPLAN
     2      -0      60      -0      -0      -0      -0      -0      -0      -0

 IPRNT   METRC   IDGST   IDAYX    IHRX   IMINX
     3      -0      -0      -0      -0      -0

 ISTAQ   IHDGR      NP    NSTN    NSTR   NUHGQ   NCLRK   LOCAL   NCOMB    NEXT
     1      -0      -0      -0      -0      -0      -0      -0      -0       1

  IPNT    NDMG    IBAL   INRGY
    -0      -0      -0      -0

 STORM    SPFE     PMS   TRSPC   TRSDA   STRIL   CNSTL   RTIMP   QRCSN   RTIOR
  -.00    -.00   29.50     .87  100.00     .50     .15     .00      .0    1.00

 STRTQ   ALSMX   TLAPS   RATIO      TP      CP   TAREA
    0.    -.00    -.00    -.00    -.00    -.00  100.00

PMS PERCENTS   89.00  100.00  107.00  118.00    -.00    -.00

                         PEAK   6-HOUR  24-HOUR  72-HOUR
              CFS     166518.  149014.   63696.   22589.
           INCHES               13.86    23.70    25.22
            AC-FT               73929.  126404.  134484.

 ISTAQ   NSTPS     LAG    IRES   STORA     TSK   AMSKK       X   NCOMB    NEXT
     2      -0       2       1     -1.    -.00    -.00    -.00      -0      -1

 NSTDL   QLOSS   CLOSS     AVG    NDMG    IPNT   JPLOT
    -0    -.00    -.00     -0.      -0      -0      -0

                         PEAK   6-HOUR  24-HOUR  72-HOUR
              CFS      40730.   40648.   34339.   17692.
           INCHES                3.78    12.78    19.75
            AC-FT               20166.   68146.  105330.
```

```
   ISTAQ    IHDGR       NP     NSTN     NSTR    NUHGQ    NCLRK    LOCAL    NCOMB     NEXT
       2       -0       45       -0       -0       -0       11       -0        2        1

    IPNT     NDMG     IBAL    INRGY
      -0       -0       -0       -0

   STORM     SPFE      PMS    TRSPC    TRSDA    STRIL    CNSTL    RTIMP    QRCSN    RTIOR
   19.95     -.00     -.00     -.00     -.00     -.00     -.00     -.00   1770.0     1.49

   STRTQ    ALSMX    TLAPS    RATIO       TP       CP    TAREA
   1860.     -.00     -.00      .80     -.00     -.00   177.00

                           PEAK   6-HOUR  24-HOUR  72-HOUR
                  CFS    49295.   45244.   29931.   14230.
               INCHES               2.38     6.29     8.97
                AC-FT             22446.   59399.   84719.
HYDROGRAPH MULTIPLIED BY  .800

END-OF-PERIOD COMBINED FLOWS AT      2

                           PEAK   6-HOUR  24-HOUR  72-HOUR
                  CFS    66847.   64503.   49924.   27952.
               INCHES               2.17     6.71    11.26
                AC-FT             32001.   99075.  166411.

   ISTAQ    NSTPS      LAG     IRES    STORA      TSK    AMSKK        X    NCOMB     NEXT
       4        3        0       -0      -0.      .00     -.00     -.00       -0       -1

   NSTDL    QLOSS    CLOSS      AVG     NDMG     IPNT
       2   100.00      .20      -0.       -0       -0

                           PEAK   6-HOUR  24-HOUR  72-HOUR
                  CFS    50991.   49569.   39574.   22253.
               INCHES               1.66     5.32     8.97
                AC-FT             24593.   78535.  132485.

   ISTAQ    IHDGR       NP     NSTN     NSTR    NUHGQ    NCLRK    LOCAL    NCOMB     NEXT
       3       -0       -0       -0       -0       -0       -0       -0       -0        1
```

IPNT	NDMG	IBAL	INRGY
-0	-0	-0	-0

STORM	SPFE	PMS	TRSPC	TRSDA	STRTL	CNSTL	RTIMP	QRCSN	RTIOR
-.00	14.00	-.00	.87	100.00	1.00	.20	.00	.0	1.00

STRTQ	ALSMX	TLAPS	RATIO	TP	CP	TAREA
0.	2.10	-.00	-.00	-.00	-.00	100.00

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	58734.	52636.	22793.	7893.
INCHES		4.90	8.48	8.81
AC-FT		26114.	45232.	46992.

ISTAQ	NSTPS	LAG	IRES	STORA	TSK	AMSKK	X	NCOMB	NEXT
4	1	-0	-0	-0.	-.00	3.20	.20	2	1

NSTDL	QLOSS	CLOSS	AVG	NDMG	IPNT
-0	20.00	.10	-0.	-0	-0

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	45260.	41884.	20287.	7089.
INCHES		3.90	7.55	7.91
AC-FT		20780.	40259.	42203.

END-OF-PERIOD COMBINED FLOWS AT 4

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	70128.	67040.	53385.	29342.
INCHES		1.65	5.27	8.69
AC-FT		33260.	105942.	174688.

ISTAQ	NSTPS	LAG	IRES	STORA	TSK	AMSKK	X	NCOMB	NEXT
5	-0	2	-0	-0.	-.00	-.00	-.00	-0	-1

NSTDL	QLOSS	CLOSS	AVG	NDMG	IPNT
3	-.00	-.00	-0.	-0	-0

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	67040.	64711.	52773.	29313.

```
            INCHES                  1.60      5.21      8.68
             AC-FT               32105.   104729.   174512.

    ISTAQ    IHDGR      NP     NSTN      NSTR     NUHGQ     NCLRK     LOCAL     NCOMB      NEXT
        5        1      -0       -0        -0        -0        -0        -0         2         0

     IPNT     NDMG    IBAL    INRGY
       -0       -0      -0       -0

    STORM     SPFE     PMS    TRSPC     TRSDA     STRIL     CNSTL     RTIMP     QRCSN     RTIOR
     -.00     -.00    -.00     -.00    200.00      -.00      -.00      -.00       -.0      -.00

    STRTQ    ALSMX   TLAPS    RATIO        TP        CP     TAREA
      -0.     -.00    -.00     -.00      -.00      -.00    200.00

  END-OF-PERIOD FLOWS AT      5
  SUM=    285953.
        0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.
        0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.      170.
     1180.     2190.     2370.     1550.      780.      390.      195.      525.     2040.     4480.
     8440.    18500.    39900.    58600.    58600.    40800.    22300.    11600.     5960.     3000.
     1490.      690.      175.       20.        8.       -0.       -0.       -0.       -0.       -0.
       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.       -0.

                      PEAK    6-HOUR   24-HOUR   72-HOUR
              CFS   58600.    52647.    22852.     7943.
           INCHES               2.45      4.25      4.43
            AC-FT             26129.    45349.    47289.

  END-OF-PERIOD COMBINED FLOWS AT     5

                      PEAK    6-HOUR   24-HOUR   72-HOUR
              CFS  110544.   105474.    75611.    37256.
           INCHES               1.70      4.88      7.21
            AC-FT             52328.   150049.   221801.

                       RUNOFF SUMMARY, AVERAGE CFS

                           PEAK    6-HOUR   24-HOUR   72-HOUR      AREA
```

HYDROGRAPH AT	1	166518.	149014.	63696.	22589.	100.
ROUTED TO	2	40730.	40648.	34339.	17692.	100.
HYDROGRAPH AT	2	49295.	45244.	29931.	14230.	177.
2 COMBINED	2	66847.	64503.	49924.	27952.	277.
ROUTED TO	4	50991.	49569.	39574.	22253.	277.
HYDROGRAPH AT	3	58734.	52636.	22793.	7893.	100.
ROUTED TO	4	45260.	41884.	20287.	7089.	100.
2 COMBINED	4	70128.	67040.	53385.	29342.	377.
ROUTED TO	5	67040.	64711.	52773.	29313.	377.
HYDROGRAPH AT	5	58600.	52667.	22852.	7943.	200.
2 COMBINED	5	110544.	105474.	75611.	37256.	577.

```
                          TEST NO. 4A
                   FLOOD HYDROGRAPH PACKAGE
        STREAMFLOW OPTIMIZATION-PLATE 3 EM 1110-2-1408

   NHR    NMIN      NQ   NSTAN   NSTAR   ISNOW   IDERV   IPLOT    NSTM   NPLAN
    12      -0      15      -0      -0      -0       1      -0      -0      -0

 IPRNT   METRC   IDGST   IDAYX    IHRX   IMINX
    -0      -0      -0      -0      -0      -0

    IQ      RQ      IQ      RQ      IQ      RQ      IQ      RQ      IQ      RQ
    -0    -.00      -0    -.00      -0    -.00      -0    -.00      -0    -.00

 ISTAQ   IHDGR      NP    NSTN    NSTR   NUHGQ   NCLRK   LOCAL   NCOMB    NEXT
     1       1      -0      -0      -0      -0      -0      -0      -0       1

  IPNT    NDMG    IBAL   INRGY
    -0      -0      -0      -0

 STORM    SPFE     PMS   TRSPC   TRSDA   STRTL   CNSTL   RTIMP   QRCSN   RTIOR
  -.00    -.00    -.00    -.00  100.00    -.00    -.00    -.00     -.0    -.00

 STRTQ   ALSMX   TLAPS   RATIO      TP      CP   TAREA
   -0.    -.00    -.00    -.00    -.00    -.00    -.00

INPUT DATA

 ISTAQ   NSTPS     LAG    IRES   STORA     TSK   AMSKK       X   NCOMB    NEXT
     2      -1      -0      -0     -0.    -.00   -1.00   -1.00      -0      -0

 NSTDL   QLOSS   CLOSS     AVG    NDMG    IPNT
    -0    -.00    -.00      0.      -0      -0

DERIVED COEFFICIENTS

 ISTAQ   NSTPS     LAG    IRES   STORA     TSK   AMSKK       X   NCOMB    NEXT
     2       2      -0      -0     -0.    -.00   10.81     .04      -0      -0

 NSTDL   QLOSS   CLOSS     AVG    NDMG    IPNT
```

-0 -.00 .00 0. -0

TIME	INFL	LOCAL	OUTFL	ACTUAL
1	2200.	5.	2205.	2000.
2	14500.	16.	3639.	7000.
3	28400.	27.	9302.	11700.
4	31800.	39.	18230.	16500.
5	29700.	56.	25420.	24000.
6	25300.	68.	28085.	29100.
7	20400.	67.	26927.	28400.
8	16300.	56.	23648.	23800.
9	12600.	46.	19695.	19400.
10	9300.	36.	15810.	15300.
11	6700.	26.	12257.	11200.
12	5000.	19.	9233.	8200.
13	4100.	15.	6910.	6400.
14	3600.	12.	5323.	5200.
15	2400.	11.	4229.	4600.
SUM	212300.	500.	210913.	212800.

```
                              TEST 6
                     FLOOD HYDROGRAPH PACKAGE
                       BALANCED HYDROGRAPH

   NHR     NMIN       NQ    NSTAN    NSTAR    ISNOW    IDERV    IPLOT     NSTM    NPLAN
     2       -0       72       -0       -0       -0       -0        0       -0       -0

 IPRNT    METRC    IDGST    IDAYX     IHRX    IMINX
    -0       -0       -0       -0       -0       -0

 ISTAQ    IHDGR       NP     NSTN     NSTR    NUHGQ    NCLRK    LOCAL    NCOMB     NEXT
     1        1       -0       -0       -0       -0       -0       -0       -0       -0

  IPNT     NDMG     IBAL    INRGY
    -0       -0        1       -0

 STORM     SPFE      PMS    TRSPC    TRSDA    STRTL    CNSTL    RTIMP    QRCSN    RTIOR
  -.00     -.00     -.00     -.00  1000.00     -.00     -.00     -.00      -.0     -.00

 STRTQ    ALSMX    TLAPS    RATIO       TP       CP    TAREA
   -0.     -.00     -.00     -.00     -.00     -.00     -.00

 NQB(1) SUMB(1)   NQB(2) SUMB(2)   NQB(3) SUMB(3)   NQB(4) SUMB(4)   NQB(5) SUMB(5)
     1  310000.        3 873000.        6 1650000.      12 3000000.      36 6300000.

HYDROGRAPH BALANCE RESULTS    310000. 310000.   873000. 873000.  1650000.1650000.  3000000.3000000.
                              6300000.6300000.
NUMBER OF ITERATIONS=  1

END-OF-PERIOD FLOWS AT      1
SUM=  8795021.
   28820.    27448.    28134.    30879.    37055.    47348.    65189.    89892.   111851.   116654.
  108420.   101558.    91265.    80972.    73423.    67934.    63130.    61758.    59013.    58327.
   60386.    67934.    87834.   104262.   121056.   132252.   145547.   160941.   177735.   193830.
  206844.   224770.   248902.   258571.   280517.   310000.   282483.   264360.   254069.   243386.
  222012.   204086.   196629.   187532.   177735.   166539.   156743.   146947.   139249.   132252.
  125954.   120356.   114758.   110560.   105662.   101463.    97265.    93766.    90967.    86461.
   83716.    80972.    78227.    76168.    73423.    71365.    68620.    66561.    64503.    62444.
   59699.    57641.
```

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	310000.	291000.	250000.	175000.
INCHES		2.71	9.30	19.53
AC-FT		144372.	496124.	1041860.

TEST NO. 7
FLOOD HYDROGRAPH PACKAGE
SYSTEM INTERPOLATION ROUTINE

NHR	NMIN	NQ	NSTAN	NSTAR	ISNOW	IDERV	IPLOT	NSTM	NPLAN
2	-0	96	-0	-0	-0	-0	-0	5	-0

IPRNT	METRC	IDGST	IDAYX	IHRX	IMINX
4	-0	-0	-0	-0	-0

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	158257.	155078.	124966.	78504.
INCHES		.41	1.33	2.50
AC-FT		76938.	247994.	467375.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	154382.	151296.	121850.	76508.
INCHES		.40	1.29	2.44
AC-FT		75062.	241810.	455488.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	148696.	145724.	117230.	73443.
INCHES		.39	1.25	2.34
AC-FT		72297.	232643.	437242.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	145435.	142527.	114576.	71695.
INCHES		.38	1.22	2.28
AC-FT		70711.	227375.	426836.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	141959.	139119.	111751.	69834.
INCHES		.37	1.19	2.23
AC-FT		69020.	221770.	415758.

INTERPOLATED HYDROGRAPH. 3503.0 SQ MI

END-OF-PERIOD FLOWS AT 4865

SUM= 3949338.

1169.	1139.	1109.	1080.	1052.	1025.	999.	973.	948.	923.
1023.	1501.	2762.	5435.	9757.	15135.	20318.	23936.	25109.	23736.
20671.	17091.	13769.	11025.	8929.	7890.	8527.	11120.	15011.	18890.
21534.	21985.	20682.	18720.	17068.	16664.	17399.	18446.	20214.	23105.
26066.	28673.	31511.	34836.	37849.	40492.	42864.	44017.	43686.	42450.
40761.	39123.	38112.	38099.	39445.	41935.	44766.	47340.	49184.	50537.
52160.	54685.	58650.	64661.	73419.	87353.	106767.	127020.	143596.	152657.
152460.	143699.	130899.	118279.	106010.	94075.	82559.	71546.	61203.	51470.
42996.	36316.	31635.	30861.	34311.	41343.	50993.	60532.	67121.	68580.
65654.	59414.	50816.	42614.	35116.	28257.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	152657.	149605.	120448.	75578.
INCHES		.40	1.28	2.41
AC-FT		74223.	239028.	449951.

FLOOD 1. 1000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	139621.	138159.	118791.	75151.
INCHES		.37	1.26	2.39
AC-FT		68544.	235740.	447410.

FLOOD 2. 3000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	136172.	134743.	115818.	73123.
INCHES		.36	1.23	2.33
AC-FT		66849.	229840.	435339.

FLOOD 3. 5000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	131086.	129703.	111399.	70094.
INCHES		.34	1.18	2.23
AC-FT		64348.	221071.	417306.

FLOOD 4. 7000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	128164.	126807.	108860.	68359.
INCHES		.34	1.16	2.18
AC-FT		62912.	216032.	406977.

FLOOD 5, 9000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	125052.	123724.	106159.	66511.
INCHES		.33	1.13	2.12
AC-FT		61382.	210673.	395971.

INTERPOLATED HYDROGRAPH, 3503.0 SQ MI

END-OF-PERIOD FLOWS AT 4890
SUM= 3366813.

1169.	1169.	1169.	1169.	1169.	1169.	1169.	1168.	1168.	1165.
1161.	1153.	1140.	1124.	1103.	1080.	1058.	1044.	1054.	1123.
1315.	1734.	2518.	3814.	5723.	8240.	11198.	14264.	17004.	18993.
19939.	19768.	18635.	16877.	14918.	13183.	12023.	11663.	12158.	13371.
15001.	16660.	17992.	18786.	19041.	18940.	18776.	18839.	19342.	20386.
21966.	24007.	26394.	29001.	31694.	34331.	36755.	38801.	40320.	41224.
41524.	41344.	40910.	40502.	40385.	40746.	41651.	43050.	44820.	46846.
49103.	51716.	54978.	59319.	65220.	73067.	82957.	94508.	106770.	118325.
127597.	133265.	134629.	131746.	125317.	116381.	106001.	95047.	84139.	73701.
64069.	55580.	48609.	43554.	40753.	40365.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	134629.	133213.	114477.	72204.
INCHES		.35	1.22	2.30
AC-FT		66090.	227179.	429867.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	113254.	106500.	73383.	44230.
INCHES		.57	1.56	2.82
AC-FT		52837.	145629.	263325.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	110730.	104113.	71697.	43158.

		6-HOUR	24-HOUR	72-HOUR
INCHES		.55	1.52	2.75
AC-FT		51653.	142283.	256943.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	107039.	100626.	69211.	41561.
INCHES		.53	1.47	2.65
AC-FT		49923.	137350.	247435.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	104929.	98630.	67780.	40645.
INCHES		.52	1.44	2.59
AC-FT		48933.	134510.	241980.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	102680.	96501.	66257.	39667.
INCHES		.51	1.41	2.53
AC-FT		47877.	131486.	236154.

INTERPOLATED HYDROGRAPH, 1750.0 SQ MI

END-OF-PERIOD FLOWS AT 4885
SUM= 2435706.

272.	264.	256.	249.	242.	235.	526.	1234.	1782.	1750.
2222.	4629.	9182.	15650.	23030.	28543.	29493.	26015.	20205.	14195.
9381.	6095.	3967.	2593.	2143.	4132.	9636.	17072.	22164.	22176.
18480.	13901.	10922.	10319.	10874.	12312.	14999.	16032.	16535.	20584.
24015.	22772.	22962.	27787.	32154.	32734.	30283.	27903.	27101.	25952.
23440.	21635.	22467.	26084.	29861.	31515.	31934.	32512.	32998.	33320.
34416.	37793.	43606.	50789.	59762.	76628.	99586.	111968.	104298.	87481.
73607.	63060.	54014.	45497.	37801.	31277.	25638.	20386.	15331.	10433.
8122.	8607.	10556.	16502.	27387.	38435.	45819.	48645.	44490.	35312.
27528.	21386.	15306.	10011.	6392.	4115.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	111968.	105284.	72525.	43684.
INCHES		.56	1.54	2.79
AC-FT		52234.	143925.	260074.

FLOOD 1, 1000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	94911.	92693.	71711.	43973.
INCHES		.49	1.52	2.80
AC-FT		45937.	142310.	261791.

FLOOD 2, 3000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	92765.	90594.	70065.	42906.
INCHES		.48	1.49	2.74
AC-FT		44946.	139044.	255442.

FLOOD 3, 5000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	89628.	87524.	67630.	41318.
INCHES		.47	1.44	2.64
AC-FT		43422.	134212.	245984.

FLOOD 4, 7000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	87828.	85761.	66229.	40406.
INCHES		.46	1.41	2.58
AC-FT		42548.	131432.	240559.

FLOOD 5, 9000.0 SQ MI TRANSPOSITION

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	85909.	83882.	64738.	39433.
INCHES		.45	1.38	2.52
AC-FT		41616.	128472.	234765.

INTERPOLATED HYDROGRAPH, 1750.0 SQ MI

END-OF-PERIOD FLOWS AT 4890
SUM= 2341877.

272.	272.	272.	272.	271.	270.	267.	263.	264.	286.

363.	531.	811.	1207.	1777.	2730.	4438.	7259.	11260.	15987.
20471.	23548.	24363.	22775.	19382.	15181.	11111.	7797.	5572.	4664.
5296.	7534.	10967.	14600.	17207.	17983.	16997.	15073.	13249.	12247.
12270.	13131.	14517.	16206.	18077.	19995.	21829.	23609.	25501.	27469.
29082.	29811.	29493.	28410.	26991.	25591.	24552.	24261.	24967.	26533.
28454.	30189.	31478.	32418.	33343.	34719.	37072.	40938.	46845.	55242.
66082.	78070.	88391.	93818.	92662.	85810.	75853.	65303.	55527.	46866.
39228.	32456.	26430.	21108.	16620.	13318.	11703.	12279.	15357.	20782.
27681.	34475.	39350.	40988.	39117.	34522.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	93818.	91624.	70872.	43430.
INCHES		.49	1.51	2.77
AC-FT		45457.	140646.	258557.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	146532.	143975.	117285.	74590.
INCHES		.41	1.32	2.53
AC-FT		71430.	232752.	444071.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	142982.	140479.	114380.	72709.
INCHES		.40	1.29	2.46
AC-FT		69695.	226987.	432873.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	137758.	135334.	110076.	69825.
INCHES		.38	1.24	2.36
AC-FT		67142.	218446.	415700.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	134759.	132381.	107602.	68179.
INCHES		.37	1.21	2.31
AC-FT		65677.	213536.	405904.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	131564.	129233.	104969.	66428.
INCHES		.36	1.19	2.25
AC-FT		64116.	208311.	395475.

INTERPOLATED HYDROGRAPH. 3296.0 SQ MI

END-OF-PERIOD FLOWS AT 4890
SUM= 3780845.

388.	377.	366.	356.	346.	336.	326.	317.	308.	300.
414.	894.	2094.	4552.	8481.	13422.	18390.	22200.	24003.	23526.
21222.	18040.	14807.	11976.	9742.	8493.	8740.	10725.	13955.	17405.
20081.	21071.	20461.	18962.	17368.	16737.	17139.	17905.	19438.	21920.
24449.	26841.	29420.	32437.	35489.	38012.	40190.	41756.	42047.	41256.
39904.	38448.	37534.	37419.	38273.	40115.	42549.	44940.	46852.	48289.
49748.	51990.	55424.	60449.	67905.	79884.	96369.	114096.	129561.	139454.
142020.	137120.	127054.	115811.	104727.	93784.	83170.	72854.	63035.	53758.
45482.	38700.	33628.	31850.	33755.	38897.	46759.	54939.	61258.	63821.
62382.	57775.	50859.	43061.	36046.	29616.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	142020.	139531.	113588.	72178.
INCHES		.39	1.28	2.44
AC-FT		69225.	225414.	429709.

END-OF-PERIOD COMBINED FLOWS AT 4890

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	278002.	276319.	253927.	192546.
INCHES		.30	1.11	2.51
AC-FT		137088.	503916.	1146317.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	271065.	269420.	247561.	187662.
INCHES		.29	1.08	2.45
AC-FT		133666.	491283.	1117243.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	260808.	259214.	238072.	180237.
INCHES		.28	1.04	2.35
AC-FT		128602.	472453.	1073039.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	254915.	253350.	232621.	175995.

	PEAK	6-HOUR	24-HOUR	72-HOUR
INCHES		.28	1.01	2.30
AC-FT		125693.	461634.	1047784.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	248641.	247108.	226824.	171477.
INCHES		.27	.99	2.24
AC-FT		122596.	450131.	1020885.

INTERPOLATED HYDROGRAPH, 8549.0 SQ MI

END-OF-PERIOD FLOWS AT 4890
SUM= 8711427.

1829.	1818.	1807.	1796.	1786.	1774.	1762.	1748.	1738.	1744.
1896.	2430.	3682.	6158.	10123.	15362.	21321.	27264.	32496.	36389.
38535.	38827.	37355.	34524.	31142.	28460.	27656.	29219.	32607.	36706.
40551.	43310.	44832.	45166.	44305.	42869.	41310.	39964.	40207.	42744.
46649.	51221.	56142.	61242.	66032.	70034.	73557.	76651.	79060.	81031.
82657.	83817.	84862.	86164.	88146.	91010.	94552.	98380.	102184.	105763.
109131.	112622.	116599.	121783.	129518.	142377.	160897.	182453.	204127.	223121.
237719.	246710.	249924.	248519.	242638.	233448.	223619.	215103.	208462.	202729.
196748.	189584.	180653.	171447.	163100.	156504.	152644.	150556.	149068.	146674.
142660.	136676.	128208.	117745.	106911.	96383.				

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	249924.	248385.	228010.	172401.
INCHES		.27	.99	2.25
AC-FT		123229.	452484.	1026387.

RUNOFF SUMMARY, AVERAGE CFS

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	4865	152657.	149605.	120448.	75578.	3503.
ROUTED TO	4890	134629.	133213.	114477.	72204.	3503.
HYDROGRAPH AT	4885	111968.	105284.	72525.	43684.	1750.
ROUTED TO	4890	93818.	91624.	70872.	43430.	1750.
HYDROGRAPH AT	4890	142020.	139531.	113588.	72178.	3296.
3 COMBINED	4890	249924.	248385.	228010.	172401.	8549.

```
                                        TEST 8
                              FLOOD HYDROGRAPH PACKAGE
                                  MULTIPLE FLOOD TEST

     NHR      NMIN        NQ     NSTAN     NSTAR     ISNOW     IDERV     IPLOT      NSTM     NPLAN
       3        -0       100        -0        -0        -0        -0        -0        -0         2

   IPRNT     METRC     IDGST     IDAYX      IHRX     IMINX
       3        -0        -0        -0        -0        -0

 NRTIO=   8  RTIO=   .500   .600   .700   .800   .950 1.100 1.300 1.600

   ISTAQ     IHDGR        NP      NSTN      NSTR     NUHGQ     NCLRK     LOCAL     NCOMB      NEXT
      -1        -0        24        -0        -0        -0        -0        -0        -0         1

    IPNT      NDMG      IBAL     INRGY
      -0        -0        -0        -0

   STORM      SPFE       PMS     TRSPC     TRSDA     STRIL     CNSTL     RTIMP     QRCSN     RTIOR
   -.00      -.00      -.00      1.00   2851.00      -.00      -.00      -.00   13300.0      1.17

   STRTQ     ALSMX     TLAPS     RATIO        TP        CP     TAREA
   3990.      -.00      -.00      1.00      -.00      -.00      -.00

                               PEAK    6-HOUR   24-HOUR   72-HOUR
                   CFS       36852.    36823.    36013.    31162.
                INCHES                    .23       .89      2.30
                 AC-FT                 18269.    71468.   185524.

                               PEAK    6-HOUR   24-HOUR   72-HOUR
                   CFS       18426.    18412.    18007.    15581.
                INCHES                    .11       .44      1.15
                 AC-FT                  9134.    35734.    92762.

   ISTAQ     NSTPS       LAG      IRES     STORA       TSK     AMSKK         X     NCOMB      NEXT
      -3         1         6        -0       -0.      -.00      -.00      -.00        -0        -1

   NSTDL     QLOSS     CLOSS       AVG      NDMG      IPNT
      12      -.00      -.00       -0.        -0        -1
```

```
ISTAQ   IHDGR      NP    NSTN    NSTR   NUHGQ   NCLRK   LOCAL   NCOMB    NEXT
   -2      -0      24      -0      -0      -0      -0      -0      -0       1

 IPNT    NDMG    IBAL   INRGY
   -0      -0      -0      -0

STORM    SPFE     PMS   TRSPC   TRSDA   STRTL   CNSTL   RTIMP   QRCSN   RTIOR
 -.00    -.00    -.00    1.00 2851.00    -.00    -.00    -.00  5240.0    1.37

STRTQ   ALSMX   TLAPS   RATIO      TP      CP   TAREA
1570.    -.00    -.00    1.00    -.00    -.00    -.00

                     PEAK   6-HOUR  24-HOUR  72-HOUR
           CFS     25940.   25841.   23448.   15606.
        INCHES                 .47     1.72     3.44
         AC-FT              12820.   46532.   92911.

                     PEAK   6-HOUR  24-HOUR  72-HOUR
           CFS     12970.   12920.   11724.    7803.
        INCHES                 .24      .86     1.72
         AC-FT               6410.   23266.   46455.

ISTAQ   NSTPS     LAG    IRES   STORA     TSK   AMSKK       X   NCOMB    NEXT
   -3       1       4      -0     -0.    -.00    -.00    -.00       2      -1

NSTDL   QLOSS   CLOSS     AVG    NDMG    IPNT
    9    -.00    -.00     -0.      -0      -2

ISTAQ   IHDGR      NP    NSTN    NSTR   NUHGQ   NCLRK   LOCAL   NCOMB    NEXT
   -3      -0      24      -0      -0      -0      -0      -0       2       1

 IPNT    NDMG    IBAL   INRGY
   -0      -0      -0      -0

STORM    SPFE     PMS   TRSPC   TRSDA   STRTL   CNSTL   RTIMP   QRCSN   RTIOR
 -.00    -.00    -.00    1.00 2851.00    -.00    -.00    -.00  5240.0    1.38

STRTQ   ALSMX   TLAPS   RATIO      TP      CP   TAREA
1570.    -.00    -.00    1.00    -.00    -.00    -.00
```

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	19332.	19232.	17666.	12085.
INCHES		.45	1.66	3.42
AC-FT		9542.	35058.	71945.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	9666.	9616.	8833.	6042.
INCHES		.23	.83	1.71
AC-FT		4771.	17529.	35973.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 1
SUM= 1281501.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27361.	27341.	26985.	25020.
INCHES		.64	2.54	7.07
AC-FT		82966.	327549.	911086.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 1
SUM= 1281501.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27361.	27341.	26985.	25020.
INCHES		.64	2.54	7.07
AC-FT		82966.	327549.	911086.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 2
SUM= 1537802.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	32833.	32809.	32382.	30024.
INCHES		.77	3.05	8.48
AC-FT		99559.	393059.	1093303.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 2
SUM= 1537802.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	32833.	32809.	32382.	30024.

	PEAK	6-HOUR	24-HOUR	72-HOUR
INCHES		.77	3.05	8.48
AC-FT		99559.	393059.	1093303.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 3
SUM= 1794102.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	38305.	38277.	37779.	35028.
INCHES		.90	3.56	9.90
AC-FT		116152.	458569.	1275520.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 3
SUM= 1794102.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	38305.	38277.	37779.	35028.
INCHES		.90	3.56	9.90
AC-FT		116152.	458569.	1275520.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 4
SUM= 2050402.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	43778.	43745.	43176.	40032.
INCHES		1.03	4.07	11.31
AC-FT		132746.	524079.	1457737.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 4
SUM= 2050402.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	43778.	43745.	43176.	40032.
INCHES		1.03	4.07	11.31
AC-FT		132746.	524079.	1457737.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 5
SUM= 2434852.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	51986.	51947.	51272.	47538.

INCHES		1.22	4.83	13.43
AC-FT		157635.	622344.	1731063.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 5
SUM= 2434852.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	51986.	51947.	51272.	47538.
INCHES		1.22	4.83	13.43
AC-FT		157635.	622344.	1731063.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 6
SUM= 2819303.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	60194.	60150.	59368.	55044.
INCHES		1.42	5.59	15.56
AC-FT		182525.	720608.	2004389.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 6
SUM= 2819303.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	60194.	60150.	59368.	55044.
INCHES		1.42	5.59	15.56
AC-FT		182525.	720608.	2004389.

COMBINED FLOWS AT -3 PLAN 1 FLOOD 7
SUM= 3331903.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	71139.	71086.	70162.	65052.
INCHES		1.67	6.61	18.38
AC-FT		215711.	851628.	2368823.

COMBINED FLOWS AT -3 PLAN 2 FLOOD 7
SUM= 3331903.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	71139.	71086.	70162.	65052.

```
              INCHES                   1.67     6.61    18.38
               AC-FT                215711.  851628. 2368823.

COMBINED FLOWS AT      -3 PLAN 1 FLOOD 8
SUM=  4100804.

                          PEAK    6-HOUR   24-HOUR   72-HOUR
                 CFS    87555.    87490.    86353.    80064.
              INCHES                2.06      8.13     22.63
               AC-FT             265491.  1048158.  2915474.

COMBINED FLOWS AT      -3 PLAN 2 FLOOD 8
SUM=  4100804.

                          PEAK    6-HOUR   24-HOUR   72-HOUR
                 CFS    87555.    87490.    86353.    80064.
              INCHES                2.06      8.13     22.63
               AC-FT             265491.  1048158.  2915474.

  ISTAQ   NSTPS     LAG    IRES   STORA     TSK   AMSKK       X   NCOMB    NEXT
     -4       1       4      -0     -0.    -.00    -.00    -.00      -0      -1

  NSTDL   QLOSS   CLOSS     AVG    NDMG    IPNT
      9    -.00    -.00     -0.      -0      -1

  ISTAQ   IHDGR      NP    NSTN    NSTR   NUHGQ   NCLRK   LOCAL   NCOMB    NEXT
     -4      -0      24      -0      -0      -0      -0      -0       2       1

   IPNT    NDMG    IBAL   INRGY
     -0      -0      -0      -0

  STORM    SPFE     PMS   TRSPC   TRSDA   STRTL   CNSTL   RTIMP   QRCSN   RTIOR
   -.00    -.00    -.00    1.00 2851.00    -.00    -.00    -.00  3650.0    1.23

  STRTQ   ALSMX   TLAPS   RATIO      TP      CP   TAREA
  1090.    -.00    -.00    -.00    -.00    -.00    -.00

                          PEAK    6-HOUR   24-HOUR   72-HOUR
                 CFS    14682.    14617.    14016.    11049.
              INCHES                 .31      1.20      2.84
```

AC-FT		7252.	27814.	65780.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	7341.	7309.	7008.	5524.
INCHES		.16	.60	1.42
AC-FT		3626.	13907.	32890.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 1
SUM= 1506395.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	33063.	33015.	32516.	29494.
INCHES		.71	2.78	7.57
AC-FT		107353.	422916.	1150820.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 1
SUM= 1506395.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	33063.	33015.	32516.	29494.
INCHES		.71	2.78	7.57
AC-FT		107353.	422916.	1150820.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 2
SUM= 1807674.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	39676.	39618.	39019.	35392.
INCHES		.85	3.34	9.08
AC-FT		128824.	507499.	1380983.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 2
SUM= 1807674.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	39676.	39618.	39019.	35392.
INCHES		.85	3.34	9.08
AC-FT		128824.	507499.	1380983.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 3

SUM= 2108953.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	46289.	46222.	45522.	41291.
INCHES		.99	3.89	10.60
AC-FT		150294.	592082.	1611147.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 3
SUM= 2108953.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	46289.	46222.	45522.	41291.
INCHES		.99	3.89	10.60
AC-FT		150294.	592082.	1611147.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 4
SUM= 2410232.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	52902.	52825.	52025.	47190.
INCHES		1.13	4.45	12.11
AC-FT		171765.	676665.	1841311.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 4
SUM= 2410232.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	52902.	52825.	52025.	47190.
INCHES		1.13	4.45	12.11
AC-FT		171765.	676665.	1841311.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 5
SUM= 2862150.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	62821.	62729.	61780.	56038.
INCHES		1.34	5.28	14.38
AC-FT		203971.	803540.	2186557.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 5

SUM= 2862150.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	62821.	62729.	61780.	56038.
INCHES		1.34	5.28	14.38
AC-FT		203971.	803540.	2186557.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 6
SUM= 3314069.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	72740.	72634.	71535.	64886.
INCHES		1.55	6.12	16.65
AC-FT		236177.	930415.	2531803.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 6
SUM= 3314069.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	72740.	72634.	71535.	64886.
INCHES		1.55	6.12	16.65
AC-FT		236177.	930415.	2531803.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 7
SUM= 3916627.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	85965.	85840.	84541.	76683.
INCHES		1.84	7.23	19.68
AC-FT		279118.	1099581.	2992131.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 7
SUM= 3916627.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	85965.	85840.	84541.	76683.
INCHES		1.84	7.23	19.68
AC-FT		279118.	1099581.	2992131.

COMBINED FLOWS AT -4 PLAN 1 FLOOD 8

SUM= 4820464.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	105803.	105649.	104051.	94380.
INCHES		2.26	8.90	24.22
AC-FT		343530.	1353330.	3682623.

COMBINED FLOWS AT -4 PLAN 2 FLOOD 8
SUM= 4820464.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	105803.	105649.	104051.	94380.
INCHES		2.26	8.90	24.22
AC-FT		343530.	1353330.	3682623.

ISTAQ	NSTPS	LAG	IRES	STORA	TSK	AMSKK	X	NCOMB	NEXT
5	-0	-0	-1	-0.	-.00	-.00	-.00	-0	1

NSTDL	QLOSS	CLOSS	AVG	NDMG	IPNT
-0	-.00	-.00	-0.	-0	-0

ISTAQ	NSTPS	LAG	IRES	STORA	TSK	AMSKK	X	NCOMB	NEXT
5	-0	-0	1	-1.	-.00	-.00	-.00	-0	0

NSTDL	QLOSS	CLOSS	AVG	NDMG	IPNT
-0	-.00	-.00	-0.	3	-0

ROUTED FLOWS AT 5 PLAN 2 FLOOD 1
SUM= 1503248.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 2
SUM= 1803897.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 3
SUM= 2104546.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 4
SUM= 2389343.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 5
SUM= 2431064.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 6
SUM= 2463621.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 7
SUM= 2502200.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

ROUTED FLOWS AT 5 PLAN 2 FLOOD 8
SUM= 2553156.

	PEAK	6-HOUR	24-HOUR	72-HOUR
CFS	27600.	27600.	27600.	27600.
INCHES		.59	2.36	7.08
AC-FT		89744.	358977.	1076932.

```
ECONOMIC DATA FOR STA     5
FREQ        .200       .140       .100       .060       .040       .030       .020       .010        -.000
PEAK      34500.     38000.     43000.     47000.     53000.     59000.     70000.     91000.          -0.
DAMG       5.000     40.000    115.000    215.000    370.000    580.000   1030.000   2600.000        -.000
DAMG       2.000     16.000     46.000     86.000    148.000    232.000    412.000   1040.000        -.000
DAMG       3.000     24.000     69.000    129.000    222.000    348.000    618.000   1440.000        -.000

FLOOD DAMAGES FOR STATION       5   PLAN  1
    DAMAGE TYPE          1        2        3
 NO.    FLOW    PROB
  1    33063.   .186       .0       .0       .0
  2    39676.   .201     13.1      5.2      7.9
  3    46289.   .105     20.8      8.3     12.5
  4    52902.   .057     21.1      8.4     12.6
  5    62821.   .025     18.2      7.3     10.9
  6    72740.   .015     18.2      7.3     10.7
  7    85965.   .007     16.1      6.5      9.0
  8   105803.   .003     10.2      4.1      5.5
  AVG ANN DAMAGE        117.7     47.1     69.2
TOTAL    221.800

FLOOD DAMAGES FOR STATION       5   PLAN  2
    DAMAGE TYPE          1        2        3
 NO.    FLOW    PROB
  1    27600.   .186       .0       .0       .0
  2    27600.   .201       .0       .0       .0
  3    27600.   .105       .0       .0       .0
  4    27600.   .057       .0       .0       .0
  5    27600.   .025       .0       .0       .0
  6    27600.   .015       .0       .0       .0
  7    27600.   .007       .0       .0       .0
  8    27600.   .003       .0       .0       .0
  AVG ANN DAMAGE           .0       .0       .0
TOTAL       .000
 AVG ANN BENEFIT        110.9     44.4     66.5
TOTAL    221.800
```

RUNOFF SUMMARY, AVERAGE CFS
PLAN 1, FLOOD 1

		PEAK	6-HOUR	24-HOUR	72-HOUR	AREA
HYDROGRAPH AT	-1	18426.	18412.	18007.	15581.	1514.
ROUTED TO	-3	17520.	17497.	17200.	15182.	1514.
HYDROGRAPH AT	-2	12970.	12920.	11724.	7803.	507.
ROUTED TO	-3	11457.	11437.	10772.	7660.	507.
2 COMBINED	-3	22207.	22196.	22046.	20511.	2021.
HYDROGRAPH AT	-3	9666.	9616.	8833.	6042.	395.
2 COMBINED	-3	27361.	27341.	26985.	25020.	2416.
ROUTED TO	-4	26902.	26874.	26594.	24663.	2416.
HYDROGRAPH AT	-4	7341.	7309.	7008.	5524.	435.
2 COMBINED	-4	33063.	33015.	32516.	29494.	2851.
ROUTED TO	5	33063.	33015.	32516.	29494.	2851.

Sample Plotting of Test No. 1

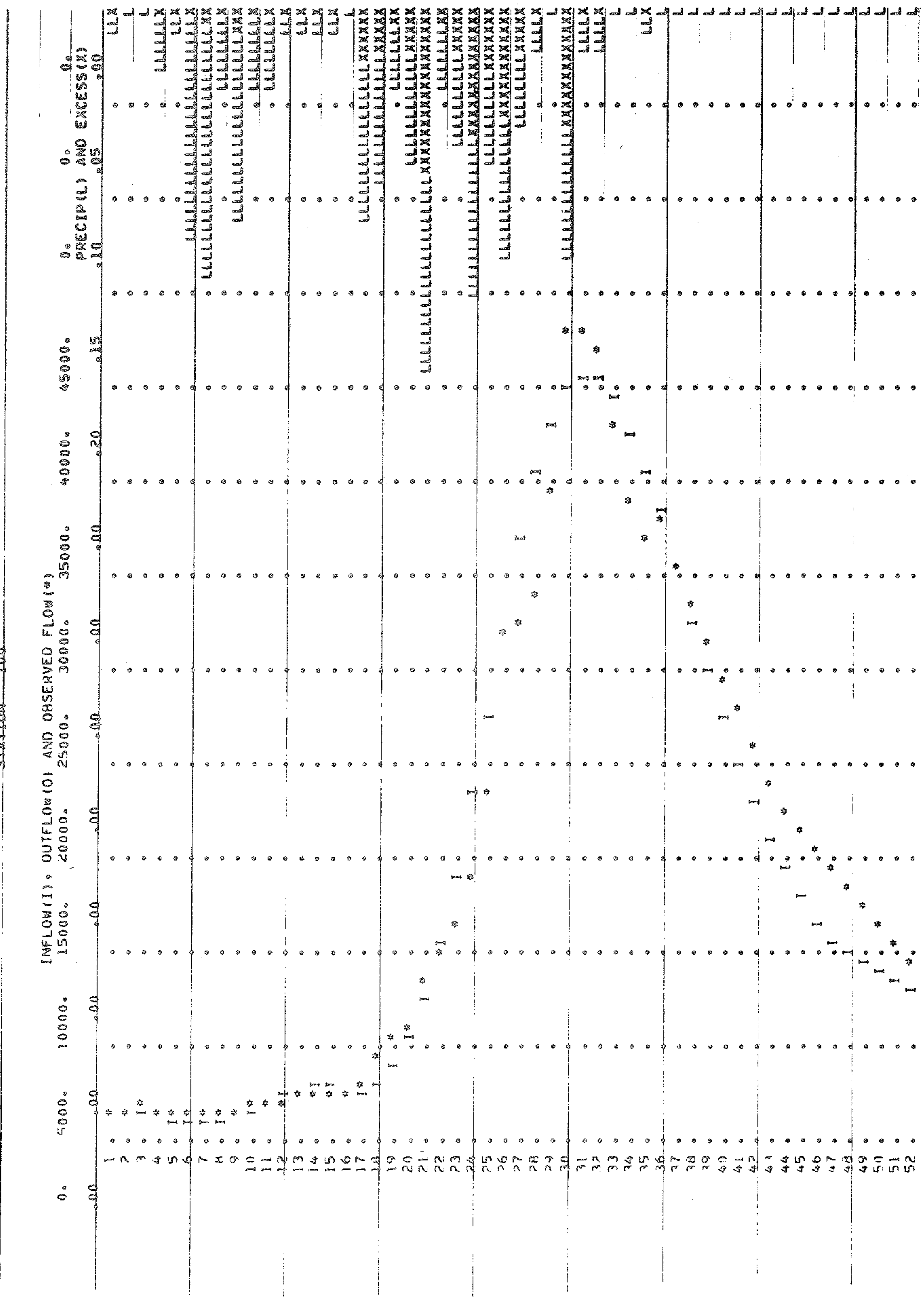


 EXHIBIT 2

EXHIBIT 3

DEFINITIONS

HEC-1

AI	- Real conversion of I
AJ	- Real conversion of J
AK	- Real conversion of K
ALAG	- Lag in hours
ALBDO	- Albedo ratio
ALOSS	- Loss in inches (mm)
ALSMX	- Maximum possible loss rate in inches per hour (mm/hr)
AMSKK	- Muskingum K coefficient
ANAP (J)	- Normal annual precipitation in inches (mm) for basin
ANAPN (K)	- Normal annual precipitation in inches (mm) for non-recording station
ANDAY (J)	- Number of days since last snowfall
ANQ	- Real conversion of NQ
AREA (J)	- Area in square miles (KM^2)
AVAN (N)	- Average annual damage or benefit in thousand dollars for each type of damage
AVG	- Average
AVGQ	- Average flow in cfs (cms)
AVGQO	- Average observed flow in cfs (cms)
AVTMP	- Average temperature in degrees F (c)
AX (I)	- Variation of A
AY	- Temporary variable
BX (I)	- Temporary variable
BY	- Temporary variable
CA	- Coefficient
CB	- Coefficient
CEX	- Ratio for successively reducing adjustment of loss coefficients for volume adjustment. This is reduced whenever coefficients have been over-adjusted and direction of adjustment is reversed.
CIT	- Time factor in time-area function
CL	- Interpolation quantity for time-area function
CLARK	- Number of ordinates in time-area curve
CLOSS	- Ratio of flow lost in channel
CNSTL	- Uniform rainfall loss in inches (mm) per hour
CP	- Snyder's coefficient C_p
CPTMP	- Variation of CP
CUML (J)	- Accumulated loss in zone J in inches (mm)
CX (I)	- Temporary array
CY	- Temporary variable
DA (IH)	- Drainage area in square miles (KM^2)
DAMAG (K,N)	- Damage in thousand dollars corresponding to flood peak (Peak(K))
DEWPT (I)	- Dew point in degrees F (c)
DLTK	- Increment of rain loss coefficient at start of storm
DMG (K)	- Average annual damage in thousand dollars for each type of damage computed for the first plan.

DQ	- Difference between computed and observed flow in cfs (cms)
DX (I)	- Temporary array
DY	- Temporary variable
EX	- Excess in inches (mm)
EXCR	- Rainfall excess in inches (mm) for preceding system computation
EXCS	- Snowmelt excess in inches (mm) for preceding system computation
EXCSR (I)	- Rainfall excess in inches (mm)
EXCSS (I)	- Snowmelt excess in inches (mm)
FREQ (K)	- Given frequency of occurrence of corresponding flood peak, events per year
I	- Index of period
IBAL	- Indicator calling for hydrograph balance routine
IDAY	- Day at end of interval
IDAYX	- Day at start of storm
IDERV	- Indicator calling for derivation of coefficient
IDGST	- Indicator calling for diagnostic print-out
IEND	- A value of 1 indicates first iteration after complete search of all variables used in deriving unit hydrograph and loss coefficients This calls for volume check when NC equals 1.
IFREZ (M)	- Indicator calling for no change in corresponding variable
IFRST	- Indicator for first iteration
IFST	- Positive value calls for computing value of EX to represent excess needed for correct runoff volume. Subsequent iterations when IFST is zero will attempt to obtain this amount of excess.
IH	- Index of hydrograph
IHR	- Hour at end of interval
IHRX	- Hour at start of storm
IHX	- Temporary value of IH
IHY	- Temporary value of IH
IHDGR	- Indicator calling for reading hydrograph
IMIN	- Minute at end of interval
IMINX	- Minute at start of storm
INH (NH)	- System hydrograph sequence number for stored hydrograph
INRGY	- Indicator to call for energy budget snowmelt computation
IOPER (NH)	- Indicator, 1 = hydrograph, 2 = routing, 3 = combining
IP	- Temporary variable
IPLOT	- Indicator calling for plotting
IPNT	- Negative value suppresses print-out for one particular location
IPRNT	- Negative value suppresses hydrograph print-out for all sub-areas
IQ (I)	- Serial number of observed flow to be adjusted temporarily
IRES	- Indicator calling for reservoir routing
IRTIO	- Index of flood ratio used for economic computation
ISNOW	- Indicator calling for snowfall and snowmelt routines
ISTAN (K)	- Number for each non-recording precipitation station read
ISTAQ	- Streamflow station number
ISTAR (K)	- Number for each recording precipitation station read
ISTM	- Indicator to control multi-flood system computation

EXHIBIT 3

ISTN (K)	- Number for each non-recording precipitation station used in a basin study
ISTQ (NH)	- Streamflow station number
ISTR (K)	- Number for each recording precipitation station used in a basin study
ISUB	- Transfer indicator within a subroutine
IT	- Temporary variable
ITB	- Base of time-area curve
ITEMP	- Temporary variable
ITMP	- Temporary variable
ITP	- Temporary variable
ITRNS	- Indicator to control a transfer
IUHGQ	- Indicator when positive causes unit hydrograph to be read
IX	- Indicator in Snyder unit hydrograph computation
IZONE	- Lowest elevation zone number
J	- Index for elevation zone
JLAG	- Positive value indicates that optimum lag has been passed as LG is incremented (LG-1 is optimum lag at this time)
JPJ	- Transfer indicator
JSUB	- Transfer indicator to a subroutine
JTRNS	- Indicator to control a transfer
K	- Subscript for station
KH	- Dimension limit for hydrograph subscript
KHGR	- Maximum number of locations for which hydrographs can be contained in memory at one time
KHN	- Dimension limit for number of non-recording stations used in a hydrograph computation
KHR	- Dimension limit for number of recording stations used in a hydrograph computation
KINH	- Maximum number of hydrographs for all locations, plans and ratios that can be contained in memory at one time
KN	- Dimension limit for number of non-recording stations read
KNH	- Maximum locations for a run
KQ	- Dimension limit for number of hydrograph ordinates
KQH	- Maximum product of NQ by the number of locations, plans and ratios contained in memory at one time
KR	- Dimension limit for number of recording stations read
KTRNS	- Indicator to control a transfer
KUHGQ	- Dimension limit for number of unit hydrograph ordinates
L	- Subscript
LAG	- Sequence number of maximum ordinate of the unit hydrograph
LG	- Number of computation intervals in routing lag
LOCAL	- Indicator when positive causes computation of local inflow from routed upstream flows and total given flow
LTMP	- Temporary variable
LTRA	- Letter A
LTRNS	- Indicator to control a transfer

M	- Subscript of VAR
METRC	- Positive value indicates that metric units (mm, km^2, cms, deg c, thousand m^3) are used. Otherwise English units (in, sq. mi., cfs, deg. F, ac-ft) are used.
MRTIO	- Same as NRTIO
MTRNS	- Positive value indicates that SUMQ has been computed for previous iteration and is available for refined volume adjustment
M1	- Preceding subscript of VAR
N	- Subscript
NA	- Number of ordinates to compute flow average
NB	- Number of ordinates to compute flow average
NC	- Number of ordinates to compute flow average
NCLRK	- Number of time-area ordinates
NCOMB	- Number of hydrographs to be combined
NCMB	- Stored record of number of hydrographs combined at location NH
NC1	- Lower limit of NC
NC2	- Upper limit of NC
NDMG	- Number of damage functions for economic evaluation
NEX	- A sequence number of latest positive excess
NEXT	- Indicator calling for next operation, -1 for hydrograph, 1 for routing and 0 to end job
NFLOD	- Number of points on damage - flow - frequency table
NH	- Serial number of hydrographs computed
NHR	- Number of whole hours in computation interval
NINTV	- Number of intervals in a 6-hour period
NMIN	- Number of minutes remaining in computation interval after subtracting NHR
NP	- Number of precipitation intervals
NPLAN	- Number of plans of development for which hydrographs are to be computed in the same job
NPR	- Temporary constant in hypothetical storm computation
NQ	- Number of flow intervals
NQB (K)	- Number of flows for hydrograph balance computation
NRTIO	- Number of ratios of the basic flood to be used for each plan of development
NSTAN	- Total number of non-recording precipitation stations read
NSTAR	- Total number of recording precipiation stations read
NSTDL	- Number of ordinates averaged for routing
NSTL	- Number of ordinates averaged for routing
NSTM	- Number of system floods to be computed for different storm sizes in order to interpalate to obtain the hydrograph for the size of storm corresponding to the size of each drainage area.
NSTN	- Total number of non-recording precipitation stations used to compute a hydrograph
NSTP	- Number of repetitions in routing
NSTPS	- Number of repetitions in routing
NSTR	- Number of storage values in table
NTMP	- Iteration counter for volume adjustment routine

EXHIBIT 3

NUHGQ	- Total number of unit hydrograph ordinates
NV	- Number of variables to be plotted, or indicator
NVAR	- Number of variables in optimization
NX	- Iteration counter for Snyder coefficients, number of precipitation intervals per hour
NZONE	- Uppermost elevation zone number
N24HR	- Number of 24-hour periods in storm
OUTFL (K)	- Outflow in cfs (cms) in table
PEAK (K)	- Peak flow in cfs (cms) in table of frequencies and damages
PMS	- Index rainfall for probable maximum storm
PRCP (I)	- Precipitation in inches (mm)
PRCPA	- Average station precipitation in inches (mm)
PRCPN (K)	- Precipitation in inches (mm) at non-recording station
PRCPR (I,K)	- Precipitation in inches (mm) at recording station
PROB (K)	- Probability of occurrence in one year of flood at each damage point
Q (I)	- Flow in cfs (cms)
QA	- Base flow in cfs (cms)
QCLK (I)	- Time-area ordinate
QH (I,IH)	- Flow in cfs (cms)
QLOSS	- Constant channel loss in cfs (cms)
QM (NH)	- Peak flow in cfs (cms) for hydrograph NH
QMAX	- Maximum ordinate
QMX	- Stored record of peak flow for hydrograph IH
QO (I)	- Observed flow in cfs (cms)
QR	- Recession flow in cfs (cms)
QRC	- QRCSN as read in
QRCSN	- Flow in cfs (cms) below which recession can control
QSQ	- Sum of squares of errors
QUNGR (I)	- Unit hydrograph ordinate in cfs (cms)
R	- Storage coefficient for unit hydrograph
RAIN	- Rainfall in inches (mm)
RAINA (I)	- Rainfall in inches (mm)
RATIO	- Ratio by which hydrograph is to be multiplied
RAVQO	- Reciprocal of average observed flow
RDAYS	- Reciprocal of number of days
RES	- Indicator calling for reservoir routing
RINTV	- Reciprocal of NINTV
RLOSS	- Rainfall loss in inches (mm)
RN	- Precipitation for current interval during system storm corresponding to next smaller area size
RNQ	- Reciprocal of NQ
RNX	- Reciprocal of NX
RQ (I)	- Ratio by which observed flow is multiplied temporarily
RTIMP	- Ratio of basin that is impervious
RTIO (I)	- Ratio of hydrograph to computed for each plan of development
RTIOR	- Ratio of recession flow to that 10 intervals later
R6	- Maximum 6-hour rainfall in inches
R6HR (K)	- Maximum 6-hour rainfall in inches

R12	- Maximum 12-hour rainfall in inches
R24	- Maximum 24-hour rainfall in inches
R24HR (K)	- Maximum 24-hour rainfall in inches
R48	- Maximum 48-hour rainfall in inches
R72	- Maximum 72-hour rainfall in inches
R96	- Maximum 96-hour rainfall in inches
SAREA	- Total basin area in square miles (KM^2)
SLOSS	- Snowmelt loss in inches (mm)
SM (NH)	- Maximum 6-hour or 10-day flow in cfs (cms) for hydrograph NH
SMLCL	- Sum of local flows
SMT	- Snowmelt is inches (mm) for preceding system computation
SMX (NH)	- Maximum 24-hour or 30-day flow in cfs (cms) for hydrograph NH
SMY (NH)	- Maximum 72-hour or 90-day flow in cfs (cms) for hydrograph NH
SNAP	- Sum of normal precipitation
SNMT (I)	- Snowmelt in inches (mm)
SNO (J)	- Snowpack water equivalent in inches (mm)
SNOW (J)	- Snowpack water equivalent in inches (mm)
SNWMT	- Snowmelt in inches (mm)
SOL (I)	- Solar radiation in langleys
SPFE	- Standard project precipitation index for Eastern U.S.
STDER (NC)	- Standard error
STOR (K)	- Storage in acre-feet (cm) in table
STORA	- Initial storage in acre-feet (cm)
STORM	- Storm total precipitation in inches (mm)
STORX	- Initial reservoir storage in acre-feet (thousand m^3)
STR (I)	- Storage in acre-feet (cm)
STRI	- Initial storage in acre-feet (cm)
STRM (I)	- Storm total precipitation for each system computation
STRTL	- Starting value of loss coefficient
STRTQ	- Starting value of flow
SUM	- Temporary sum
SUMA (K)	- Sum obtained in hydrograph balance computation
SUMB (K)	- Sum desired in hydrograph balance computation
SUME	- Sum of excess in inches (mm)
SUMER	- Sum of rainfall excess in inches (mm)
SUMES	- Sum of snowmelt excess in inches (mm)
SUMP	- Sum of precipitation in inches (mm)
SUMQ	- Sum of computed flows in cfs (cms)
SUMQC	- Sum of observed flows in cfs (cms)
SUMQU	- Sum of unit hydrograph flows in cfs (cms)
SUMX	- Temporary sum
SUMY	- Temporary sum
T	- Time factor in time-area function
TAREA	- Total area of sub-basin in sq. mi. (sq. KM)
TC	- Time of concentration in hours
TCEX	- Preceding ratio of volume error to runoff in volume adjustment routine
TEMP	- Temporary variable

TEMPA	- Temporary variable
TEMPR (I)	- Average air temperature in degrees F (c) at bottom of lowest zone for each period
TESTA	- Criterion for optimizing routing lag
TESTB	- Criterion for optimizing number of routing steps
TESTC	- Criterion for optimizing straddle
TLAPS	- Lapse Rate in degrees F per thousand feet (degrees c per)
TLOSR	- Total rainfall loss in inches (mm)
TLOSS	- Total snowmelt loss in inches (mm)
TMP	- Temporary variable
TMPA	- Temporary variable
TMPR (I)	- Temperature in degrees F (c)
TP	- Time to unit hydrograph peak (lag)
TR	- Computation interval in minutes
TRAIN	- Total rainfall in inches (mm)
TRDA (I)	- Drainage area size in square miles (Km^2) corresponding to storm size (STRM) for each system computation
TRHR	- Computation interval in hours
TRSDA	- Transposition drainage area in square miles (Km^2)
TRSPC	- Transposition coefficient
TSK	- Time-of-storage routing coefficient
TSNMT	- Total snowmelt in inches (mm)
TSNO	- Total snowpack in inches (mm)
VAR (M)	- Variable
VOL	- Sum of unit hydrograph ordinates needed to obtain 1 inch
VRA	- Base temperature in degrees F (c) for snowmelt computation
VRB	- Temperature in degrees F (c) below which precipitation falls as snowfall
WIND (I)	- Wind speed in miles per hour (kph)
WTN (K)	- Weight of non-recording station
WTR (K)	- Weight of recording station
X	- Variable used in multiple correlation

EXHIBIT 3

Source Program Listing

```
C      HEC-1 FLOOD HYDROGRAPH PACKAGE 723-X6-L2010  BEARD APR 1968
C      HEC-1 FLOOD HYDROGRAPH PACKAGE 723-X6-L2010  MODIFIED  OCT 1970
C      READ,PRINT
C      32,000 WORDS IN CDC-6600
C      FUNCTIONS
C      SUBSCRIPTS I=INTERVAL J=ELEV NC=COMPUTATION IH=HYDROGRAPH, K=STA
C      NESTING OF QH - NQ INSIDE KHGR INSIDE(NSTM) OR (NPLAN INSIDE NRTIO
       COMMON /MAINA/ KHN,KHR,KN,KQH,KH
       COMMON /ROUTA/ AMSKK,CLOSS,JLAG,JTRNS,KTRNS,LTRNS,NSTDL,NSTL,NSTP,
      1NSTPS,OUTFL(10),QLOSS,STORA,TESTA,TESTB,TESTC,TSK
       COMMON /MACMB/ KINH,KNH,LOCAL,NCMB(120),NQ8(5),SUMA(5),SUMB(5)
       COMMON /MARUN/ ANQ,CNSTL,CUML(10),EXCSS(150),IQ(5),QRCSN,RQ(5),RTI
      1MP,STRTL,ALSMX,QRC
       COMMON /RUNA/ ANDAY(10),RAINA(150),SNOW(10)
       COMMON /MABAS/ ANAPN(50),CP,ISTAN(50),ISTAR(11),KQ,KR,KUHGQ,NCLRK,
      1NSTAN,NSTAR,NSTN,NSTR,PMS,PRCPN(50),PRCPR(150,11),SPFE,STORM,STRM(
      25),TRSPC,TAREA
       COMMON /BASA/ ISTN(25),ISTR( 9),QCLK(100),R24HR(4),R6HR(4),TEMPR(1
      150),WTN(25),WTR( 9)
       COMMON /MAROC/ IBAL,NCOMB,NEXT,RATIO
       COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
      1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
      2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
      3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
       COMMON /BARUN/ AI,ALAG,ANAP(10),AREA(10),AVTMP,CPTMP,EX,IFRST,IZON
      1E,NZONE,QUNGR(100),R,SNO(10),SOL(150),SUMP,SUMQU,TC,VRA,VRB
       COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
      1TDER(3),VAR(10)
       COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
      1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
      2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
      3X,IHRX,IMINX
       COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
       KUHGQ=100
       KQ=150
       KH=270
       KQH=4800
       KN=50
       KR=11
       KHN=25
       KHR= 9
       KNH=120
       KINH=KH
       ISTAQ=0
       ISUB=2
       JSUB=1
20     GO TO (30,40,50,60,70), JSUB
30     CALL MANE
       GO TO 20
40     CALL CMBIN
       GO TO 20
50     CALL BASIN
       GO TO 20
60     CALL ROUTE
       GO TO 20
70     CALL RUNOF
       GO TO 20
       END
```

```
      SUBROUTINE MANE
      COMMON /MAINA/ KHN,KHR,KN,KQH,KH
      COMMON /MACMB/ KINH,KNH,LOCAL,NCMB(120),NQB(5),SUMA(5),SUMB(5)
      COMMON /MARUN/ ANQ,CNSTL,CUML(10),EXCSS(150),IQ(5),QRCSN,RQ(5),RTI
     1MP,STRTL,ALSMX,QRC
      COMMON /MABAS/ ANAPN(50),CP,ISTAN(50),ISTAR(11),KQ,KR,KUHGQ,NCLRK,
     1NSTAN,NSTAR,NSTN,NSTR,PMS,PRCPN(50),PRCPR(150,11),SPFE,STORM,STRM(
     25),TRSPC,TAREA
      COMMON /MAROC/ IBAL,NCOMB,NEXT,RATIO
      COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
     1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
     2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
     3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
     1TDER(3),VAR(10)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHRX,IMINX
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
      COMMON /TME/ IMIN,NMIN,IHR,NHR,IDAY
      DATA LTRA/1HA/
 1000 FORMAT (1X,A3,19A4)
 1010 FORMAT (1X,F7.0,9F8.0)
 1020 FORMAT (1XI7,9I8)
 1030 FORMAT (1H1)
 1040 FORMAT (A1,A3,19A4)
      GO TO (1340,1050,1370,1500,1570,1500,1620), ISUB
C      * * * * START NEW JOB WITH 3 TITLE CARDS, A IN COL. 1 * * * * * *
 1050 READ 1040, ITMP,(Q(I),I=1,20)
      IF (ITMP.NE.LTRA) GO TO 1050
      READ 1000, (Q(I),I=21,60)
C             JOB SPECIFICATION
      READ 1020, NHR,NMIN,NQ,NSTAN,NSTAR,ISNOW,IDERV,IPLOT,NSTM,NPLAN
C             FOUR BLANK CARDS CAUSE STOP, A IN COL. 1
      IF (NQ.LE.0) STOP
      READ 1020, IPRNT,METRC,IDGST,IDAYX,IHRX,IMINX
      IF (NQ.GT.KQ.OR.NSTAN.GT.KN.OR.NSTAR.GT.KR) GO TO 1340
      MRTIO=0
      NRTIO=0
      ANQ=NQ
      RNQ=1./ANQ
      PRINT 1030
      PRINT 1000, (Q(I),I=1,60)
      PRINT 1060
 1060 FORMAT (/80H     NHR     NMIN       NQ    NSTAN    NSTAR    ISNOW    IDE
     1RV    IPLOT    NSTM     NPLAN)
      PRINT 1020, NHR,NMIN,NQ,NSTAN,NSTAR,ISNOW,IDERV,IPLOT,NSTM,NPLAN
      PRINT 1070
 1070 FORMAT (/48H    IPRNT    METRC    IDGST    IDAYX     IHRX    IMINX)
      PRINT 1020, IPRNT,METRC,IDGST,IDAYX,IHRX,IMINX
C             INITIATE CONSTANTS FOR SUBROUTINE OPTIM
      IF (NSTM.LE.0) NSTM=1
      ISTM=1
      IF (NSTM.LE.1) GO TO 1090
```

```
      READ 1010, (TRDA(I),STRM(I),I=1,NSTM)
      IF (IPRNT.LT.3) PRINT 1080, (TRDA(I),STRM(I),I=1,NSTM)
1080  FORMAT (/15H AREA VS PRECIP5(F10.0,F8.2))
1090  ITRNS=-1
      IF (NPLAN.LE.0) GO TO 1120
      READ 1100, NRTIO,(RTIO(J),J=1,9)
1100  FORMAT (1X,I7,9F8.0)
      MRTIO=NRTIO
      IF (NRTIO.LT.0) NRTIO=(-NRTIO)
      IF (NRTIO.GT.9) READ 1010, (RTIO(J),J=10,NRTIO)
      IF (IPRNT.LT.4) PRINT 1110, NRTIO,(RTIO(J),J=1,NRTIO)
1110  FORMAT (7H0NRTIO=I3,7H  RTIO=16F6.3)
1120  NH=1
      ITMP=NPLAN*NRTIO
      IF (ITMP.LT.NSTM) ITMP=NSTM
      KHGR=KQH/(ITMP*NQ)
      ITMP=KH/ITMP
      IF(KHGR.GT.ITMP)KHGR=ITMP
      DO 1130 NC=1,3
1130  STDER(NC)=0.
      TR=NHR*60+NMIN
      TRHR=TR/60.
      DO 1140 I=1,NQ
      PRCP(I)=0.
1140  QO(I)=0.
      IF (IDERV.LE.0) GO TO 1220
C      * * * * OBSERVED FLOWS  * * * * * * * * * * * * * * * * * * * * *
      READ 1010, (QO(I),I=1,NQ)
      DO 1150 I=1,10
1150  IFREZ(I)=0
      SUMQO=0.
      DO 1160 I=1,NQ
      ITMP=QO(I)+.5
      TMP=ITMP
1160  SUMQO=SUMQO+TMP
C               TEMPORARY DISTORTION OF OBSERVED FLOWS
      READ 1170, (IQ(I),RQ(I),I=1,5)
1170  FORMAT (1X,I7,F8.0,I8,F8.0,I8,F8.0,I8,F8.0,I8,F8.0)
      IF (IPRNT.GE.3) GO TO 1200
      PRINT 1180
1180  FORMAT (/5(6X2HIQ,6X2HRQ))
      PRINT 1190, (IQ(I),RQ(I),I=1,5)
1190  FORMAT (1X,I7,F8.2,I8,F8.2,I8,F8.2,I8,F8.2,I8,F8.2)
1200  AVGQO=SUMQO*RNQ
      RAVQO=.5/AVGQO
      DO 1210 N=1,5
      I=IQ(N)
      IF (I.LE.0) GO TO 1210
      IF (RQ(N).LT..01) RQ(N)=.01
      QO(I)=QO(I)*RQ(N)
1210  CONTINUE
C      * * * * PRECIPITATION STATION DATA  * * * * * * * * * * * * * * *
1220  IF (NSTAN.LE.0) GO TO 1360
      READ 1230, (ISTAN(K),PRCPN(K),ANAPN(K),K=1,NSTAN)
1230  FORMAT (1X,I7,2F8.0)
      IF (IPRNT.GE.3) GO TO 1260
      PRINT 1240
1240  FORMAT (/21H NON-RECORDING PRECIP/5X19HSTA   STORM     NAP)
      PRINT 1250, (ISTAN(K),PRCPN(K),ANAPN(K),K=1,NSTAN)
1250  FORMAT (1X,I7,2F8.2)
```

```
1260  DO 1270 K=1,NSTAN
      IF (ANAPN(K).LE.0.) ANAPN(K)=1.
1270  CONTINUE
      IF (IPRNT.LT.3) PRINT 1280
1280  FORMAT (/17H RECORDING PRECIP)
      DO 1330 K=1,NSTAR
      READ 1290, ISTAR(K),(PRCPR(I,K),I=1,NQ)
1290  FORMAT (1XI7/(1XF7.0,9F8.0))
      IF (IPRNT.LT.3) PRINT 1300, ISTAR(K),(PRCPR(I,K),I=1,NQ)
1300  FORMAT (I8/(10F8.2))
      TEMP=0.
      DO 1310 I=1,NQ
      TMP=PRCPR(I,K)
      IF (TMP.LT.(-.1)) GO TO 1330
1310  TEMP=TEMP+TMP
      DO 1320 J=1,NSTAN
      IF (ISTAR(K).EQ.ISTAN(J)) PRCPN(J)=TEMP
1320  CONTINUE
1330  CONTINUE
      GO TO 1360
1340  PRINT 1350
1350  FORMAT (/19H DIMENSION EXCEEDED)
      GO TO 1050
1360  IH=0
      IF (NSTAN.LE.(-1)) NSTAN=-NSTAN
      IF (NSTAR.LE.(-1)) NSTAR=-NSTAR
C      * * * * HYDROGRAPH, ENTRY FROM 4740,4320+6 (CMBIN)* * * * * * * *
1370  IF (ISTM.LE.1.OR.ISTAQ.GE.0) GO TO 1410
      ITP=(IH-1)*NQ
      DO 1390 K=1,NRTIO
      ITMP=ITP+KHGR*NQ*(ISTM-1)
      DO 1380 I=1,NQ
      ITP=ITP+1
      ITMP=ITMP+1
1380  QH(ITMP)=QH(ITP)
1390  ITP=ITP-NQ+KHGR*NPLAN*NQ
      ITP=ISTM-1
      IF (IPNT.GT.(-1).AND.IPRNT.LT.1) PRINT 1400, ISTM,ITP
1400  FORMAT (5HOPLANI2,13H SAME AS PLANI2)
      JSUB=2
      ISUB=3
      RETURN
1410  READ 1020, ISTAQ,IHDGR,NP,NSTN,NSTR,NUHGQ,NCLRK,LOCAL,NCOMB,NEXT,I
     1PNT,NDMG,IBAL,INRGY
      IOPER(NH)=1
      IF (ISTM.LE.1) IH=IH+1
      IF (IH.GT.KHGR.AND.ISTM.LE.1) GO TO 1340
      IF (ISTM.GT.1.AND.MRTIO.LT.0) IH=IH+KHGR
      IF (IPRNT.GE.4) GO TO 1440
      PRINT 1420
1420  FORMAT (/80H    ISTAQ    IHDGR       NP     NSTN     NSTR    NUHGQ    NCL
     1RK    LOCAL    NCOMB     NEXT)
      PRINT 1020, ISTAQ,IHDGR,NP,NSTN,NSTR,NUHGQ,NCLRK,LOCAL,NCOMB,NEXT
      PRINT 1430
1430  FORMAT (/32H     IPNT     NDMG     IBAL    INRGY)
      PRINT 1020, IPNT,NDMG,IBAL,INRGY
1440  IF (NSTN.GT.KHN.OR.NSTR.GT.KHR) GO TO 1340
      IF (NP.GT.KQ) GO TO 1340
      IUHGQ=0
      IF (NUHGQ.GT.KUHGQ) GO TO 1340
```

```
      IF (NUHGQ.GT.0) IUHGQ=1
      READ 1450, STORM,SPFE,PMS,TRSPC,TRSDA,STRTL,CNSTL,RTIMP,QRCSN,RTIO
     1R,STRTQ,ALSMX,TLAPS,RATIO,TP,CP,TAREA
 1450 FORMAT (1XF7.0,9F8.0/1XF7.0,6F8.0,2I8)
      QRC=QRCSN
      IF (IPRNT.GE.4) GO TO 1480
      PRINT 1460, STORM,SPFE,PMS,TRSPC,TRSDA,STRTL,CNSTL,RTIMP,QRCSN,RTI
     1OR
 1460 FORMAT (/80H   STORM     SPFE      PMS    TRSPC    TRSDA    STRTL    CNS
     1TL    RTIMP    QRCSN   RTIOR/4F8.2,F8.0,3F8.2,F8.0,F8.2)
      PRINT 1470, STRTQ,ALSMX,TLAPS,RATIO,TP,CP,TAREA
 1470 FORMAT (/56H   STRTQ    ALSMX    TLAPS    RATIO       TP       CP    TAR
     1EA/F8.0,6F8.2)
 1480 IF (RTIOR.LE.0.) RTIOR=1.
      IF (ALSMX.LE.0.) ALSMX=9.
      IF (RATIO.LE.0.) RATIO=1.
      IF (NSTM.GT.1) TRSDA=TRDA(1)
      IRTIO=1
      IF (IHDGR.LE.0) GO TO 1490
      ISUB=1
      JSUB=2
      RETURN
 1490 CNSTL=CNSTL*TRHR
      RTIOR=1./RTIOR**.1
      RTIMP=1.-RTIMP
      ISUB=1
      JSUB=3
      RETURN
 1500 CALL SUMRY (IH)
C     **********************************
C                  PLOT
      IF (IPLOT.LE.0.OR.ISTM.GT.1) GO TO 1510
      CALL GRAPH
C     **********************************
 1510 QMX(IH)=QMAX
      IF (NPLAN.GT.0) GO TO 1520
      ISUB=4
      JSUB=2
      RETURN
 1520 IRTIO=IRTIO+1
      IF (IRTIO.GT.NRTIO) GO TO 1540
      IH=IH+KHGR*NPLAN
      ITP=(IH-1)*NQ
      DO 1530 I=1,NQ
      ITP=ITP+1
 1530 Q(I)=QH(ITP)
      ISUB=2
      JSUB=4
      RETURN
 1540 ISTM=ISTM+1
      IF (ISTM.GT.NPLAN) GO TO 1560
      IH=IH-KHGR*NPLAN*(NRTIO-1)+KHGR
      ITP=(IH-1)*NQ
      DO 1550 I=1,NQ
      ITP=ITP+1
 1550 Q(I)=QH(ITP)
      ISUB=1
      JSUB=4
      RETURN
 1560 IH=IH-(NRTIO*NPLAN-1)*KHGR
```

```
      IF (NCOMB.LE.0) CALL ECONO
C     **********************************
      ISTM=1
      ISUB=5
      JSUB=2
      RETURN
C                 ENTRY FROM 5790 (ROUTE)
1570  ITP=(IH-1)*NQ
      IF (IDERV.LE.0) GO TO 1590
      DO 1580 I=1,NQ
      ITP=ITP+1
1580  STR(I)=QH(ITP)
      NV=8
      GO TO 1610
1590  DO 1600 I=1,NQ
      ITP=ITP+1
1600  QO(I)=QH(ITP)
      NV=2
1610  CALL GRAPH
C     **********************************
      IF (IDERV.GT.0) GO TO 1050
      ISUB=6
      JSUB=2
      RETURN
C                 ENTRY FROM 4760+2 (CMBIN)
1620  IF (NH.LE.2.OR.NPLAN.GE.1) GO TO 1050
      PRINT 1630
1630  FORMAT (//23X27HRUNOFF SUMMARY, AVERAGE CFS)
      NH=NH-1
      IF (TRHR*ANQ.LE.700.) PRINT 1640
1640  FORMAT (/28X34HPEAK     6-HOUR   24-HOUR    72-HOUR)
      IF (TRHR*ANQ.GT.700.) PRINT 1650
1650  FORMAT (/28X34HPEAK     10-DAY    30-DAY     90-DAY)
      DO 1720 IH=1,NH
      ITP=IOPER(IH)
      GO TO (1660,1680,1700), ITP
1660  PRINT 1670, ISTQ(IH),QM(IH),SM(IH),SMX(IH),SMY(IH)
      GO TO 1720
1670  FORMAT (14H HYDROGRAPH ATI8,4F10.0)
1680  PRINT 1690, ISTQ(IH),QM(IH),SM(IH),SMX(IH),SMY(IH)
      GO TO 1720
1690  FORMAT (10H ROUTED TOI12,4F10.0)
1700  PRINT 1710, NCMB(IH),ISTQ(IH),QM(IH),SM(IH),SMX(IH),SMY(IH)
1710  FORMAT (I3,9H COMBINEDI10,4F10.0)
1720  CONTINUE
      GO TO 1050
      END



      SUBROUTINE BASIN
      COMMON /MABAS/ ANAPN(50),CP,ISTAN(50),ISTAR(11),KQ,KR,KUHGQ,NCLRK,
     1NSTAN,NSTAR,NSTN,NSTR,PMS,PRCPN(50),PRCPR(150,11),SPFE,STORM,STRM(
     225),TRSPC,TAREA
      COMMON /BASA/ ISTN(25),ISTR( 9),QCLK(100),R24HR(4),R6HR(4),TEMPR(1
     150),WTN(25),WTR( 9)
      COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
     1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
```

```
     2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
     3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
      COMMON /BARUN/ AI,ALAG,ANAP(10),AREA(10),AVTMP,CPTMP,EX,IFRST,IZON
     1E,NZONE,QUNGR(100),R,SNO(10),SOL(150),SUMP,SUMQU,TC,VRA,VRB
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
     1TDER(3),VAR(10)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHRX,IMINX
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
C      * * * * PRECIPITATION FROM STATION DATA * * * * * * * * * * * * * *
 2000 FORMAT (1X,F7.0,9F8.0)
 2010 FORMAT (1X,I7,F8.0,I8,F8.0,I8,F8.0,I8,F8.0,I8,F8.0)
 2020 FORMAT (1X,I7,F8.2,I8,F8.2,I8,F8.2,I8,F8.2,I8,F8.2)
 2030 FORMAT (14F8.2,F6.0,F8.2,F6.2)
      GO TO (2040,2950,2250), ISUB
 2040 IF (NSTN.LE.0) GO TO 2250
      READ 2010, (ISTN(K),WTN(K),K=1,NSTN)
      IF (IPRNT.GE.3) GO TO 2070
      PRINT 2050
 2050 FORMAT (/14H PRECIP STA WT)
      PRINT 2060
 2060 FORMAT (21HONON RECORDING PRECIP)
      PRINT 2020, (ISTN(K),WTN(K),K=1,NSTN)
 2070 READ 2010, (ISTR(K),WTR(K),K=1,NSTR)
      IF (IPRNT.GE.3) GO TO 2090
      PRINT 2080
 2080 FORMAT (/17H RECORDING PRECIP)
      PRINT 2020, (ISTR(K),WTR(K),K=1,NSTR)
 2090 PRCPA=0.
      TEMP=0.
      DO 2130 K=1,NSTN
      DO 2100 L=1,NSTAN
      IF (ISTAN(L).EQ.ISTN(K)) GO TO 2120
 2100 CONTINUE
      PRINT 2110
 2110 FORMAT (13H WRONG STA NO)
      GO TO 2140
 2120 TEMP=TEMP+WTN(K)*ANAPN(L)
 2130 PRCPA=PRCPA+PRCPN(L)*WTN(K)
      PRCPA=PRCPA/TEMP
      GO TO 2150
 2140 ISUB=2
      JSUB=1
      RETURN
C             SEE 2670+ FOR ADJUSTMENT TO BASIN NAP
 2150 DO 2160 I=1,NQ
      Q(I)=0.
 2160 PRCP(I)=0.
      DO 2200 K=1,NSTR
      DO 2170 L=1,NSTAR
      IF (ISTAR(L).EQ.ISTR(K)) GO TO 2180
 2170 CONTINUE
      PRINT 2110
      GO TO 2140
 2180 DO 2190 I=1,NQ
      TEMP=PRCPR(I,L)
      IF (TEMP.LE.(-.01)) GO TO 2190
      PRCP(I)=PRCP(I)+TEMP*WTR(K)
```

```
      Q(I)=Q(I)+WTR(K)
2190  CONTINUE
2200  CONTINUE
      SUMP=0.
      DO 2230 I=1,NQ
      IF (Q(I).GT.0.) GO TO 2220
      PRINT 2210, I
2210  FORMAT (/19H NO PRECIP DATA PERI3,14H, ASSUMED ZERO)
      GO TO 2230
2220  PRCP(I)=PRCP(I)/Q(I)
      SUMP=SUMP+PRCP(I)
      IF (PRCP(I).GT.0.) NP=I
2230  CONTINUE
      TEMP=PRCPA/SUMP
      DO 2240 I=1,NQ
2240  PRCP(I)=PRCP(I)*TEMP
      GO TO 2550
C                ENTRY FROM 4370+3 (CMBIN)
2250  IF (TRSPC.GT.0.) GO TO 2260
      TRSPC=1.
      IF (SPFE+PMS.GT.0.) TRSPC=1.-.3008/TRSDA**.17718
C      * * * * STANDARD PROJECT AND PROBABLE MAX. PRECIP * * * * * * * * *
2260  IF (SPFE+PMS.LE.0.) GO TO 2490
      IF (SPFE.LE.0.) GO TO 2420
C                STANDARD PROJECT 24-HR PERCENTAGES
      TEMP=1.
      IF (METRC.GT.0) TEMP=0.3861
      R24HR(3)=182.15-14.3537*ALOG(TRSDA*TEMP+80.)
      R24HR(1)=3.5
      R24HR(2)=15.5
      R24HR(4)=6.
      N24HR=4
C                6-HOUR RATIOS OF 24-HR AMOUNTS
      TMP=1.
      IF (METRC.GT.0) TMP=25.4
      R6HR(3)=13.42/(SPFE/TMP+11.)**.93
      R6HR(2)=.055*(SPFE/TMP-6.)**.51
      R6HR(4)=(1.-R6HR(3)-R6HR(2))*.5+.0165
      R6HR(1)=R6HR(4)-.033
      TEMP=SPFE*TRSPC*.01
2270  NINTV=360./TR
      ITP=NP
      NP=NINTV*4*N24HR
      IF(NQ.LT.NP)NQ=NP
      IF (NP.LE.KQ) GO TO 2290
2280  ISUB=1
      JSUB=1
      RETURN
2290  IF (ITP.LE.(-1)) NP=-NP
      RINTV=TR/360.
      TMP=NINTV
      K=360.5-TMP*TR
      IF (K.EQ.0) GO TO 2310
      PRINT 2300
2300  FORMAT (22H UNACCEPTABLE INTERVAL)
      GO TO 2140
C                SUBDIVISION OF MAX 6-HR RAIN EACH DAY
2310  IF (NINTV-2) 2320,2330,2340
2320  Q(1)=1.
      GO TO 2360
```

```
2330   Q(1)=.33
       Q(2)=.67
       GO TO 2360
2340   IF (NINTV.GE.6) GO TO 2350
       Q(1)=.26
       Q(2)=.53
       Q(3)=.21
       GO TO 2360
2350   Q(1)=.10
       Q(2)=.12
       Q(3)=.15
       Q(4)=.38
       Q(5)=.14
       Q(6)=.11
2360   NX=NINTV/6
       RNX=NX
       RNX=1./RNX
       I=0
       DO 2410 J=1,N24HR
       DO 2400 K=1,4
       TMP=TEMP*R24HR(J)*R6HR(K)
       DO 2390 L=1,NINTV
       I=I+1
       IF (K.EQ.3) GO TO 2370
       PRCP(I)=TMP*RINTV
       GO TO 2390
2370   IF (NINTV.GT.6) GO TO 2380
       PRCP(I)=TMP*Q(L)
       GO TO 2390
2380   NPR=(L-1)/NX+1
       PRCP(I)=TMP*Q(NPR)*RNX
2390   CONTINUE
2400   CONTINUE
2410   CONTINUE
       GO TO 2550
C                PROBABLE MAX STORM AMOUNTS
2420   READ 2000, R6,R12,R24,R48,R72,R96
       PRINT 2430, R6,R12,R24,R48,R72,R96
2430   FORMAT (/13H PMS PERCENTS6F8.2)
       IF (R96.LE.0.) GO TO 2440
       N24HR=4
       R24HR(3)=R24
       R24HR(2)=R48-R24
       R24HR(4)=R72-R48
       R24HR(1)=R96-R72
       GO TO 2480
2440   IF (R72.LE.0.) GO TO 2450
       N24HR=3
       R24HR(3)=R72-R48
       GO TO 2460
2450   IF (R48.LE.0.) GO TO 2470
       N24HR=2
2460   R24HR(2)=R24
       R24HR(1)=R48-R24
       GO TO 2480
2470   N24HR=1
       R24HR(1)=R24
2480   TEMP=PMS*TRSPC*.01
       R6HR(3)=R6/R24
       R6HR(2)=(R12-R6)/R24
```

```
      R6HR(1)=(R24-R12)*.4/R24
      R6HR(4)=R6HR(1)*1.5
      GO TO 2270
C      * * * * READ BASIN PRECIPITATION  * * * * * * * * * * * * * * * *
2490  ITP=NP
      IF (ITP.LT.0) ITP=-ITP
      IF (NP.GT.0) GO TO 2500
      IF (NP.LE.(-1)) GO TO 2510
      IF (NP.LE.0) GO TO 2550
2500  READ 2000, (PRCPR(I,KR),I=1,NP)
2510  DO 2520 I=1,ITP
2520  PRCP(I)=PRCPR(I,KR)
      SUMP=0.
      DO 2530 I=1,ITP
2530  SUMP=SUMP+PRCP(I)
      TEMP=TRSPC
      IF (STORM.GT.0.) TEMP=TEMP*STORM
      TMP=1.
      IF (NSTM.GT.1) TMP=STRM(1)
C                 COMPUTE PRECIP FOR INCREMENTAL TRANSPOSITION AREA
      IF (ISTM.GT.1.AND.NSTM.GT.1) TMP=(STRM(ISTM)*TRDA(ISTM)-STRM(ISTM-
     11)*TRDA(ISTM-1))/(TRDA(ISTM)-TRDA(ISTM-1))
      TEMP=TEMP*TMP
      IF (STORM.GT.0..OR.NSTM.GT.1) TEMP=TEMP/SUMP
      SUMP=0.
      DO 2540 J=1,ITP
      PRCP(J)=TEMP*PRCP(J)
 2540 SUMP=SUMP+PRCP(J)
      IF (NP.LE.(-1)) GO TO 2570
C               SNOWMELT DATA
2550  DO 2560 J=1,10
2560  SNO(J)=0.
      IF (ISNOW.LE.0) GO TO 2590
      READ 2000, (TEMPR(I),I=1,NQ)
      IF (ENRGY.LE.0.) GO TO 2570
      READ 2000, (DEWPT(I),I=1,NQ)
      READ 2000, (WIND(I),I=1,NQ)
      READ 2000, (SOL(I),I=1,NQ)
2570  AVTMP=0.
C      * * * * DRAINAGE BASIN DATA * * * * * * * * * * * * * * * * * * *
      IF (ISNOW.LE.0) GO TO 2590
      DO 2580 I=1,NQ
      TMPR(I)=TEMPR(I)
2580  AVTMP=AVTMP+TMPR(I)
      AVTMP=AVTMP*RNQ
      IF (ISTM.GT.1) GO TO 2590
      READ 2000, (SNO(J),J=1,10)
2590  IF (NP.LE.(-1)) NP=-NP
      IF (NP.GE.NQ) GO TO 2610
      J=NP+1
      DO 2600 I=J,NQ
2600  PRCP(I)=0.
 2610 IF(ISTM.GT.1.AND.NPLAN.LE.0)  GO TO 2700
      IF(ISTM.GT.1.AND.ISTAQ.LE.(-1)) GO TO 2700
      IF (TAREA.LE.0.) GO TO 2620
      SAREA=TAREA
      SNAP=1.
      ANAP(1)=1.
      AREA(1)=SAREA
      IZONE=1
```

```
      NZONE=1
      GO TO 2700
 2620 READ 2000, (AREA(J),J=1,10)
      SAREA=AREA(1)
      IF (NP.LE.0) GO TO 2960
      READ 2000, (ANAP(J),J=1,10)
      TEMP=NQ
      TEMP=TEMP*TRHR
      IF (IPRNT.GE.3) GO TO 2660
      PRINT 2630, (SNO(J),J=1,10)
 2630 FORMAT (/8H   SNOW=10F8.1)
      PRINT 2640, (AREA(J),J=1,10)
      PRINT 2650, (ANAP(J),J=1,10)
 2640 FORMAT (/8H   AREA=10F8.1)
 2650 FORMAT (/8H    NAP=10F8.2)
 2660 SAREA=0.
      SNAP=0.
      IZONE=1
      DO 2670 J=1,10
      SAREA=SAREA+AREA(J)
      IF (SAREA.LE.0.) IZONE=J+1
      IF (AREA(J).GT.0.) NZONE=J
      IF (ANAP(J).LE.0.) ANAP(J)=1.
 2670 SNAP=SNAP+ANAP(J)*AREA(J)
      SNAP=SNAP/SAREA
      IF (IPRNT.LT.3) PRINT 2680, SAREA,SNAP
 2680 FORMAT (/6H AREA=F8.1,5X4HNAP=F7.2)
C              COMPLETION OF COMPUTATION AT 2130+AND 2540
      IF (SNAP.LE.0.) SNAP=1.
      IF (NSTN.LE.0) GO TO 2700
      DO 2690 I=1,NP
 2690 PRCP(I)=PRCP(I)*SNAP
 2700 ITEMP=0
      SUMP=0.
      DO 2710 I=1,NP
      ITMP=PRCP(I)*100.+.5
      TEMP=ITMP
      PRCP(I)=TEMP*.01
 2710 SUMP=SUMP+PRCP(I)
      IF(ISTM.GT.1.AND.NPLAN.LE.0) GO TO 3180
      IF (ISTM.GT.1.AND.ISTAQ.LE.(-1)) GO TO 3180
      TSNO=0.
      DO 2720 J=IZONE,NZONE
      ANAP(J)=ANAP(J)/SNAP
      AREA(J)=AREA(J)/SAREA
      IF (ISNOW.GT.0) TSNO=TSNO+SNO(J)*AREA(J)
 2720 CONTINUE
      VOL=SAREA*645./TRHR
      IF (METRC.GT.0) VOL=SAREA*.278/TRHR
C      * * * * HYDROGRAPH COMPUTATION DATA * * * * * * * * * * * * * * *
      DA(NH)=SAREA
      IFRST=1
      M1=0
      NC=1
      IEND=1
      NC2=0
      NVAR=10
      IF (IDERV.GT.0.AND.IPRNT.LT.3) PRINT 2730
 2730 FORMAT (/1X,10HINPUT DATA)
      IF (IPRNT.LT.3) PRINT 2740
```

```
2740  FORMAT(/6X2HTC7X1HR4X60HCOEF    STRKR    STRKS    RTIOK    ERAIN    FRZ
     1TP    DLTKR    RTIOL)
2750  FORMAT (4X4HTC+R9H R/(TC+R)3X60HCOEF    STRKR    STRKS    RTIOK    ERA
     1IN    FRZTP    DLTKR    RTIOL)
C              SAVE INPUT VALUES IN DUMMY ARRAY
      READ 2000, (STOR(I),I=1,NVAR)
      IF (STOR(1).LT.(-1.1).AND.IPRNT.LT.3) PRINT 2760
2760  FORMAT (10X,7H/(TC+R))
      IF (STOR(4).LT.(-1.1).AND.IPRNT.LT.3) PRINT 2770
2770  FORMAT (65X,6H/STRKR)
      IF (IPRNT.LT.3) PRINT 2030, (STOR(I),I=1,NVAR)
      IF (IDERV.GT.0) GO TO 2810
      IF (STOR(1).LT.(-.1)) VAR(1)=TC
      IF (STOR(2).LT.(-.1)) VAR(2)=R
      DO 2780 I=1,NVAR
C              VALUE OF VAR FROM PREVIOUS JOB IF STOR IS NEGATIVE
      IF (STOR(I).GT.(-.1)) VAR(I)=STOR(I)
2780  CONTINUE
      IF(NUHGQ.GT.0)GO TO 2850
      IF (VAR(1).LT.TRHR) PRINT 2790
2790  FORMAT (21H TC INCREASED TO TRHR)
      IF (VAR(1).LT.TRHR*1.001) VAR(1)=TRHR*1.001
      IF (VAR(2).LT.TRHR*.5) PRINT 2800
2800  FORMAT (22H R INCREASED TO TRHR/2)
      IF (VAR(2).LT.TRHR*.5001) VAR(2)=TRHR*.5001
      GO TO 2840
2810  DO 2820 I=1,NVAR
2820  VAR(I)=STOR(I)
      IF (STOR(1).LT.(-1.1)) GO TO 2830
      IF (VAR(1).LE.0.) VAR(1)=-1.
      IF (VAR(1).LE.0.) VAR(2)=-1.
      IF (VAR(2).LE.0.) VAR(1)=-1.
2830  IF (VAR(1).LE.0.) GO TO 2850
      IF (VAR(2).LT.TRHR*.5) VAR(2)=TRHR*.5
      IF (VAR(1).LT.TRHR*1.03) VAR(1)=TRHR*1.03
2840  VAR(1)=(VAR(1)+VAR(2))/TRHR
      VAR(2)=VAR(2)/(VAR(1)*TRHR)
2850  IF (IDERV.LE.0) GO TO 2950
      TMP=NQ
      TMP=TRHR*TMP
      IF (TMP.LE.700..OR.ISNOW.LE.0) GO TO 2860
      VAR(9)=0.
      IFREZ(9)=1
      IFREZ(10)=1
C              COMPUTE VOLUME OF EXCESS(EX) FROM OBSERVED RUNOFF
2860  TEMP=0.
      TMP=QO(NQ)
      QA=STRTQ
      IF (QO(NQ)-STRTQ) 2880,2900,2870
2870  QA=QO(NQ)
      TMP=STRTQ
2880  DO 2890 I=1,NQ
      QA=QA*RTIOR
      IF (QA.LT.TMP) GO TO 2900
      TEMP=TEMP+QA
2890  CONTINUE
2900  IF (QO(NQ).GT.STRTQ) TEMP=-TEMP
      EX=(SUMQO-TEMP)/VOL
      DO 2910 I=1,NVAR
      IFREZ(I)=1
```

```
      IF (VAR(I).LT.(-.1)) IFREZ(I)=0
2910  CONTINUE
C      * * * * INITIATE VARIABLES  * * * * * * * * * * * * * * * * * * * *
      IF (IFREZ(1).GT.0) GO TO 2920
      VAR(1)=SAREA**.5/TRHR
      IF (METRC.GT.0) VAR(1)=(SAREA*.3861)**.5/TRHR
      IF (VAR(1).LT.3.) VAR(1)=3.
      IF (IFREZ(2).LT.1) VAR(2)=.5
2920  IF (IFREZ(3).GT.0) GO TO 2930
      VAR(3)=.07
      IF (INRGY.GT.0) VAR(3)=1.
2930  IF (IFREZ(4).LE.0) VAR(4)=.2
      IF (IFREZ(5).LE.0) VAR(5)=.2
      IF (IFREZ(6).LE.0) VAR(6)=2.
      IF (IFREZ(7).LE.0) VAR(7)=.5
      IF (IFREZ(8).LE.0) VAR(8)=32.
      IF (IFREZ(9).LE.0) VAR(9)=.5
      IF (IFREZ(10).LE.0) VAR(10)=2.
      CALL OPTIM
C     **********************************
      IF (IPRNT.GE.3) GO TO 2950
      PRINT 2940
2940  FORMAT (/1X,17HINITIAL ESTIMATES)
      PRINT 2750
      PRINT 2030, (VAR(I),I=1,NVAR)
C              ENTER FROM 1860-1920
2950  VRA=VAR(8)-TLAPS/2.
      VRB=VRA+2.
C      * * * * UNIT HYDROGRAPH * * * * * * * * * * * * * * * * * * * * *
      IF (IUHGQ.LE.0) GO TO 2960
      IF (IFRST.LE.0) GO TO 3180
      IFREZ(1)=1
      IFREZ(2)=1
      READ 2000, (QUNGR(I),I=1,NUHGQ)
      SUMQU=-1.
      ALAG=-1.
      CPTMP=-1.
      GO TO 3180
2960  IF (IFRST.LE.0.AND.IFREZ(1)+IFREZ(2).EQ.2) GO TO 3180
      IF (M1.LE.2.AND.NC2.EQ.1) GO TO 2970
      IF (IFRST.LE.0.AND.M.GT.3) GO TO 3180
2970  R=VAR(1)*VAR(2)
      TC=VAR(1)-R
      NX=0
      ITB=TC
      IF (ITB.GE.KUHGQ) GO TO 2280
      IF (NCLRK.LE.0) GO TO 3010
      IF (IFRST.LE.0) GO TO 2990
      READ 2000, (Q(I),I=1,NCLRK)
      CLARK=NCLRK-1
C              CHANGE TIME-AREA ORDINATES TO CFS FOR 1 INCH
      DO 2980 I=1,NCLRK
2980  QCLK(I)=Q(I)*VOL/Q(NCLRK)
      QCLK(NCLRK+1)=QCLK(NCLRK)
C              INTERPOLATION
2990  CL=CLARK/TC
      ITB=TC
      ISUB=1
      JSUB=1
      IF (ITB.GE.KUHGQ) RETURN
```

```
      DO 3000 I=1,ITB
      AI=I
C                END OF PERIOD 1 IS INDEXED 2, ETC.
      T=AI*CL+1.
      IT=T
      CIT=IT
      CA=T-CIT
      CB=1.-CA
3000  QUNGR(I)=QCLK(IT)*CB+QCLK(IT+1)*CA
      GO TO 3040
C                SYNTHETIC TIME-AREA CURVE
3010  TEMP=.5/.5**1.5*VOL
      DO 3030 I=1,ITB
      AI=I
      IF (AI.GT.TC*.5) GO TO 3020
      QUNGR(I)=TEMP*(AI/TC)**1.5
      GO TO 3030
3020  QUNGR(I)=VOL-TEMP*((TC-AI)/TC)**1.5
3030  CONTINUE
3040  ITB=ITB+1
      QUNGR(ITB)=VOL
      DO 3050 L=2,ITB
      I=ITB-L+2
3050  QUNGR(I)=QUNGR(I)-QUNGR(I-1)
C                BASIN ROUTING
      CA=1./(R+.5)
      CB=1.-CA
      Q(1)=QUNGR(1)*CA
      QUNGR(1)=Q(1)*.5
      QMAX=0.
      SUMQU=QUNGR(1)
      DO 3070 I=2,KUHGQ
      IF (I.LE.ITB) Q(I)=QUNGR(I)*CA+Q(I-1)*CB
      IF (I.GT.ITB) Q(I)=Q(I-1)*CB
      QUNGR(I)=(Q(I)+Q(I-1))*.5
      SUMQU=SUMQU+QUNGR(I)
      IF (QUNGR(I).LE.QMAX) GO TO 3060
      QMAX=QUNGR(I)
      LAG=I
3060  IF (SUMQU.GT..995*VOL) GO TO 3080
3070  CONTINUE
      NUHGQ=KUHGQ
      GO TO 3090
3080  NUHGQ=I
      IX=0
3090  ALAG=LAG
      IF (LAG-1) 3100,3100,3110
3100  ALAG=1.5-(QUNGR(1)-QUNGR(2))/QUNGR(1)*.5
      GO TO 3140
3110  IF (QUNGR(LAG-1)-QUNGR(LAG+1)) 3120,3140,3130
3120  ALAG=ALAG+.5-(QUNGR(LAG)-QUNGR(LAG+1))/(QUNGR(LAG)-QUNGR(LAG-1))
      GO TO 3140
3130  ALAG=ALAG-.5+(QUNGR(LAG)-QUNGR(LAG-1))/(QUNGR(LAG)-QUNGR(LAG+1))
3140  ALAG=(ALAG-.75)*TRHR*1.048
C                ITERATE TO OBTAIN DESIRED SNYDER COEFFICIENTS
      CPTMP=QMAX*ALAG/(645.*SAREA)
      IF (CP.LE.0.) GO TO 3170
      TEMP=CP/CPTMP
      IF (TEMP.LE.1.01.AND.TEMP.GE..99) GO TO 3150
      R=R/TEMP
```

```
      IF (R.LT.TRHR*.5) R=TRHR*.5
      IX=1
3150  TEMP=TP/ALAG
      IF (TEMP.LE.1.01.AND.TEMP.GE..99) GO TO 3160
      TC=TC*TEMP
      IF (TC.LT.TRHR) TC=TRHR
      IX=1
3160  IF (IX.EQ.1) NX=NX+1
      IF (IX.EQ.1.AND.NX.LT.10) GO TO 2990
3170  SUMQU=SUMQU/VOL
      ISUB=3
      JSUB=5
      IF (NP.LE.0) RETURN
      ISUB=1
      RETURN
3180  JSUB=5
      ISUB=2
      RETURN
      END




      SUBROUTINE RUNOF
      COMMON /MARUN/ ANQ,CNSTL,CUML(10),EXCSS(150),IQ(5),QRCSN,RQ(5),RTI
     1MP,STRTL,ALSMX,QRC
      COMMON /RUNA/ ANDAY(10),RAINA(150),SNOW(10)
      COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
     1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
     2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
     3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
      COMMON /BARUN/ AI,ALAG,ANAP(10),AREA(10),AVTMP,CPTMP,EX,IFRST,IZON
     1E,NZONE,QUNGR(100),R,SNO(10),SOL(150),SUMP,SUMQU,TC,VRA,VRB
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
     1TDER(3),VAR(10)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QU(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHRX,IMINX
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
      COMMON /TME/ IMIN,NMIN,IHR,NHR,IDAY
3000  FORMAT (1X,F7.0,9F8.0)
3010  FORMAT (I11,2F7.2,2F10.0)
3020  FORMAT (I4,2I3,2F7.2,2F10.2)
3030  FORMAT (//X4H SUM2F7.2,2F10.0)
3040  FORMAT (I11,F7.2,F7.1,4F10.2,2F10.0)
3050  FORMAT (I4,2I3,F7.2,F7.1,4F10.2,2F10.0)
3060  FORMAT (//X4H SUMF7.2,F7.0,4F10.2,2F10.0)
      GO TO (3070,3080,3450), ISUB
3070  NTMP=0
      ITRNS=0
      CEX=1.
      TCEX=1.
      IFST=1
C     * * * * COMPUTE EXCESS, ENTER FROM 4260+8,3180+3,3320+5 * * * * *
3080  SUMES=0.
      SUMEZ=0.
      SUMP=0.
      DO 3090 J=IZONE,NZONE
```

```
      CUML(J)=0.
      SNOW(J)=SNO(J)
 3090 ANDAY(J)=0.
      TRAIN=0.
      TSNMT=0.
      DO 3290 I=1,NQ
      TLOSR=0.
      TLOSS=0.
      IF ( RTIO.GE.0) GO TO 3110
      TEMP=RTIO(IRTIO)
      IF (IRTIO.GT.1) TEMP=TEMP/RTIO(IRTIO-1)
      SUMP=0.
      DO 3100 J=1,NQ
      PRCP(J)=PRCP(J)*TEMP
 3100 SUMP=SUMP*PRCP(J)
 3110 IF (TSTM.LT.2) GO TO 3120
C                 SAVE FLOOD-A EXCESS
      EXCR=EXCSR(I)
      EXCS=EXCSS(I)
      RN=RAINA(I)
      SMT=SNMT(I)
 3120 EXCSR(I)=0.
      EXCSS(I)=0.
      SNMT(I)=0.
      RAINA(I)=0.
      RDAYS=TRHR/24.
      DO 3260 J=IZONE,NZONE
      SNWMT=0.
      ANDAY(J)=ANDAY(J)+TRHR/24.
      AJ=J
C                 RAIN AT WARM TEMPERATURES
      RAIN=PRCP(I)*ANAP(J)
      IF (ISNOW.LE.0) GO TO 3190
      IF (TMPR(I).GE.TLAPS*AJ+VRB) GO TO 3130
C                 ADD SNOWFALL TO SNOWPACK IN EACH ZONE
      SNOW(J)=SNOW(J)+PRCP(I)*ANAP(J)
      RAIN=0.
      ANDAY(J)=1.
C                 COMPUTE SNOWMELT IN EACH ZONE
 3130 TMP=TMPR(I)-TLAPS*AJ-VRA
      IF (INRGY.GT.0.) GO TO 3140
C                 DEGREE-DAY METHOD
      IF (TMP.GT.0.) SNWMT=TMP
      GO TO 3180
C                 ENERGY-BUDGET METHOD
C                 DISTINGUISH BETWEEN RAIN-FREE AND RAINY EVENTS
 3140 ALBDO=.75/ANDAY(J)**.2
      IF (ALBDO.LT..4) ALBDO=.4
      TEMP=DEWPT(I)-TLAPS*AJ-VRA
      IF (METRC.GT.0) GO TO 3160
      IF (PRCP(I).LE.0.) GO TO 3150
      SNWMT=.09
      IF (TMP.LE.0.) GO TO 3180
      SNWMT=SNWMT+(.029+.00504*WIND(I)+.007*RAIN)*TMP
      GO TO 3180
 3150 SNWMT=.002*SOL(I)*(1.-ALBDO)
      IF (TMP.LE.0.) GO TO 3180
      SNWMT=SNWMT+(.00111*WIND(I)+.0145)*TMP
      IF (TEMP.GT.0.) SNWMT=SNWMT+.00393*WIND(I)*TEMP
      GO TO 3180
```

```
3160  IF (PRCP(I).LE.0.) GO TO 3170
      SNWMT=2.3
      IF (TMP.GT.0.) SNWMT=SNWMT+(1.33+.516*WIND(I)+.0126*RAIN)*TMP
      GO TO 3180
3170  SNWMT=.0508*SOL(I)*(1.-ALBDO)
      IF (TMP.LE.0.) GO TO 3180
      SNWMT=SNWMT+(.114*WIND(I)+.663)*TMP
      IF (TEMP.GT.0.) SNWMT=SNWMT+.401*WIND(I)*TEMP
3180  SNWMT=SNWMT*VAR(3)*RDAYS
      IF (SNWMT.GT.SNOW(J)) SNWMT=SNOW(J)
      SNMT(I)=SNMT(I)+SNWMT*AREA(J)
      SNOW(J)=SNOW(J)-SNWMT
C               COMPUTE RAIN LOSS AND SNOWMELT LOSS
3190  RAINA(I)=RAINA(I)+RAIN*AREA(J)
      TEMPA=RAIN+SNWMT
      ALOSS=0.
      RLOSS=0.
      SLOSS=0.
      IF (TEMPA.LE.0.) GO TO 3260
      IF (CNSTL.LE.0.) GO TO 3210
C               INITIAL AND UNIFORM LOSS OPTION
      TMP=STRTL
      IF (SNWMT.GT.0.) TMP=0.
      ALOSS=CNSTL
      IF (SNWMT.GT.0.) TEMP=VAR(5)
      IF (CUML(J).GE.STRTL) GO TO 3250
      TMP=STRTL-CUML(J)
      IF (TEMPA.LE.TMP) GO TO 3200
      ALOSS=CNSTL*(1.-TMP/TEMPA)+TMP
      GO TO 3250
3200  ALOSS=TEMPA
      GO TO 3250
C               LOSS AS PARABOLIC FUNCTION
3210  IF (SNWMT.LE.0.) GO TO 3220
      AK=VAR(5)/VAR(6)**(.1*CUML(J))
      GO TO 3240
3220  IF (TRHR*ANQ.GT.700..AND.ISNOW.GT.0) GO TO 3230
      AK=VAR(4)/VAR(10)**(.1*CUML(J))
      TMP=VAR(9)
      IF (STOR(4).LT.(-1.1)) TMP=TMP*VAR(4)
      IF (CUML(J).GE.TMP) GO TO 3240
      DLTK=(1.-CUML(J)/TMP)**2*.2*TMP
      AK=AK+DLTK
      GO TO 3240
C               INCREASING RAIN LOSS FOR SNOWMELT FLOODS(30 DAYS OR LONGE
3230  TEMP=I
      AK=VAR(4)*(1.+.0004*TRHR*TEMP)
3240  ALOSS=TRHR*AK*(TEMPA/TRHR)**VAR(7)
3250  IF (ALOSS.GT.TEMPA) ALOSS=TEMPA
      IF (ALOSS.GT.ALSMX*TRHR) ALOSS=ALSMX*TRHR
      CUML(J)=CUML(J)+ALOSS
      ALOSS=ALOSS*RTIMP
      RLOSS=ALOSS*RAIN/TEMPA
      SLOSS=ALOSS*SNWMT/TEMPA
      TLOSR=TLOSR+RLOSS*AREA(J)
      TLOSS=TLOSS+SLOSS*AREA(J)
      EXCSR(I)=EXCSR(I)+(RAIN-RLOSS)*AREA(J)
      EXCSS(I)=EXCSS(I)+(SNWMT-SLOSS)*AREA(J)
3260  CONTINUE
      IF (ISTM.LT.2.OR.NSTM.LE.1) GO TO 3270
```

```
C       RETAIN PROPORTIONAL PART OF HIGH EXCESS FROM SMALLER-AREA FLOOD
        EXCSR(I)=(EXCSR(I)*(TRDA(ISTM)-TRDA(ISTM-1))+EXCR*TRDA(ISTM-1))/TR
       1DA(ISTM)
        EXCSS(I)=(EXCSS(I)*(TRDA(ISTM)-TRDA(ISTM-1))+EXCS*TRDA(ISTM-1))/TR
       1DA(ISTM)
        RAINA(I)=(RAINA(I)*(TRDA(ISTM)-TRDA(ISTM-1))+RN*TRDA(ISTM-1))/TRDA
       1(ISTM)
        PRCP(I)=(PRCP(I)*(TRDA(ISTM)-TRDA(ISTM-1))+STR(I)*TRDA(ISTM-1))/TR
       1DA(ISTM)
        SNMT(I)=(SNMT(I)*(TRDA(ISTM)-TRDA(ISTM-1))+SMT*TRDA(ISTM-1))/TRDA(
       1ISTM)
 3270   IF (TSNOW.LE.0) GO TO 3280
        ITMP=EXCSS(I)*100.+.5
        TMP=ITMP
        SUMES=SUMES+TMP
        ITMP=SNMT(I)*100.+.5
        TMP=ITMP
        TSNMT=TSNMT+TMP
 3280   ITMP=RAINA(I)*100.+.5
        TMP=ITMP
        TRAIN=TRAIN+TMP
        ITMP=PRCP(I)*100.+.5
        TMP=ITMP
        SUMP=SUMP+TMP
        ITMP=EXCSR(I)*100.+.5
        TMP=ITMP
        IF (EXCSR(I)+EXCSS(I).GT.0.) NEX=I
        SUMER=SUMER+TMP
 3290   CONTINUE
        TRAIN=TRAIN*.01
        TSNMT=TSNMT*.01
        SUMES=SUMES*.01
        SUMER=SUMER*.01
        SUMP=SUMP*.01
        IF (IEND.EQ.(-1)) GO TO 3300
        IF (IEND.NE.1.OR.NC.NE.1.OR.IDERV.LE.0) GO TO 3330
C                  MAKE EXCESS (SUME) EQUAL RUNOFF (EX)
 3300   IF (IFREZ(4).GT.0.AND.IFREZ(9).GT.0.AND.IFREZ(5).GT.0) GO TO 3330
        IF (IFRST.EQ.0.AND.IFST.EQ.1) EX=SUME+(SUMQO-SUMQ)/VOL
        SUME=SUMES+SUMER
        IFST=0
        IF (SUME/EX.GT..99.AND.SUME/EX.LT.1.01) GO TO 3330
        IF (NTMP.GT.20) GO TO 3330
        IF (MTRNS.GT.0.AND.SUME.GT.0.) GO TO 3310
        TEMP=.9
        IF (SUME.GT.EX) TEMP=1.1
        IF (SUME.GT.0.) MTRNS=1
        GO TO 3320
 3310   TEMP=(SUME-EX)/EX
        IF (TEMP*ICEX.LT.0..AND.IFRST.EQ.0) CEX=CEX*.4
        ICEX=TEMP
        TEMP=1.+TEMP*CEX
        IF (TEMP.LT..8) TEMP=.8
        IF (TEMP.GT.1.2) TEMP=1.2
 3320   IF (IFREZ(4).LT.1) VAR(4)=VAR(4)*TEMP
        IF (IFREZ(5).LT.1) VAR(5)=VAR(5)*TEMP
        IF (IFREZ(9).LT.1) VAR(9)=VAR(9)*TEMP
        NTMP=NTMP+1
        IFRST=0
        GO TO 3080
```

```
C       * * * * COMPUTE RUNOFF, ENTER FROM 3290+7 * * * * * * * * * * * * *
3330    QA=STRTQ
        SUME=SUMES+SUMER
        CEX=1.
        TCEX=1.
        SUMQ=0.
        QSQ=0.
        QMAX=0.
        ITP=(IH-1)*NQ
        DO 3370 I=1,NQ
        ITP=ITP+1
        AI=I
        IF (QRC.LT.0.) QRCSN=QMAX*(-QRC)
        QA=QA*RTIOR
        Q(I)=QA
        IX=1
        IF (I.GT.NUHGQ) IX=I-NUHGQ+1
        IF (IX.GT.NEX) GO TO 3350
        ITMP=NEX
        IF (ITMP.GT.I) ITMP=I
        DO 3340 L=IX,ITMP
        N=I+1-L
3340    Q(I)=Q(I)+(EXCSS(L)+EXCSR(L))*QUNGR(N)
        IF (I.LE.1) GO TO 3360
3350    TMP=Q(I)-Q(I-1)
        QR=Q(I-1)*RTIOR
        IF (Q(I).LE.QRCSN.AND.Q(I).LE.QR) Q(I)=QR
        IF (Q(I)-Q(I-1).LT.TMP) Q(I)=Q(I-1)+TMP
        IF (QMAX.LT.Q(I)) QMAX=Q(I)
3360    ITMP=Q(I)+.5
        TMP=ITMP
        SUMQ=SUMQ+TMP
        QH(ITP)=Q(I)
C       * * * * COMPUTE STANDARD ERROR  * * * * * * * * * * * * * * * * * *
        IF (IDERV.LE.0.OR.IEND.EQ.(-1)) GO TO 3370
        DQ=Q(I)-QO(I)
        QSQ=QSQ+DQ**2*(QO(I)+AVGQO)*RAVQO
3370    CONTINUE
        AVGQ=SUMQ*RNQ
        IF (IEND.EQ.(-1)) GO TO 3460
        IF(IDERV.LE.0) GO TO 3560
        STDER(NC)=(QSQ*RNQ)**.5
        CALL OPTIM
C       ***********************************
        IF (ITRNS.EQ.1) GO TO 3450
        IFRST=0
        IF (NC2.GT.1) GO TO 3440
C       * * * * CHECK FOR REASONABLE MAGNITUDE  * * * * * * * * * * * * * *
        GO TO (3380,3390,3440,3440,3440,3420,3410,3430,3440,3420), M1
3380    IF (VAR(1)*(1.-VAR(2)).LT.1.03) VAR(1)=1.03/(1.-VAR(2))
        GO TO 3440
3390    IF (VAR(2)*VAR(1).GE..52) GO TO 3400
        VAR(2)=.52/VAR(1)
        GO TO 3440
3400    IF (VAR(2)+1.03/VAR(1).GT.1.) VAR(2)=1.-1.03/VAR(1)
        GO TO 3440
3410    IF (VAR(7).GT.1.) VAR(7)=1.
        GO TO 3440
3420    IF (VAR(M1).LT.1.) VAR(M1)=1.
        GO TO 3440
```

```
3430  IF (VAR(8).LT.30.) VAR(8)=30.
      IF (VAR(8).GT.38.) VAR(8)=38.
3440  ISUB=2
      JSUB=3
      RETURN
C      * * * * PRINT RESULTS AND PLOT, ENTER FROM 3170,3370+3 * * * * *
3450  IF (IDERV.LE.0) GO TO 3560
      IEND=(-1)
      GO TO 3070
3460  TEMP=.1
      ITEMP=0
3470  ITMP=0
      ITEMP=ITEMP+1
      SUM=0.
      DO 3480 I=1,NQ
      TMP=RAINA(I)+SNMT(I)-TEMP
      IF (TMP.LE.0.) GO TO 3480
      SUM=SUM+TMP
      ITMP=ITMP+1
3480  CONTINUE
      IF (ITMP.LE.0) TEMP=TEMP*.9
      IF (ITMP.LE.0) GO TO 3470
      TMP=(SUM-EX)/EX
      IF (TMP.GT..99.AND.TMP.LT.1.01) GO TO 3490
      TMP=ITMP
      TEMP=TEMP+(SUM-EX)/TMP
      IF (ITEMP.LE.20) GO TO 3470
3490  PRINT 3500, TEMP
3500  FORMAT (/21H INFILTRATION INDEX =F5.3)
      IF (TRHR*ANQ.GT.700..AND.ISNOW.GT.0) GO TO 3520
      TEMP=CUML(1)*.05
      TMP=VAR(4)/VAR(10)**TEMP
      TMP=TMP*3.**TEMP
      PRINT 3510, TMP
3510  FORMAT (/24H STRTK FOR RTIOL OF 3. =F5.2)
3520  PRINT 3530
3530  FORMAT (/1X,20HOPTIMIZATION RESULTS)
      PRINT 3540
3540  FORMAT (6X2HTC7X1HR4X60HCOEF    STRKR    STRKS    RTIOK    ERAIN    FRZ
     1TP    DLTKR    RTIOL)
      R=VAR(1)*VAR(2)
      TC=VAR(1)-R
      TC=TC*TRHR
      R=R*TRHR
      IF (IPNT.LE.(-1)) GO TO 3580
      IF (STOR(4).LT.(-1.1)) VAR(9)=VAR(9)*VAR(4)
      PRINT 3550, TC,R,(VAR(I),I=3,NVAR)
3550  FORMAT (14F8.2,F6.0,F8.2,F6.2)
3560  IF (ISTM.GT.1.AND.NPLAN.LE.0) GO TO 3580
      IF (IPRNT.GE.2) GO TO 3580
      PRINT 3570, NUHGQ,ALAG,CPTMP,SUMQU
3570  FORMAT (/16H UNIT HYDROGRAPHI3,30H END-OF-PERIOD ORDINATES, LAG=F7
     1.2,11H HOURS, CP=F5.2,6H   VOL=F5.2)
      PRINT 3000, (QUNGR(I),I=1,NUHGQ)
3580  IF (NP.GT.0) GO TO 3600
3590  ISUB=2
      JSUB=1
      RETURN
3600  IF (IPNT.LE.(-1)) GO TO 3640
      IF (NSTM.GT.1.AND.IPRNT.LT.1) PRINT 3610, ISTM,TRSDA
```

```
3610  FORMAT (/6H FLOODI2,2H, F8.1,20H SQ MI TRANSPOSITION)
      IF (IPRNT.GE.1.AND.IDERV.LE.0.AND.NSTM.GT.1) GO TO 3640
      IF(ISNOW.GT.0.AND.IPRNT.LT.1) PRINT 3620
3620  FORMAT (/68X,18HEND-OF-PERIOD FLOW/3X82H     TIME PRECIP    TEMP
     1SNOMLT    SNOW EX       RAIN    RAIN EX     COMP Q      OBS Q)
      IF(ISNOW.LE.0.AND.IPRNT.LT.1) PRINT 3630
3630  FORMAT (/28X18HEND-OF-PERIOD FLOW/3X42H     TIME    RAIN    EXCS    C
     1OMP Q      OBS Q)
3640  IF (IDERV.GT.0) GO TO 3750
      IF(IPNT.LE.(-1).OR.IPRNT.GE.1) GO TO 3690
      IF (ISNOW.GT.0) GO TO 3700
      IF (IPRNT.GE.1.AND.NSTM.GT.1) GO TO 3690
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 3660
      DO 3650 I=1,NQ
3650  PRINT 3010, I,PRCP(I),EXCSR(I),Q(I)
      GO TO 3680
3660  IDAY=IDAYX
      IHR=IHRX
      IMIN=IMINX
      DO 3670 I=1,NQ
      CALL DATE
      PRINT 3020, IDAY,IHR,IMIN,PRCP(I),EXCSR(I),Q(I)
3670  CONTINUE
3680  PRINT 3030, SUMP,SUMER,SUMQ
3690  CALL SUMRY (IH)
C     **********************************
      ISUB=7
      JSUB=2
      IF (NSTM.GT.1.AND.ISTM.LE.NSTM.AND.IPRNT.GE.1) RETURN
      GO TO 3900
3700  IF (IPRNT.GE.1.AND.NSTM.GT.1) GO TO 3690
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 3720
      DO 3710 I=1,NQ
3710  PRINT 3040, I,PRCP(I),TMPR(I),SNMT(I),EXCSS(I),RAINA(I),EXCSR(I),Q
     1(I)
      GO TO 3740
3720  IDAY=IDAYX
      IHR=IHRX
      IMIN=IMINX
      DO 3730 I=1,NQ
      CALL DATE
      PRINT 3050, IDAY,IHR,IMIN,PRCP(I),TMPR(I),SNMT(I),EXCSS(I),RAINA(I
     1),EXCSR(I),Q(I)
3730  CONTINUE
3740  PRINT 3060, SUMP,AVTMP,TSNMT,SUMES,TRAIN,SUMER,SUMQ
      GO TO 3690
C               REMOVE DISTORTION PUT IN OBSERVED FLOWS
3750  DO 3760 N=1,5
      I=IQ(N)
      IF (I.LE.0) GO TO 3760
      QO(I)=QO(I)/RQ(N)
3760  CONTINUE
      IF (ISNOW.LE.0) GO TO 3830
      IF (IPNT.LE.(-1)) GO TO 3810
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 3780
      DO 3770 I=1,NQ
3770  PRINT 3040, I,PRCP(I),TMPR(I),SNMT(I),EXCSS(I),RAINA(I),EXCSR(I),Q
     1(I),QO(I)
      GO TO 3800
3780  IDAY=IDAYX
```

```
      IHR=IHRX
      IMIN=IMINX
      DO 3790 I=1,NQ
      CALL DATE
      PRINT 3050, IDAY,IHR,IMIN,PRCP(I),TMPR(I),SNMT(I),EXCSS(I),RAINA(I
     1),EXCSR(I),Q(I),QO(I)
3790  CONTINUE
3800  PRINT 3060, SUMP,AVTMP,TSNMT,SUMES,TRAIN,SUMER,SUMQ,SUMQO
3810  IF (IPLOT.LE.0) GO TO 3590
      DO 3820 I=1,NQ
3820  STR(I)=TMPR(I)
      NV=4
      CALL GRAPH
C     ********************************
      GO TO 3590
3830  IF (IPNT.LE.(-1)) GO TO 3880
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 3850
      DO 3840 I=1,NQ
3840  PRINT 3010, I,PRCP(I),EXCSR(I),Q(I),QO(I)
      GO TO 3870
3850  IDAY=IDAYX
      IHR=IHRX
      IMIN=IMINX
      DO 3860 I=1,NQ
      CALL DATE
      PRINT 3020, IDAY,IHR,IMIN,PRCP(I),EXCSR(I),Q(I),QO(I)
3860  CONTINUE
3870  PRINT 3030, SUMP,SUMER,SUMQ,SUMQO
3880  IF (IPLOT.LE.0) GO TO 3590
      DO 3890 I=1,NQ
3890  STR(I)=EXCSR(I)
      NV=5
      CALL GRAPH
C     ********************************
      GO TO 3590
C      * * * * HYDROGRAPH SUMMARY, ENTRY FROM 3690+4 * * * * * * * * * *
3900  IF (IPLOT.LE.0) GO TO 3940
      IF (ISNOW.LE.0) GO TO 3920
      DO 3910 I=1,NQ
      QO(I)=TMPR(I)
      STR(I)=EXCSS(I)+EXCSR(I)
3910  PRCP(I)=RAINA(I)+SNMT(I)
      NV=6
      CALL GRAPH
C     ********************************
      GO TO 3940
3920  DO 3930 I=1,NQ
      QO(I)=EXCSR(I)
3930  STR(I)=PRCP(I)
      NV=3
      CALL GRAPH
C     ********************************
3940  ISUB=7
      JSUB=2
      RETURN
      END
```

```
      SUBROUTINE CMBIN
      COMMON /MACMB/ KINH,KNH,LOCAL,NCMB(120),NQB(5),SUMA(5),SUMB(5)
      COMMON /MAROC/ IBAL,NCOMB,NEXT,RATIO
      COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
     1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
     2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
     3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
     1TDER(3),VAR(10)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHRX,IMINX
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
 4000 FORMAT (1X,F7.0,9F8.0)
      GO TO (4010,4030,4320,4340,4470,4260,4040), ISUB
C      * * * * READ HYDROGRAPH SUPPLIED  * * * * * * * * * * * * * * * * *
 4010 READ 4000, (Q(I),I=1,NQ)
      ITP=(IH-1)*NQ
      DO 4020 I=1,NQ
      ITP=ITP+1
 4020 QH(ITP)=Q(I)
      DA(NH)=TRSDA
      VOL=TRSDA*645./TRHR
      IF (METRC.GT.0) VOL=TRSDA*.278/TRHR
      IF (LOCAL.GT.0) GO TO 4680
      IF (IDERV.LE.0) GO TO 4030
      ISUB=1
      JSUB=4
      RETURN
 4030 IF (NSTM.GT.1.AND.IPRNT.LT.1) PRINT 4640, ISTM,TRDA(ISTM)
C      * * * * HYDROGRAPH RATIO * * * * * * * * * * * * * * * * * * * * *
 4040 IF (ISTM.GT.1) GO TO 4260
      IF (RATIO.EQ.1.) GO TO 4080
      IF (IPNT.LE.(-1)) GO TO 4060
      PRINT 4050, RATIO
 4050 FORMAT (25H HYDROGRAPH MULTIPLIED BYF6.3)
 4060 DO 4070 I=1,NQ
 4070 Q(I)=Q(I)*RATIO
      GO TO 4220
 4080 IF (IBAL.LE.0) GO TO 4210
C      * * * * BALANCE HYDROGRAPH * * * * * * * * * * * * * * * * * * * *
      READ 4090, (NQB(K),SUMB(K),K=1,5)
 4090 FORMAT (1X,I7,F8.0,I8,F8.0,I8,F8.0,I8,F8.0,I8,F8.0)
      IF(IPRNT.LT.3) PRINT 4092,(NQB(K),SUMB(K),K=1,5)
 4092 FORMAT(/80H   NQB(1) SUMB(1)   NQB(2) SUMB(2)   NQB(3) SUMB(3)   NQB(4
     1) SUMB(4)   NQB(5) SUMB(5)/I7,F9.0,I7,F9.0,I7,F9.0,I7,F9.0,I7,F9.0)
      DO 4095 I=1,NQ
 4095 QO(I)=Q(I)
      DO 4096 K=1,5
      J=6-K
      IF(SUMB(J).LE.0.) GO TO 4096
      ITP=NQB(J)
      IF(ITP.GT.NQ) ITP=NQ
      TEMP=SUMB(J)
      GO TO 4097
 4096 CONTINUE
 4097 QMAX=0.
      DO 4098 I=1,NQ
```

```
      QMAX=QMAX+Q(I)
      IF(I.EQ.ITP) TMP=QMAX
      IF(I.LE.ITP) GO TO 4098
      ITMP=I-ITP
      QMAX=QMAX-Q(ITMP)
      IF(QMAX.GT.TMP) TMP=QMAX
 4098 CONTINUE
      TMP=TEMP/TMP
      DO 4099 I=1,NQ
 4099 Q(I)=Q(I)*TMP
      DO 4180 J=1,20
      DO 4100 I=1,NQ
4100  TMPR(I)=0.
      TEMP=0.
      DO 4160 K=1,5
      SUMA(K)=0.
      TEMP=SUMB(K)-TEMP
      IF (TEMP.LT.0.) GO TO 4160
      ITMP=NOB(K)
      IF (ITMP.GT.NQ) ITMP=NQ
      QMAX=0.
      TP=0.
      DO 4110 I=1,ITMP
      IF (TMPR(I).GT.0.) TP=TP+Q(I)
4110  QMAX=QMAX+Q(I)
      TMP=QMAX
      ITEMP=ITMP+1
      TEMPA=TP
      IP=ITMP
      IF (ITEMP.GT.NQ) GO TO 4130
      DO 4120 I=ITEMP,NQ
      ITP=I-ITMP
      TMP=TMP+Q(I)-Q(ITP)
      IF (TMPR(ITP).GT.0.) TP=TP-Q(ITP)
      IF (TMPR(I).GT.0.) TP=TP+Q(I)
      IF (TMP.LE.QMAX) GO TO 4120
      QMAX=TMP
      TEMPA=TP
      IP=I
4120  CONTINUE
 4130 TEMP=.9
      IF(QMAX.LE.TEMPA) GO TO 4135
      TEMP=(SUMB(K)-TEMPA)/(QMAX-TEMPA)
      IF (TEMP.GT.1.10) TEMP=1.10
      IF (TEMP.LT.(.90)) TEMP=.90
 4135 ITP=IP-ITMP+1
      DO 4150 I=ITP,IP
      IF (TMPR(I).GT.0.) GO TO 4140
      Q(I)=Q(I)*TEMP
      TMPR(I)=1.
4140  SUMA(K)=SUMA(K)+Q(I)
4150  CONTINUE
      TEMP=SUMB(K)
4160  CONTINUE
      DO 4168 K=1,5
      IF(SUMB(K).LE.0.) GO TO 4169
      TEMP=0.
      ITP=NOB(K)
      DO 4167 I=1,NQ
      TEMP=TEMP+Q(I)
```

```
      IF(ITP.EQ.I) TMP=TEMP
      IF(I.LE.ITP) GO TO 4167
      ITMP=I-ITP
      TEMP=TEMP-Q(ITMP)
      IF(TMP.LT.TEMP) TMP=TEMP
 4167 CONTINUE
      SUMA(K)=TMP
 4168 CONTINUE
 4169 TEMP=0.
      DO 4170 K=1,5
      IF (SUMB(K).LT.TEMP) GO TO 4190
      IF (SUMA(K).GT.SUMB(K)*1.01.OR.SUMA(K).LT.SUMB(K)*.99) GO TO 4180
      TEMP=SUMB(K)
4170  CONTINUE
      ITEMPA=J
      GO TO 4190
4180  CONTINUE
4190  PRINT 4200, (SUMA(K),SUMB(K),K=1,5)
4200  FORMAT (/27H HYDROGRAPH BALANCE RESULTS5(F10.0,F8.0))
      PRINT 4202,ITEMPA
 4202 FORMAT(/22H NUMBER OF ITERATIONS=,I3)
      ITMP=0
C               ENTRY FROM 4080
4210  IF (IP.GT.0) GO TO 4260
C               ENTRY FROM 4070+1
4220  SUMQ=0.
      ITP=(IH-1)*NQ+(ISTM-1)*NQ*KHGR
      DO 4230 I=1,NQ
      ITP=ITP+1
      QH(ITP)=Q(I)
4230  SUMQ=SUMQ+Q(I)
      IF (NSTM.GT.1.AND.IPRNT.GE.1) GO TO 4250
      PRINT 4240, ISTAQ,SUMQ,(Q(I),I=1,NQ)
4240  FORMAT (/23H END-OF-PERIOD FLOWS ATI6/5H SUM=F10.0,/(10F10.0))
4250  CALL SUMRY (IH)
C     ***********************************
C               ENTRY FROM 1610(MANE),4040
4260  IF (NPLAN.LE.0) GO TO 4340
      ITMP=KHGR*NPLAN
      IF (IRTIO.GE.0) GO TO 4270
      IRTIO=IRTIO+1
      IF (IRTIO.GT.NRTIO) GO TO 4320
      IH=IH+ITMP
      ISUB=2
      JSUB=5
      RETURN
4270  K=IH+(ISTM-1)*KHGR
      ITP=(K-1)*NQ
      DO 4310 ITEMP=1,NRTIO
      TMP=RTIO(ITEMP)
      L=ITP+1
      DO 4280 I=1,NQ
      ITP=ITP+1
4280  QH(ITP)=Q(I)*TMP
      QMX(K)=QMAX*TMP
      IF (IPNT.LE.(-1).OR.IPRNT.GE.1) GO TO 4300
      TEMP=SUMQ*TMP
      PRINT 4290, ISTAQ,ISTM,ITEMP,TEMP,(QH(I),I=L,ITP)
 4290 FORMAT (23H0END OF PERIOD FLOWS ATI7,6H PLAN I2,7H  FLOODI3/5H SUM
     1=F10.0/(10F10.0))
```

```
4300  K=K+ITMP
      ITP=ITP+ITMP*NQ-NQ
4310  CONTINUE
4320  IF (ISTM.EQ.NPLAN.AND.NCOMB.LE.0) CALL ECONO
C     ********************************
      ISTM=ISTM+1
      IF (NRTIO.LT.0) IH=IH-ITMP*(NRTIO-1)
      IF (ISTM.GT.NPLAN) GO TO 4330
      ISUB=3
      JSUB=1
      RETURN
4330  ISTM=1
      GO TO 4470
C     * * * * *MULTI-FLOOD COMPUTATION * * * * * * * * * * * * * * * * *
4340  IF (NSTM.LE.1) GO TO 4470
      ISTM=ISTM+1
      IF (ISTM.GT.NSTM) GO TO 4380
      IH=IH+KHGR
      ISUB=1
      JSUB=1
      IF (IH.GT.KINH) RETURN
      IF (IOPER(NH).LE.1) GO TO 4360
      IF (IOPER(NH).EQ.3) IH=IH+NCOMB-1
      ITP=(IH-1)*NQ
      DO 4350 I=1,NQ
      ITP=ITP+1
4350  Q(I)=QH(ITP)
      IF (IOPER(NH).EQ.3) GO TO 4500
      ISUB=2
      JSUB=4
      RETURN
4360  TRSDA=TRDA(ISTM)
      NP=-NP
      ITP=IH-KHGR
      INH(IH)=INH(ITP)
      IF (IHDGR.GT.0) GO TO 4010
C              DUMMY ARRAY
      DO 4370 I=1,NQ
4370  STR(I)=PRCP(I)
      ISUB=3
      JSUB=3
      RETURN
C      * * * * MULTI-FLOOD INTERPOLATION * * * * * * * * * * * * * * * *
4380  IF (IOPER(NH).EQ.3) NCOMB=0
      IH=IH-KHGR*(NSTM-1)
      TEMP=DA(NH)
      DO 4390 J=2,NSTM
      IF (TEMP.LE.TRDA(J)) GO TO 4400
4390  CONTINUE
      J=NSTM
4400  TEMPA=TRDA(J)
      TMP=TRDA(J-1)
      CA=1.
      IF (TMP.EQ.TEMPA) GO TO 4410
      CA=(ALOG(TEMP)-ALOG(TMP))/(ALOG(TEMPA)-ALOG(TMP))
C              RESTRICT INTERPOLATED HYDROGRAPH ABOVE LARGEST COMPONENT
      IF (IOPER(NH).NE.3) GO TO 4410
      TEMP=CA
      IF (AX(J)-AX(J-1).NE.0.) TEMP=(AY-AX(J-1))/(AX(J)-AX(J-1))
      IF (TEMP.LT.CA) CA=TEMP
```

```
      IF (BX(J)-BX(J-1).NE.0.) TEMP=(BY-BX(J-1))/(BX(J)-BX(J-1))
      IF (TEMP.LT.CA) CA=TEMP
      IF (CX(J)-CX(J-1).NE.0.) TEMP=(CY-CX(J-1))/(CX(J)-CX(J-1))
      IF (TEMP.LT.CA) CA=TEMP
      IF (DX(J)-DX(J-1).NE.0.) TEMP=(DY-DX(J-1))/(DX(J)-DX(J-1))
      IF (TEMP.LT.CA) CA=TEMP
4410  CB=1.-CA
      ITP=IH+KHGR*(J-2)
      ITMP=ITP+KHGR
      ITP=(ITP-1)*NQ
      ITMP=(ITMP-1)*NQ
      DO 4420 I=1,NQ
      ITP=ITP+1
      ITMP=ITMP+1
4420  Q(I)=QH(ITP)*CB+QH(ITMP)*CA
      IF (IPNT.LE.(-1)) GO TO 4450
      PRINT 4430, DA(NH)
4430  FORMAT (//25H INTERPOLATED HYDROGRAPH,F8.1,6H SQ MI)
      SUMQ=0.
      DO 4440 I=1,NQ
4440  SUMQ=SUMQ+Q(I)
      PRINT 4240, ISTAQ,SUMQ,(Q(I),I=1,NQ)
4450  CALL SUMRY (IH)
C     ***********************************
      NV=1
      IF (IPLOT.GT.0) CALL GRAPH
C     ***********************************
      ISTM=1
      ITP=(IH-1)*NQ
      DO 4460 I=1,NQ
      ITP=ITP+1
4460  Q(I)=QH(ITP)
C                ENTRY FROM 1560(MANE)
4470  IF (NCOMB.LE.0) GO TO 4720
C      * * * * COMBINE HYDROGRAPHS * * * * * * * * * * * * * * * * * * *
      IF (ISTM.EQ.1) NH=NH+1
      IF (NH.LE.KNH) GO TO 4480
      ISUB=1
      JSUB=1
      RETURN
4480  NCMB(NH)=NCOMB
      IOPER(NH)=3
      IF (NPLAN.GE.1) GO TO 4540
      IF (ISTM.LE.1.OR.IPRNT.LT.1) PRINT 4490, ISTAQ
4490  FORMAT (/32H END-OF-PERIOD COMBINED FLOWS ATI6)
4500  ITEMP=IH-1
      ITP=IH
      IH=IH-NCOMB+1
      ITMP=IH+1
C                FIND LARGEST COMPONENT HYDROGRAPH QUANTITIES
      I=INH(IH)
      IF (ISTM.EQ.1) DA(NH)=DA(I)
      AY=QM(I)
      BY=SM(I)
      CY=SMX(I)
      DY=SMY(I)
      IF (NSTM.LE.1) NCOMB=0
      DO 4510 J=ITMP,ITP
      I=INH(J)
      IF (QM(I).GT.AY) AY=QM(I)
```

```
      IF  (SM(I).GT.BY) BY=SM(I)
      IF  (SMX(I).GT.CY) CY=SMX(I)
      IF  (SMY(I).GT.DY) DY=SMY(I)
      IF  (ISTM.EQ.1) DA(NH)=DA(NH)+DA(I)
 4510 CONTINUE
      VOL=DA(NH)*645./TRHR
C               COMBINE FLOWS
      SUMQ=0.
      ITP=(IH-1)*NQ
      DO 4530 I=1,NQ
      ITP=ITP+1
      K=ITP
      DO 4520 J=IH,ITEMP
      Q(I)=Q(I)+QH(K)
 4520 K=K+NQ
      SUMQ=SUMQ+Q(I)
 4530 QH(ITP)=Q(I)
      GO TO 4630
C               PLANS AND RATIOS COMBINING, ENTER FROM 4480+2
 4540 IHY=IH
      IH=IH-NCOMB+1
      IHX=IH+1
      DA(NH)=0.
      DO 4550 K=IH,IHY
      I=INH(K)
 4550 DA(NH)=DA(NH)+DA(I)
      DO 4620 L=1,NRTIO
      ITP=(IHX-2)*NQ
      DO 4610 J=1,NPLAN
      ITMP=ITP+1
      ITEMP=ITP+NQ
      DO 4570 N=IHX,IHY
      K=(N-IHX+1)*NQ+ITP
      DO 4560 I=1,NQ
      ITP=ITP+1
      K=K+1
      QH(ITP)=QH(ITP)+QH(K)
 4560 CONTINUE
      ITP=ITP-NQ
 4570 CONTINUE
      SUMQ=0.
      DO 4580 I=1,NQ
      ITP=ITP+1
      Q(I)=QH(ITP)
      SUMQ=SUMQ+Q(I)
 4580 CONTINUE
      ITP=ITP+NQ*(KHGR-1)
      IHX=IHX+KHGR
      IHY=IHY+KHGR
      IF  (IPNT.LE.(-2)) GO TO 4600
      PRINT 4590, ISTAQ,J,L,SUMQ
 4590 FORMAT(18H0COMBINED FLOWS ATI7,5H PLANI2,6H FLOODI2/5H SUM=F10.0)
      IF(IPRNT.GE.1) GO TO 4600
      PRINT 4595,(QH(I),I=ITMP,ITEMP)
 4595 FORMAT(10F10.0)
 4600 CALL SUMRY (IH)
C     **********************************
      QMX(IH)=QMAX
      IH=IH+KHGR
 4610 CONTINUE
```

```
4620  CONTINUE
      IH=IH-NPLAN*NRTIO*KHGR
      CALL ECONO
C     **********************************
      ISTM=1
      GO TO 4720
4630  IF (NSTM.GT.1.AND.IPRNT.LT.1) PRINT 4640, ISTM,TRDA(ISTM)
4640  FORMAT (/6H FLOODI2,2H, F8.1,20H SQ MI TRANSPOSITION)
      IF (IPNT.LE.(-2)) GO TO 4660
      IF (IPRNT.GE.1) GO TO 4660
      PRINT 4650, SUMQ,(Q(I),I=1,NQ)
4650  FORMAT (5H SUM=F10.0/(10F10.0))
4660  CALL SUMRY (IH)
C     **********************************
      IF (IPLOT.LE.0) GO TO 4670
      NV=1
      CALL GRAPH
C     **********************************
4670  IF (NSTM.GT.1) GO TO 4340
      GO TO 4720
C      * * * * * LOCAL * * * * * * * * * * * * * * * * * * * * * * * * * *
4680  SUMQ=0.
      K=(IH-2)*NQ
      DO 4690 I=1,NQ
      K=K+1
      Q(I)=Q(I)-QH(K)
4690  SUMQ=SUMQ+Q(I)
      PRINT 4700, ISTAQ,SUMQ,(Q(I),I=1,NQ)
4700  FORMAT (/29H END-OF-PERIOD LOCAL FLOWS ATI6,/6H SUMQ=F10.0/(10F10.
     10))
      SUMQ=0.
C               FOR LOCAL, REPLACE WITH TOTAL FLOW
      K=(IH-2)*NQ
      ITP=(IH-1)*NQ
      DO 4710 I=1,NQ
      ITP=ITP+1
      K=K+1
      Q(I)=QH(ITP)
      QH(K)=Q(I)
4710  SUMQ=SUMQ+Q(I)
      IH=IH-1
C               TRANSFER FROM 4470
4720  NH=NH+1
      IF (NH.LE.KNH) GO TO 4730
      ISUB=1
      JSUB=1
      RETURN
4730  IF (NEXT) 4740,4760,4750
4740  ISUB=3
      JSUB=1
      RETURN
4750  ISUB=1
      JSUB=4
      NV=7
      RETURN
4760  ISUB=7
      JSUB=1
      RETURN
      END
```

```
      SUBROUTINE ROUTE
C      * * * * ROUTING * * * * * * * * * * * * * * * * * * * * * * * * * * *
      COMMON /ROUTA/ AMSKK,CLOSS,JLAG,JTRNS,KTRNS,LTRNS,NSTDL,NSTL,NSTP,
     1NSTPS,OUTFL(10),QLOSS,STORA,TESTA,TESTB,TESTC,TSK
      COMMON /MAROC/ IBAL,NCOMB,NEXT,RATIO
      COMMON /ALL/ AVGQO,CA,CB,DEWPT(150),INRGY,EXCSR(150),I,IDERV,IPLOT
     1,IPRNT,IRTIO,ISNOW,ISUB,ITEMP,ITMP,ITP,IUHGQ,IX,J,K,L,NP,MRTIO,N,N
     2UHGQ,QH(4800),RAVQO,RNQ,RTIO(9),RTIOR,SNMT(150),STOR(10),STRTQ,SUM
     3Q,SUMQO,TLAPS,TMPR(150),TP,TR,TRDA(5),TRSDA,WIND(150),JSUB
      COMMON /BARUN/ AI,ALAG,ANAP(10),AREA(10),AVTMP,CPTMP,EX,IFRST,IZON
     1E,NZONE,QUNGR(100),R,SNO(10),SOL(150),SUMP,SUMQU,TC,VRA,VRB
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,S
     1TDER(3),VAR(10)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHRX,IMINX
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
      COMMON /TME/ IMIN,NMIN,IHR,NHR,IDAY
5000  FORMAT (1X,F7.0,9F8.0)
      GO TO (5010,5120), ISUB
5010  IRTIO=1
      IF (ISTM.GT.1.AND.ISTAQ.LT.0) GO TO 5120
      READ 5020, ISTAQ,NSTPS,LAG,IRES,STORA,TSK,AMSKK,X,NCOMB,NEXT,NSTDL
     1,QLOSS,CLOSS,AVG,NDMG,IPNT
5020  FORMAT (1XI7,3I8,4F8.0,2I8/1X,I7,3F8.0,2I8)
      IF (IPRNT.GE.4) GO TO 5080
      IF (IDERV.GT.0) PRINT 5030
5030  FORMAT (/1X,10HINPUT DATA)
      PRINT 5040
5040  FORMAT (/80H    ISTAQ    NSTPS      LAG     IRES    STORA      TSK    AMS
     1KK         X    NCOMB     NEXT)
      PRINT 5050, ISTAQ,NSTPS,LAG,IRES,STORA,TSK,AMSKK,X,NCOMB,NEXT
5050  FORMAT (4I8,F8.0,3F8.2,2I8)
      PRINT 5060
5060  FORMAT (/48H    NSTDL    QLOSS    CLOSS      AVG     NDMG     IPNT)
      PRINT 5070, NSTDL,QLOSS,CLOSS,AVG,NDMG,IPNT
5070  FORMAT (I8,2F8.2,F8.0,2I8)
5080  IOPER(NH)=2
      DA(NH)=DA(NH-1)
      IBAL=0
      NSTL=NSTDL
      RATIO=1.
      ITP=(IH-1)*NQ
      DO 5090 I=1,NQ
      ITP=ITP+1
5090  Q(I)=QH(ITP)
      CLOSS=1.-CLOSS
      NVAR=0
C             LOCAL INFLOW OF REQUIRED VOLUME
      IF (IDERV.LE.0) GO TO 5120
      NC=1
C             USE TMPR FOR LOCAL INFLOW
      READ 5000, (TMPR(I),I=1,NQ)
      SMLCL=0.
      SUMQ=0.
```

```
      TMP=0.
      ITP=(IH-1)*NQ
      DO 5100 I=1,NQ
      ITP=ITP+1
      TEMP=(Q(I)-QLOSS)*CLOSS
      IF (TEMP.GT.0.) TMP=TMP+TEMP
      SUMQ=SUMQ+Q(I)
      QH(ITP)=Q(I)
 5100 SMLCL=SMLCL+TMPR(I)
      IF (SMLCL.LE.0.) SMLCL=1.
      TEMP=(SUMQO-TMP)/SMLCL
      IF (TEMP.LT.0.) TEMP=0.
      SMLCL=0.
      DO 5110 I=1,NQ
      TMPR(I)=TMPR(I)*TEMP
 5110 SMLCL=SMLCL+TMPR(I)
C                 ENTRY FROM 1530(MANE),4350+4(CMBIN),5010+1,5090+3
 5120 IF(TSK.GT.(-.5).AND.TSK.LE.0..AND.IRES.LE.0) GO TO 5140
C                 AVERAGE INFLOWS FOR STORAGE ROUTING
      IF (AVG.GT.0.) GO TO 5160
      IX=NQ+1
      ITMP=(IH-1)*NQ
      DO 5130 I=2,NQ
      IX=IX-1
      ITP=ITMP+IX
      Q(IX)=(Q(IX)+Q(IX-1))*.5
 5130 QH(ITP)=Q(IX)
      QH(ITP-1)=Q(1)
      GO TO 5160
 5140 IF (AVG.LE.0.) GO TO 5160
      IX=NQ+1
      ITMP=(IH-1)*NQ
      DO 5150 I=2,NQ
      IX=IX-1
      ITP=ITMP+IX
      Q(IX)=(Q(IX)+Q(IX-1))*.5
 5150 QH(ITP)=Q(IX)
C      * * * * LAG INFLOWS * * * * * * * * * * * * * * * * * * * * * * * *
 5160 LG=LAG
      JTRNS=1
      JLAG=0
      KTRNS=0
      LTRNS=0
      TESTA=999999.
      IF (LAG.EQ.(-1)) GO TO 5170
      IF (LAG.LE.0) GO TO 5240
      GO TO 5210
 5170 DO 5180 I=1,NQ
 5180 SOL(I)=Q(I)
      LG=1
 5190 DO 5200 I=1,NQ
 5200 Q(I)=SOL(I)
 5210 ITP=LG+1
      DO 5220 J=ITP,NQ
      I=NQ-J+ITP
      IX=I-LG
 5220 Q(I)=Q(IX)
      DO 5230 I=1,LG
 5230 Q(I)=Q(1)
C      * * * * NUMBER OF ROUTING STEPS * * * * * * * * * * * * * * * * * *
```

```
5240  KTRNS=0
      TESTR=999999.
      IF (NSTPS.EQ.(-1)) GO TO 5250
      IF (NSTPS.LE.0) NSTPS=1
      NSTP=NSTPS
      GO TO 5290
C               SAVE INFLOWS IN TEMPORARY ARRAY
5250  DO 5260 I=1,NQ
5260  WIND(I)=Q(I)
C               OPTIMIZE NUMBER OF ROUTING STEPS
      NSTP=1
5270  DO 5280 I=1,NQ
5280  Q(I)=WIND(I)
5290  IF (IRES) 5300,5330,5870
C               IF IRES NEG, NPLAN IS POS AND SKIP RES ROUTING THIS PLAN
 5300 ISTM=ISTM+1
      IH=IH+KHGR
      ISUB=3
      JSUB=2
      IF(ISTM.LE.NPLAN) GO TO 5010
      IH=IH-KHGR*NPLAN
      ISTM=NPLAN
      RETURN
C      * * * * TIME-OF-STORAGE ROUTING * * * * * * * * * * * * * * * * * *
 5330 IF(TSK.GT.(-.5).AND.TSK.LE.0.) GO TO 5400
      VAR(1)=TSK
      IF(TSK.GT.(-.5)) GO TO 5370
      NVAR=1
      VAR(1)=TRHR*3.
      IFREZ(1)=0
C               SAVE INFLOWS IN TEMPORARY ARRAY
      DO 5340 I=1,NQ
5340  SNMT(I)=Q(I)
      ITRNS=-1
C               OPTIMIZE STORAGE COEFFICIENT
5350  CALL OPTIM
C     *********************************
      IF (ITRNS.GT.0) GO TO 5640
      DO 5360 I=1,NQ
5360  Q(I)=SNMT(I)
5370  DO 5390 J=1,NSTP
      TEMP=Q(1)
      DO 5380 I=1,NQ
      TEMPA=TEMP
      IF (TEMPA.LT.1.) TEMPA=1.
      TMP=(Q(I)-TEMP)*TRHR/(VAR(1)*TEMPA**(-.2)+TRHR/2.)+TEMP
      Q(I)=TMP
      IF (J.LT.NSTP) Q(I)=(TMP+TEMP)*.5
      TEMP=TMP
5380  CONTINUE
5390  CONTINUE
      JTRNS=-1
      GO TO 5590
C      * * * * MUSKINGUM ROUTING * * * * * * * * * * * * * * * * * * * *
 5400 IF(AMSKK.GT.(-.5).AND.AMSKK.LE.0.) GO TO 5500
      VAR(1)=AMSKK
      IFREZ(1)=1
      IF(AMSKK.GT.(-.5)) GO TO 5410
      VAR(1)=TRHR
      NVAR=1
```

```
      IFREZ(1)=0
5410  VAR(2)=X
      IF (X.GE.0.) GO TO 5420
      NVAR=2
      VAR(2)=.2
      IFREZ(2)=0
5420  IF (NVAR.LE.0) GO TO 5470
C               SAVE FLOWS IN TEMPORARY ARRAY
      DO 5430 I=1,NQ
5430  DEWPT(I)=Q(I)
      ITRNS=-1
C               OPTIMIZE MUSKINGUM COEFFICIENTS
5440  CALL OPTIM
C     ********************************
      IF (ITRNS.GT.0) GO TO 5640
      IF (NC2.GT.1) GO TO 5450
      TEMP=TRHR/(2.*VAR(2))
      IF (M1.EQ.2) TEMP=TRHR/(2.*VAR(1))
      IF (VAR(M1).GT.TEMP) VAR(M1)=TEMP
5450  DO 5460 I=1,NQ
5460  Q(I)=DEWPT(I)
5470  CA=2.*TRHR/(2.*VAR(1)*(1.-VAR(2))+TRHR)
      CB=(TRHR-2.*VAR(1)*VAR(2))/(2.*VAR(1)*(1.-VAR(2))+TRHR)
      DO 5490 J=1,NSTP
      TEMP=Q(1)
      DO 5480 I=2,NQ
      TMP=Q(I)
      Q(I)=(CA-CB)*TEMP+CB*TMP+(1.-CA)*Q(I-1)
5480  TEMP=TMP
5490  CONTINUE
      JTRNS=0
      GO TO 5590
C      * * * * STRADDLE-STAGGER ROUTING, TRANSFER FROM 5400   * * * * * *
5500  NSTL=NSTDL
      LTRNS=0
      IF (NSTDL.NE.(-1).AND.NSTDL.LE.0) GO TO 5590
      IF (NSTDL.GT.0) GO TO 5540
      TESTC=999999.
C               SAVE FLOWS IN TEMPORARY ARRAY
      DO 5510 I=1,NQ
5510  EXCSR(I)=Q(I)
C               OPTIMIZE STRADDLE SPAN
      NSTL=1
5520  DO 5530 I=1,NQ
5530  Q(I)=EXCSR(I)
5540  TMP=NSTL
      DO 5580 J=1,NSTP
      DO 5560 I=1,NQ
C               USE TEMPORARY ARRAY FOR SUM
      PRCP(I)=0.
      DO 5550 L=1,NSTL
      K=I+L-(NSTL+2)/2
      IF (K.LT.1) K=1
      IF (K.GT.NQ) K=NQ
5550  PRCP(I)=PRCP(I)+Q(K)
5560  CONTINUE
      DO 5570 I=1,NQ
5570  Q(I)=PRCP(I)/TMP
5580  CONTINUE
C      * * * * CHANNEL LOSSES  * * * * * * * * * * * * * * * * * * * * *
```

```
5590  DO 5600 I=1,NQ
      Q(I)=(Q(I)-QLOSS)*CLOSS
      IF (Q(I).LT.0.) Q(I)=0.
5600  CONTINUE
      IF (LTRNS.EQ.1) GO TO 5640
      IF (IDERV.LE.0) GO TO 5800
C               COMPUTE STANDARD ERROR, TMPR IS LOCAL INFLOW
      QSQ=0.
      DO 5610 I=1,NQ
      Q(I)=Q(I)+TMPR(I)
5610  QSQ=QSQ+(Q(I)-QO(I))**2*(QO(I)+AVGQO)*RAVQO
      STDER(NC)=(QSQ*RNQ)**.5
      IF (JTRNS) 5350,5440,5620
5620  IF (ISTDL.NE.(-1)) GO TO 5640
C               OPTIMUM STRADDLE PASSED WHEN STDER INCREASES
      IF (STDER(1).GT.TESTC) GO TO 5630
      TESTC=STDER(1)
      NSTL=NSTL+1
      IF (NSTL.LE.10) GO TO 5520
5630  LTRNS=1
      NSTL=NSTL-1
      GO TO 5520
5640  IF (KTRNS.EQ.1) GO TO 5660
      IF (NSTPS.NE.(-1)) GO TO 5660
C               OPTIMUM STEPS PASSED WHEN STDER INCREASES
      IF (STDER(1).GT.TESTB) GO TO 5650
      TESTB=STDER(1)
      NSTP=NSTP+1
      IF (NSTP.LE.10) GO TO 5270
5650  NSTP=NSTP-1
      KTRNS=1
      GO TO 5270
5660  IF (JLAG.EQ.1) GO TO 5680
      IF (LAG.GT.0.OR.LAG.NE.(-1)) GO TO 5680
C               OPTIMUM LAG PASSED WHEN STDER INCREASES
      IF (STDER(1).GT.TESTA) GO TO 5670
      TESTA=STDER(1)
      LG=LG+1
      IF (LG.LE.10) GO TO 5190
5670  LG=LG-1
      JLAG=1
      GO TO 5190
5680  SUMQ=0.
      IF(TSK.LE.(-1.)) TSK=VAR(1)
      IF(AMSKK.LE.(-1.)) AMSKK=VAR(1)
      IF(X.LE.(-1.)) X=VAR(2)
      IF (IDERV.LE.0) GO TO 5800
      DO 5690 I=1,NQ
5690  SUMQ=SUMQ+Q(I)
      IF (IPRNT.GE.1) GO TO 5720
C               PRINT OPTIMIZATION RESULTS
      PRINT 5700
5700  FORMAT (/21H DERIVED COEFFICIENTS)
      PRINT 5040
      CLOSS=1.-CLOSS
      PRINT 5050, ISTAQ,NSTP,LG,IRES,STORA,TSK,AMSKK,X,NCOMB,NEXT
      PRINT 5060
      PRINT 5070, NSTDL,QLOSS,CLOSS,AVG,NDMG,IPNT
      PRINT 5710
5710  FORMAT (/7X44HTIME       INFL      LOCAL      OUTFL      ACTUAL)
```

```
5720  TEMP=0.
      ITP=(IH-1)*NQ
      IF (IPRNT.GE.1) GO TO 5770
      DO 5750 I=1,NQ
      ITP=ITP+1
      TEMP=TEMP+QH(ITP)
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 5740
      PRINT 5730, I,QH(ITP),TMPR(I),Q(I),QO(I)
5730  FORMAT (I11,4F10.0)
      GO TO 5750
5740  IDAY=IDAYX
      IHR=IHRX
      IMIN=IMINX
      CALL DATE
      PRINT 6100, IDAY,IHR,IMIN,QH(ITP),TMPR(I),Q(I),QO(I)
5750  CONTINUE
      PRINT 5760, TEMP,SMLCL,SUMQ,SUMQO
5760  FORMAT (7X4H SUM4F10.0)
5770  JSUB=1
      IF (IPLOT) 5780,5780,5790
5780  ISUB=2
      RETURN
5790  ISUB=5
      RETURN
C               ENTER FROM 3560+2,3680+4
5800  IF (NSTM.GT.1.AND.IPNT.GT.(-1)) PRINT 5810, ISTM,TRDA(ISTM)
5810  FORMAT (/6H FLOODI2,2H, F8.1,20H SQ MI TRANSPOSITION)
      SUMQ=0.
      ITP=(IH-1)*NQ
      DO 5820 I=1,NQ
      ITP=ITP+1
      QH(ITP)=Q(I)
5820  SUMQ=SUMQ+Q(I)
      IF (IPNT.LE.(-1).OR.IPRNT.GE.1) GO TO 5850
      IF (NPLAN.GT.0) PRINT 5830, ISTAQ,ISTM,IRTIO,SUMQ,(Q(I),I=1,NQ)
5830  FORMAT (16H0ROUTED FLOWS ATI6,5H PLANI2,6H FLOODI2/5H SUM=F10.0/
     1 (10F10.0))
      IF (NPLAN.LE.0) PRINT 5840, ISTAQ,SUMQ,(Q(I),I=1,NQ)
5840  FORMAT (/23H END-OF-PERIOD FLOWS ATI6/5H SUM=F10.0,/(10F10.0))
5850  IF (IPLOT.LE.0.OR.ISTM.GT.1) GO TO 5860
      NV=1
5860  ISUB=6
      JSUB=1
      RETURN
C      * * * * RESERVOIR ROUTING, MODIFIED PULS, ENTRY FROM 3240 * * * *
5870  TMPA=12.1
      IF(METRC.GT.0) TMPA=.278
      IF (ISTM.GT.1.AND.NPLAN.LE.0) GO TO 5920
      IF (ISTM.GT.1.AND.ISTAQ.LT.0) GO TO 5920
      IF (IRTIO.GT.1) GO TO 5920
      READ 5000, (STOR(K),K=1,10)
      READ 5000, (OUTFL(K),K=1,10)
      IF(STORA.LT.0.) GO TO 5878
      DO 5875 K=2,10
      IF(STORA.LT.STOR(K)) GO TO 5876
 5875 CONTINUE
      K=10
 5876 AK=0
      IF(STOR(K).GT.STOR(K-1))AK=(STORA-STOR(K-1))/(STOR(K)-STOR(K-1))
      IF(AK.GT.1.) AK=1.
```

```
      TMP=OUTFL(K)*AK+OUTFL(K-1)*(1.-AK)
      IF(TMP.LT.0.) TMP=0.
      STRI=STORA*TMPA/TRHR+TMP*.5
 5878 IF(IPRNT.GE.3) GO TO 5900
      PRINT 5880, (STOR(K),K=1,10)
 5880 FORMAT (/18H RESERVOIR STORAGE10F10.0)
      PRINT 5890, (OUTFL(K),K=1,10)
 5890 FORMAT (18H RESERVOIR OUTFLOW10F10.0)
C               CONVERT TO STORAGE INDICATION
 5900 DO 5910 K=1,10
 5910 STOR(K)=STOR(K)*TMPA/TRHR+OUTFL(K)*.5
 5920 IF(NPLAN.GT.0) GO TO 5940
      IF (NSTM.GT.0.AND.IPRNT.GE.1) GO TO 5940
      IF (NSTM.GT.1.AND.IPNT.GT.(-1)) PRINT 5810, ISTM,TRDA(ISTM)
      IF (ISTM.LE.1.AND.IPNT.GT.(-1)) PRINT 5930
 5930 FORMAT (/6X35H TIME  EOP STOR    AVG IN   EOP OUT)
 5940 IF(STORA.GE.0.) GO TO 6010
C               INITIAL STOR FROM INITIAL FLOW, IF NOT GIVEN
      DO 5950 K=2,10
      IF (OUTFL(K).LT.OUTFL(K-1)) GO TO 5960
      IF (Q(1)-OUTFL(K)) 5970,5980,5950
 5950 CONTINUE
      K=10
      GO TO 5970
 5960 K=K-1
      IF (K-1) 5980,5980,5970
 5970 IF (OUTFL(K).GT.OUTFL(K-1)) GO TO 5990
 5980 STRI=STOR(K)
      GO TO 6010
 5990 AK=(Q(1)-OUTFL(K-1))/(OUTFL(K)-OUTFL(K-1))
      IF (AK.LT.0.) AK=0.
      STRI=(1.-AK)*STOR(K-1)+AK*STOR(K)
 6010 TMP=Q(1)
C               ROUTING COMPUTATION
      STORX=STRI
      QA=Q(1)
      QX=TMP
      SUMQ=0.
      ITP=(IH-1)*NQ
      IDAY=IDAYX
      IHR=IHRX
      IMIN=IMINX
      DO 6140 J=1,NSTPS
      STRI=STORX
      TMP=QX
      ITMP=0
      DO 6130 I=1,NQ
      IF(J.EQ.1)QO(I)=Q(I)
      IF (ITMP.EQ.0) STRI=STRI-TMP+Q(I)
      DO 6020 K=2,10
      IF (STOR(K).LT.STOR(K-1)) GO TO 6030
      ITMP=0
      IF (STRI.LE.STOR(K)) GO TO 6040
 6020 CONTINUE
      K=10
      GO TO 6040
 6030 K=K-1
      TEMP=Q(I)
      IF (I.LT.NQ) TEMP=(Q(I+1)+TEMP)*.5
      IF (TEMP.GE.OUTFL(K)) GO TO 6070
```

```
      IF (K.EQ.1) GO TO 6050
6040  IF (STOR(K).GT.STOR(K-1)) GO TO 6060
6050  TEMP=OUTFL(K)
      GO TO 6080
6060  AK=(STRI-STOR(K-1))/(STOR(K)-STOR(K-1))
      TEMP=OUTFL(K)*AK+OUTFL(K-1)*(1.-AK)
      IF(TEMP.LT.0.) TEMP=0.
      GO TO 6080
6070  STRI=STOR(K)+.001
      ITMP=1
6080  STR(I)=(STRI-TEMP*.5)*TRHR/TMPA
      IF (J.LT.NSTPS) GO TO 6120
      ITP=ITP+1
      IF(NPLAN.GT.0) GO TO 6110
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 6090
      IF(IPRNT.LT.3.AND.IPNT.GT.(-1)) PRINT 5730,I,STR(I),QO(I),TEMP
      GO TO 6110
 6090 CALL DATE
      IF(IPRNT.LT.3.AND.IPNT.GT.(-1)) PRINT 6100,IDAY,IHR,IMIN,STR(I),
     1QO(I),TEMP
6100  FORMAT (I4,2I3,4F10.0)
6110  QH(ITP)=TEMP
      Q(I)=TEMP
      SUMQ=SUMQ+TEMP
      GO TO 6130
 6120 Q(I)=(TMP+TEMP)*.5
 6130 TMP=TEMP
6140  CONTINUE
      ISUB=6
      JSUB=1
      NV=7
      IF(IPRNT.GT.1.AND.NPLAN.GE.1) PRINT 5830,ISTAQ,ISTM,IRTIO,SUMQ
      IF (IPNT.LE.(-1).OR.IPRNT.GE.1) RETURN
      IF (NPLAN.LE.0) PRINT 6150,SUMQ
 6150 FORMAT (7X4H SUMF30.0)
      IF (NPLAN.LE.0) RETURN
      PRINT 5830, ISTAQ,ISTM,IRTIO,SUMQ,(Q(I),I=1,NQ)
      PRINT 6160, (STR(I),I=1,NQ)
6160  FORMAT (5H STOR/(10F10.0))
      RETURN
      END
```

```
      SUBROUTINE OPTIM
C                FOR FLOOD HYDROGRAPH PACKAGE
      DIMENSION GAIN(10)
      COMMON /ALPHA/ IDGST,IEND,IFREZ(10),IHDGR,ITRNS,M,M1,NC,NC2,NVAR,C
     1RITN(3),VAR(10)
      IF (ITRNS) 6000,6070,6070
C                INITIATE CONSTANTS
6000  NCYCL=0
      FIN=0.
      CORMX=50.
      CORMN=-33.3333
      TEST=999999.
6010  DO 6020 M=1,NVAR
6020  GAIN(M)=0.
```

```
      M=0
 6030 M=M+1
      M1=M
      IF (IFREZ(M)) 6040,6040,6030
 6040 NC1=1
      NC2=3
      GO TO 6060
 6050 NC1=1
      NC2=1
 6060 ITRNS=0
      NC=NC1
      RETURN
 6070 IF (IEND.EQ.1.AND.NC.EQ.1) TEST=CRITN(1)
      IF (NC.EQ.1) TEMP2=VAR(M)
      TMP=NC
      VAR(M)=TEMP2*(1.-TMP*.01)
      NC=NC+1
      IF (NC.LE.NC2) RETURN
      IF (NC2-1) 6080,6080,6220
 6080 IF (CRITN(1)-TEST) 6130,6130,6090
 6090 IF (NADJ-2) 6100,6110,6110
 6100 VAR(M1)=.3*VAR(M1)+.7*TEMP1
      NADJ=NADJ+1
      VAR(M)=TEMP2
      GO TO 6060
 6110 VAR(M1)=TEMP1
 6120 FORMAT (4H VARI3,9H ADJ FROMF7.2,3H TOF7.2)
      VAR(M)=TEMP2
      GAIN(M1)=0.
      IEND=IEND+1
      IF (NCYCL-3) 6040,6040,6160
 6130 NC1=2
      NC2=3
      IF (IDGST) 6150,6150,6140
 6140 PRINT 6120, M1,TEMP1,VAR(M1)
 6150 GAIN(M1)=1.-CRITN(1)/TEST
      TEST=CRITN(1)
      IEND=IEND+1
      IF (NCYCL-3) 6060,6060,6160
C               AFTER 3 CYCLES, WORK ON VARIABLE HAVING MOST EFFECT
 6160 GANMX=0.
      IEND=10
      DO 6180 MX=1,NVAR
      IF (GAIN(MX)-GANMX) 6180,6180,6170
 6170 GANMX=GAIN(MX)
      L=MX
 6180 CONTINUE
      IF (GANMX-.01) 6200,6200,6190
 6190 VAR(M)=TEMP2
      M=L
      GO TO 6040
 6200 IF (FIN) 6210,6210,6370
C               CALL FOR ONE MORE SEARCH
 6210 FIN=1.
      VAR(M)=TEMP2
      GO TO 6010
C               OPTIMIZATION
 6220 IF (IDGST) 6250,6250,6230
 6230 PRINT 6240, M,(CRITN(NC),NC=1,3)
 6240 FORMAT (/23H CRITERION FOR VARIABLEI2,3F12.4)
```

```
 6250   DSER1=CRITN(2)-CRITN(1)
        DSER2=CRITN(3)-CRITN(2)
        DIF2=DSER2-DSER1
        IF (DIF2) 6260,6270,6290
 6260   IF (DSER1) 6320,6320,6310
 6270   IF (DSER1) 6320,6280,6310
 6280   CORR=0.
        GO TO 6330
 6290   CORR=DSER1/DIF2-.5
        IF (CORR-CORMN) 6320,6330,6300
 6300   IF (CORR-CORMX) 6330,6330,6310
 6310   CORR=CORMX
        GO TO 6330
 6320   CORR=CORMN
 6330   TEMP1=TEMP2
        M1=M
        VAR(M1)=TEMP2*(1.+CORR*.01)
        NADJ=0
        IEND=10
 6340   IF (M-NVAR) 6360,6350,6350
 C               INCREMENT CYCLE
 6350   M=0
        NCYCL=NCYCL+1
        IEND=0
 C               INCREMENT VARIABLE NUMBER
 6360   M=M+1
        IF (IFREZ(M)) 6050,6050,6340
 6370   VAR(M)=TEMP2
        IF (IHDGR.LE.0) PRINT 6380, (VAR(N),N=1,NVAR)
 6380   FORMAT (/18H DERIVED VARIABLES/10F8.2)
        ITRNS=1
        RETURN
        END



        SUBROUTINE GRAPH
 C      PRINTER PLOT      FOR A 132-COLUMN PRINTER
        DIMENSION ISPAN(4), ISTEP(4), ISTRT(4), PLOT(121), SAVE(121), SCAL
       1E(13), STP(4), STRT(4), ISCAL(3)
        COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
       1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
       2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
       3X,IHRX,IMINX
        COMMON /TME/ IMIN,NMIN,IHR,NHR,IDAY
        DATA BLANK/1H /,PER/1H./,ALTRI/1HI/,ASTRK/1H*/,ALTRS/1HS/,ALTRP/1H
       1L/,ALTRO/1HO/,ALTRT/1HT/,ALTRE/1HX/
 7000   FORMAT (80A1)
 7010   FORMAT (I9,1X,121A1)
 7020   FORMAT (I4,2I3,121A1)
 7030   FORMAT (4X,F6.0,12F10.0)
 7040   FORMAT (4X,F6.1,12F10.1)
 7050   FORMAT (4X,F6.2,12F10.2)
        ISCAL(1)=1
        ISCAL(2)=2
        ISCAL(3)=3
 C      SUPPRESS PAGE EJECT
        PRINT 7060
```

```
7060   FORMAT (6H1*0VF*)
       PRINT 7070, ISTAQ
7070   FORMAT (50X7HSTATIONI6//)
C                INITIATE VARIABLES
       DO 7080 I=1,121
       PLOT(I)=BLANK
7080   SAVE(I)=BLANK
       PRINT 7090
7090   FORMAT (29X42HINFLOW(I), OUTFLOW(O) AND OBSERVED FLOW(*))
       NS=0
C                INITIATE STANDARD PLOT VARIABLES
       ISTRT(1)=0
       ISTRT(2)=0
       ISTRT(3)=60
       ISTRT(4)=120
       ISPAN(1)=0
       ISPAN(2)=100
       ISPAN(3)=40
       ISPAN(4)=-40
       AX(1)=ALTRI
       AX(2)=ASTRK
       AX(3)=ALTRS
       AX(4)=ALTRP
       GO TO (7100,7110,7120,7130,7140,7150,7160,7170), NV
7100   ISPAN(1)=120
       GO TO 7180
7110   AX(1)=ALTRO
       AX(2)=ALTRI
       GO TO 7180
7120   ISCAL(2)=3
       ISTRT(2)=0
       ISTRT(3)=120
       ISPAN(1)=100
       ISPAN(2)=0
       ISPAN(3)=-40
       AX(2)=ALTRE
       AX(3)=ALTRP
       GO TO 7180
7130   AX(3)=ALTRT
       GO TO 7180
7140   ISCAL(2)=3
       ISPAN(3)=0
       AX(3)=ALTRE
       NV=4
       GO TO 7180
7150   ISTRT(2)=60
       ISPAN(1)=100
       ISPAN(2)=40
       ISPAN(3)=0
       AX(2)=ALTRT
       AX(3)=ALTRE
       NV=4
       GO TO 7180
7160   ISCAL(2)=4
       AX(1)=ALTRO
       AX(2)=ALTRI
       NV=3
       GO TO 7180
7170   ISTRT(3)=0
       ISPAN(2)=0
```

```
      ISPAN(3)=100
      AX(1)=ALTRO
      AX(3)=ALTRI
      NV=3
 7180 JPJ=0
      DO 7430 J=1,NV
      IF (JPJ.GT.0) GO TO 7190
      AMIN=99999999.
      AMAX=-99999999.
C              USE SAME SCALE AS FOLLOWING VARIABLE IF ISPAN IS ZERO
 7190 JPJ=0
      IF (ISPAN(J).EQ.0) GO TO 7230
      NS=NS+1
      IF (ISCAL(NS).EQ.2) PRINT 7200
 7200 FORMAT (70X14HTEMPERATURE(T))
      IF (ISCAL(NS).EQ.3) PRINT 7210
 7210 FORMAT (104X23HPRECIP(L) AND EXCESS(X))
      IF (ISCAL(NS).EQ.4) PRINT 7220
 7220 FORMAT (81X10HSTORAGE(S))
      IF (ISTRT(J).GE.0) GO TO 7230
C              NEGATIVE ISTRT SETS ZERO SCALE LIMIT
      AMIN=0.
      ISTRT(J)=-ISTRT(J)
C              CENTER AND PRINT SCALE TITLE
C              FIND EXTREME VALUES
 7230 DO 7290 K=1,NQ
      GO TO (7240,7250,7260,7270), J
 7240 TEMP=Q(K)
      GO TO 7280
 7250 TEMP=QO(K)
      GO TO 7280
 7260 TEMP=STR(K)
      GO TO 7280
 7270 TEMP=PRCP(K)
 7280 IF (TEMP.GT.AMAX) AMAX=TEMP
      IF (TEMP.LT.AMIN) AMIN=TEMP
 7290 CONTINUE
      IF (ISPAN(J).NE.0) GO TO 7300
      JPJ=1
      GO TO 7430
C              DETERMINE INCREMENT FOR 10 SPACES
 7300 TMP=ISPAN(J)/10
      IF (TMP.LT.0.) TMP=-TMP
      IF (AMAX.LE.AMIN) AMAX=1.01*AMIN
      RATIO=(AMAX-AMIN)/TMP
      STEP=1.
      IFMT=1
 7310 IF (RATIO.LE..5) GO TO 7320
      IF (RATIO.GT.5.) GO TO 7330
      IF (RATIO.LE.2..AND.RATIO.GT.1.) STEP=2.*STEP
      IF (RATIO.LE.4..AND.RATIO.GT.2.) STEP=4.*STEP
      IF (RATIO.GT.4.) STEP=5.*STEP
      GO TO 7340
 7320 STEP=STEP*.1
      RATIO=RATIO*10.
      IFMT=IFMT+1
      GO TO 7310
 7330 STEP=STEP*10.
      RATIO=RATIO*.1
      GO TO 7310
```

```
C                LOCATE AND ASSIGN SCALE VALUES, PRINT SCALE
7340   ITP=AMIN/STEP
       TMP=ITP
       TMP=(TMP-.01)*STEP
       IF (AMIN.LT.TMP) ITP=ITP-1
       ITMP=AMAX/STEP
       TMP=ITMP
       TMP=(TMP+.01)*STEP
       IF (AMAX.GT.TMP) ITMP=ITMP+1
       IF (IFMT.GT.3) IFMT=3
       ITEMP=1
       IF (ISPAN(J).LT.0) ITEMP=-ITEMP
       DO 7350 L=1,13
7350   SCALE(L)=0.
       LX=ISTRT(J)/10+1
       TEMP=ITP
       TEMP=TEMP*STEP
       ITMP=ITMP-ITP+1
       DO 7360 L=1,ITMP
       IF (LX.GT.13) GO TO 7370
       IF (LX.LT.1) GO TO 7370
       SCALE(LX)=TEMP
       LX=LX+ITEMP
7360   TEMP=TEMP+STEP
7370   GO TO (7380,7390,7400), IFMT
7380   PRINT 7030, (SCALE(LX),LX=1,13)
       GO TO 7410
7390   PRINT 7040, (SCALE(LX),LX=1,13)
       GO TO 7410
7400   PRINT 7050, (SCALE(LX),LX=1,13)
C                STORE SCALE INCREMENTS AND LOCATIONS
7410   STP(J)=STEP*.1
       TMP=ITP
       STRT(J)=TMP*STEP
       ISTEP(J)=1
       IF (ISPAN(J).LT.0) ISTEP(J)=-1
       DO 7420 K=1,J
       IF (ISPAN(K).NE.0) GO TO 7420
       STP(K)=STP(J)
       STRT(K)=STRT(J)
       ISTEP(K)=ISTEP(J)
       ISTRT(K)=ISTRT(J)
       ISPAN(K)=ISPAN(J)
7420   CONTINUE
7430   CONTINUE
C                DRAW SCALE LINES
       LX=1
       DO 7440 L=1,13
       PLOT(LX)=PER
       SAVE(LX)=PER
7440   LX=LX+10
       IDAY=IDAYX
       IHR=IHRX
       IMIN=IMINX
C                COMPUTE LOCATION OF EACH POINT AND PLOT
       DO 7590 K=1,NQ
       DO 7550 J=1,NV
       GO TO (7450,7460,7470,7480), J
7450   TEMP=Q(K)
       GO TO 7490
```

```
7460  TEMP=QO(K)
      GO TO 7490
7470  TEMP=STR(K)
      GO TO 7490
7480  TEMP=PRCP(K)
7490  ITMP=(TEMP-STRT(J))/STP(J)+.5
      LX=ISTRT(J)+ITMP*ISTEP(J)+1
      IF (LX.GT.121) LX=121
      IF (LX.LT.1) LX=1
      IF (AX(J).NE.ALTRP) GO TO 7540
      IF (AX(J-1).NE.ALTRE) GO TO 7510
      DO 7500 L=LTMP,120
      IF (LTMP.EQ.121) GO TO 7520
7500  PLOT(L+1)=ALTRE
      GO TO 7520
7510  LTMP=122
7520  LTMP=LTMP-1
      DO 7530 L=LX,LTMP
      PLOT(L)=ALTRP
7530  CONTINUE
7540  PLOT(LX)=AX(J)
      LTMP=LX
7550  CONTINUE
      IF (IDAYX+IHRX+IMINX.GT.0) GO TO 7560
      PRINT 7010, K,(PLOT(L),L=1,121)
      GO TO 7570
7560  CALL DATE
      PRINT 7020, IDAY,IHR,IMIN,(PLOT(L),L=1,121)
7570  DO 7580 L=1,121
7580  PLOT(L)=SAVE(L)
7590  CONTINUE
C     NORMALIZE PAGE EJECT
      PRINT 7600
7600  FORMAT (///6H1*OVN*)
      RETURN
      END



      SUBROUTINE ECONO
C              FUNCTIONS - ALOG AT 8080+3
      DIMENSION FREQ(9), PEAK(9), DAMAG(9,10), PROB(9), AVAN(9), Q(9), A
     1VGAN(9),RATIO(9),DMG(9),DAMG(9)
C
      COMMON /GAMMA/ IH,KHGR,NDMG,NPLAN,NRTIO,QMX(270)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM
8000  FORMAT (1XI7,9F8.0,/(1XF7.0,9F8.0))
      IF (NDMG.LE.0) RETURN
      READ 8010, ISTN,(FREQ(K),K=1,9)
8010  FORMAT (1X,I7,9F8.0)
      IF (ISTN.LE.0.AND.ISTN.GT.(-1)) RETURN
      PRINT 8020
8020  FORMAT (1H1)
      IF (ISTN.NE.ISTAQ.AND.ISTN.NE.(-ISTAQ)) PRINT 8040, ISTAQ,ISTN
      READ 8000, NFLOD,(PEAK(K),K=1,9),(AVGAN(N),(DAMAG(K,N),K=1,9),N=1,
     1NDMG)
      PRINT 8030, ISTAQ,(FREQ(K),K=1,9),(PEAK(K),K=1,9),((DAMAG(K,N),K=1
```

```
     1,9),AVGAN(N),N=1,NDMG)
8030  FORMAT (22H0ECONOMIC DATA FOR STAI5,/5H FREQ9F10.3/5H PEAK9F10.0/(
     15H DAMG9F10.3,9H  AVG ANNF10.3))
 8040 FORMAT (14H0ECON DATA FORI7,14H IDENTIFIED ASI7)
      DO 8050 J=1,NRTIO
8050  PROB(J)=0.
      DO 8060 N=1,NDMG
8060  RATIO(N)=1.
      ITMP=KHGR*NPLAN
      Q(1)=QMX(IH)
      DO 8090 K=1,NFLOD
      TMP=PEAK(K)
      ITP=IH
      DO 8070 J=2,NRTIO
      ITP=ITP+ITMP
      IF (TMP.LE.QMX(ITP)) GO TO 8080
8070  CONTINUE
      J=NRTIO
8080  ITEMP=ITP-ITMP
      TEMP=QMX(ITEMP)
      TP=QMX(ITP)
      TMP=(ALOG(TMP)-ALOG(TP))/(ALOG(TEMP)-ALOG(TP))
      IF (TMP.LT.0.) TMP=0.
      IF (TMP.GT.1.) TMP=1.
      PROB(J-1)=FREQ(K)*TMP+PROB(J-1)
      PROB(J)=FREQ(K)*(1.-TMP)+PROB(J)
8090  CONTINUE
C               COMPUTE AVG ANNUAL DAMAGES
      ITP=IH
      DO 8290 L=1,NPLAN
      IF (L.LE.1.OR.ISTN.LE.0) GO TO 8105
      READ 8000, NFLOD,(PEAK(K),K=1,9),(AVGAN(N),(DAMAG(K,N),K=1,9),N=1,
     1NDMG)
      PRINT 8100, NFLOD,(PEAK(K),K=1,9),((DAMAG(K,N),K=1,9),AVGAN(N),N=1
     1,NDMG)
8100  FORMAT (22H0ECONOMIC DATA FOR STAI5,/5H PEAK9F10.0/(5H DAMG9F10.3,
     19H  AVG ANNF10.3))
 8105 DO 8110 N=1,NDMG
8110  AVAN(N)=0.
      PRINT 8115,ISTAQ,L,(I,I=1,NDMG)
 8115 FORMAT(26H0FLOOD DAMAGES FOR STATION,I7,2X,5H PLANI3/5X11HDAMAGE T
     1YPE,2X,9I8)
      PRINT 8117
 8117 FORMAT(2X17HNO.   FLOW   PROB)
      DO 8170 J=1,NRTIO
      DO 8160 N=1,NDMG
      TEMP=RATIO(N)*PROB(J)
      TMP=QMX(ITP)
      Q(J)=TMP
      IF (TMP.GE.PEAK(1)) GO TO 8120
      TMP=(DAMAG(2,N)-(PEAK(2)-TMP)/(PEAK(2)-PEAK(1))*(DAMAG(2,N)-DAMAG(
     11,N)))*TEMP
      GO TO 8150
8120  DO 8130 K=2,NFLOD
      IF (TMP.LE.PEAK(K)) GO TO 8140
8130  CONTINUE
      K=NFLOD
8140  TMP=(TMP-PEAK(K))/(PEAK(K-1)-PEAK(K))
      IF (TMP.GT.1.) TMP=1.
      TMP=(DAMAG(K-1,N)*TMP+DAMAG(K,N)*(1.-TMP))*TEMP
```

```
8150  IF (TMP.LT.0.) TMP=0.
      AVAN(N)=AVAN(N)+TMP
      DAMG(N)=TMP
8160  CONTINUE
      PRINT 8165,J,Q(J),PROB(J),(DAMG(I),I=1,NDMG)
 8165 FORMAT(I4,F9.0,F6.3,9F8.1)
      ITP=ITP+KHGR*NPLAN
8170  CONTINUE
      PRINT 8175,(AVAN(N),N=1,NDMG)
 8175 FORMAT(3X,14HAVG ANN DAMAG,9F8.1)
      IF (L.GT.1) GO TO 8190
      DO 8180 N=1,NDMG
      IF(AVGAN(N).LE.0.) GO TO 8180
      IF(AVAN(N).GT.0.) RATIO(N)=AVGAN(N)/AVAN(N)
      AVAN(N)=AVGAN(N)
8180  CONTINUE
8190  SUM=0.
      DO 8200 N=1,NDMG
8200  SUM=SUM+AVAN(N)
      ITP=IH+KHGR*L
      PRINT 8230, SUM
8230  FORMAT (6H TOTALF10.3)
      IF (L.EQ.1) GO TO 8270
      DO 8250 N=1,NDMG
8250  AVAN(N)=DMG(N)-AVAN(N)
      SUM=SUMA-SUM
      PRINT 8260, (AVAN(N),N=1,NDMG)
 8260 FORMAT(2X,15HAVG ANN BENEFIT,9F8.1)
      PRINT 8230, SUM
      GO TO 8290
8270  SUMA=SUM
      DO 8280 N=1,NDMG
8280  DMG(N)=AVAN(N)
8290  CONTINUE
      RETURN
      END



      SUBROUTINE SUMRY (IH)
      COMMON /BETA/ AX(9),BX(9),CX(9),DA(270),DX(9),INH(270),IOPER(120),
     1IPNT,ISTAQ,ISTM,ISTQ(120),METRC,NH,NQ,NSTM,NV,PRCP(150),Q(150),QM(
     2120),QMAX,QO(150),SM(120),SMX(120),SMY(120),STR(150),TRHR,VOL,IDAY
     3X,IHMX,IMINX
      ANQ=NQ
      QMAX=0.
      SUM=0.
      SUMX=0.
      SUMY=0.
      TEMP=1.001/TRHR
      NA=6.*TEMP
      NB=24.*TEMP
      NC=72.*TEMP
      IF (TRHR*ANQ.LE.700.) GO TO 9000
      TEMP=TEMP*24.
      NA=10.*TEMP
      NB=30.*TEMP
      NC=90.*TEMP
```

```
 9000  TP=0.
       TMP=0.
       TEMP=0.
       IF (NA.LT.1) NA=1
       IF (NB.LT.1) NB=1
       IF (NC.LT.1) NC=1
       DO 9010 I=1,NQ
       TP=TP+Q(I)
       TMP=TMP+Q(I)
       TEMP=TEMP+Q(I)
       J=I-NA
       IF (J.GT.0) TP=TP-Q(J)
       IF (TP.GT.SUM) SUM=TP
       J=I-NB
       IF (J.GT.0) TMP=TMP-Q(J)
       IF (TMP.GT.SUMX) SUMX=TMP
       J=I-NC
       IF (J.GT.0) TEMP=TEMP-Q(J)
       IF (TEMP.GT.SUMY) SUMY=TEMP
       IF (Q(I).GT.QMAX) QMAX=Q(I)
 9010  CONTINUE
       IF (NA.GT.NQ) NA=NQ
       IF (NB.GT.NQ) NB=NQ
       IF (NC.GT.NQ) NC=NQ
       TP=NA
       SUM=SUM/TP
       TMP=NB
       SUMX=SUMX/TMP
       TEMP=NC
       SUMY=SUMY/TEMP
       IF (IPNT.LE.(-1)) GO TO 9050
       IF (TRHR*ANQ.LE.700.) PRINT 9020
 9020  FORMAT (/24X34HPEAK     6-HOUR    24-HOUR    72-HOUR)
       IF (TRHR*ANQ.GT.700.) PRINT 9030
 9030  FORMAT (/24X34HPEAK     10-DAY     30-DAY     90-DAY)
       PRINT 9040, QMAX,SUM,SUMX,SUMY
 9040  FORMAT (15X3HCFS4F10.0)
 9050  QM(NH)=QMAX
       SM(NH)=SUM
       SMX(NH)=SUMX
       SMY(NH)=SUMY
       ISTQ(NH)=ISTAQ
       INH(IH)=NH
C                SAVE COMBINED VALUES FOR SYSTEM FLOODS
       IF (IOPER(NH).NE.3) GO TO 9060
       AX(ISTM)=QMAX
       BX(ISTM)=SUM
       CX(ISTM)=SUMX
       DX(ISTM)=SUMY
 9060  SUM=SUM*TP/VOL
       SUMX=SUMX*TMP/VOL
       SUMY=SUMY*TEMP/VOL
       IF (IPNT.GT.(-1)) PRINT 9070, SUM,SUMX,SUMY
 9070  FORMAT (12X6HINCHESF20.2,2F10.2)
       TMP=DA(NH)*53.3333
       SUM=SUM*TMP
       SUMX=SUMX*TMP
       SUMY=SUMY*TMP
       IF (IPNT.GT.(-1)) PRINT 9080, SUM,SUMX,SUMY
 9080  FORMAT (13X5HAC-FTF20.0,2F10.0)
```

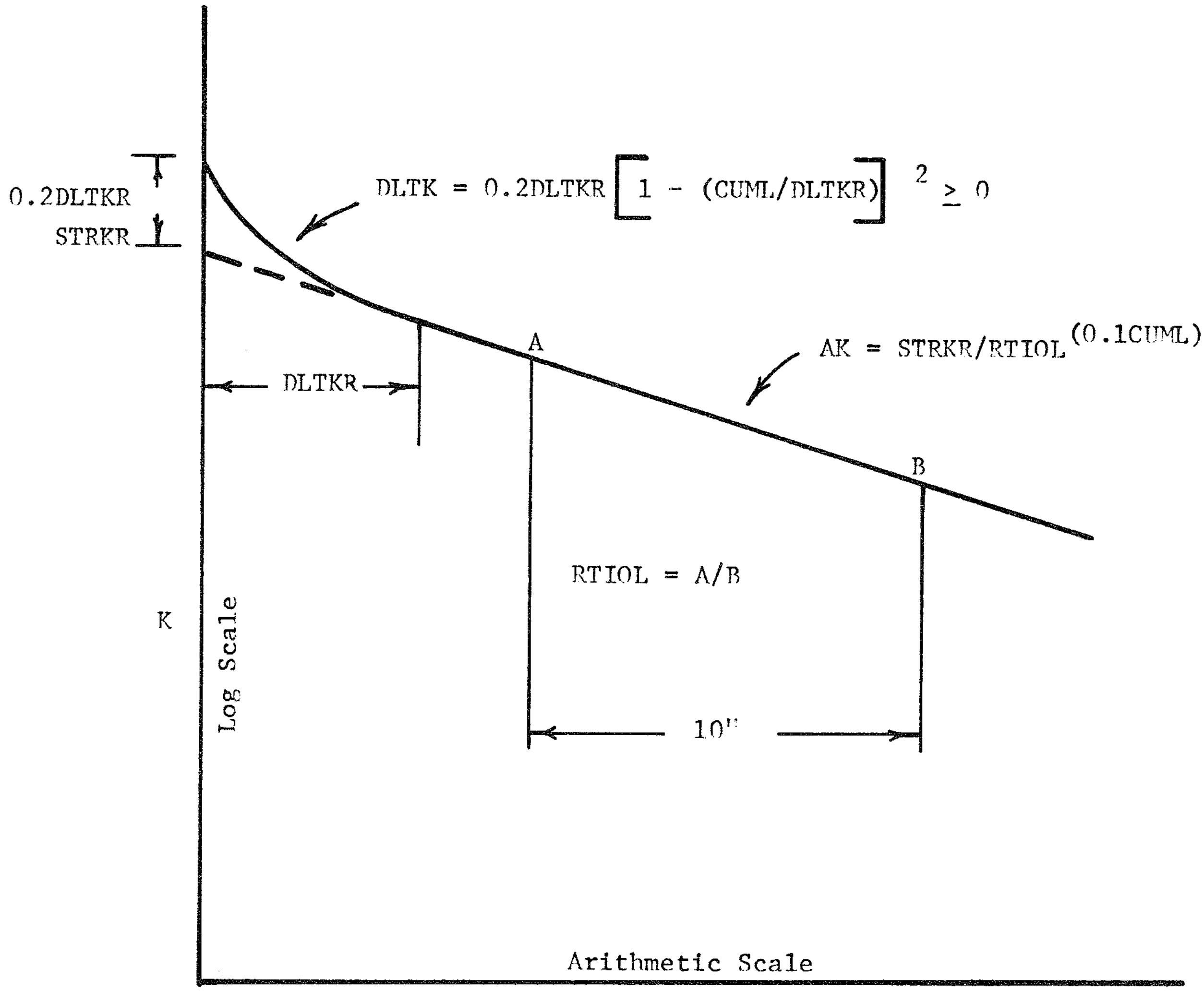
```
RETURN
END



SUBROUTINE DATE
COMMON/TME/IMIN,NMIN,IHR,NHR,IDAY
IMIN=IMIN+NMIN
ITMP=IMIN-60
IF(ITMP.GT.0) IMIN=ITMP
IF(ITMP.GT.0) IHR=IHR+1
IHR=IHR+NHR
ITMP=IHR/24
IF(ITMP.GT.0) IHR=IHR-ITMP*24
IDAY=IDAY+ITMP
RETURN
END
```


EXHIBIT 4

EXHIBIT 5

GENERAL LOSS RATE FUNCTION

ON SNOW-FREE GROUND



ACCUMULATED LOSS (CUML)

$$ALOSS = (AK + DLTK)PRCP^{ERAIN}$$

NOTE: See exhibit 3 of description for definition of terms.

EXHIBIT 6

INPUT DATA

HEC-1

A Three title cards with A in col. 1 of first card

B Job specification (all integers)

1. NHR - Number of whole hours in tabulation interval

2. NMIN - Number of minutes in tabulation interval exclusive of whole hours

3. NO - Number of computation intervals in entire hydrograph and number of items to be read when using C, E1, I, J, K, L, U1 and S cards (see program listing for dimension limits and operating instructions, paragraph 8)

4. NSTAN - Total number of nonrecording regional precipitation stations used in job, precede with minus sign if data already in computer from previous job and not to be read again on D card, zero or blank if precipitation station data not to be used (50 max)

5. NSTAR - Total number of regional recording precipitation stations to be used to distribute computed basin precipitation (11 max)

NOTE: If recording precipitation stations are to be used to compute total storm basin precipitation, they should be included in the count of both fields 4 and 5. Thus, NSTAN must be positive if NSTAR is.

6. ISNOW - Positive 1 calls for snow data (cards I to M) and computations

7. IDERV - Positive 1 calls for derivation of runoff (unit-hydrograph and loss-rate) or routing coefficients by reconstitution of observed hydrograph read on C cards

8. IPLOT - Positive 1 calls for plotting results on printout

9. NSTM - Number of system hypothetical floods to be computed simultaneously for interpolating at each concentration point in accordance with size of tributary area

10. NPLAN - Number of alternative development plans considered

11. IPRNT - Printout control indicator. Values call for printout as follows:

0 - All printout
1 - Suppress many system and plan hydrographs
2 - Also suppress unit hydrographs
3 - Also suppress input data
4 - Also suppress job specification data

12. METRC - Positive integer indicates that metric units (cms, MM, thousand cubic meters, deg. C) are used instead of English units (cfs, in., ac.-ft., deg. F).

13. IDGST - Positive integer calls for printout of error diagnostics from OPTIM subroutine

14. IDAY - Day number at start of first interval (omit if interval number is sufficient to identify the time scale)

15. IHR - Hour number at start of first enterval (omit on same condition)

16. IMIN - Minute number at start of first interval (omit on same condition)

1 Area - precipitation data (omit if NSTM (B-9) does not exceed 1) A system flood will be computed for each pair of values listed.

1. TRDA(1) - Area in square miles (sq. km.)

2. STRM(1) - Precipitation average in inches (mm). If TRSPC (G-4) varies with size of area, STRM should include transposition coefficient and TRSPC should be 1.0

3. TRDA(2) -

4. STRM(2) - Etc., NSTM pairs, increasing area sizes

2 Flood ratio data, omit if NPLAN (B-10) is zero or negative. Economic evaluation may be used with this option only.

1. NRTIO - Number of flood ratios to be read if positive. If negative, number of storm ratios to be read (9 max)

2. RTIO(1) - Ratio by which all flood (or storm) ordinates of each subarea hydrograph are multiplied for all plans.

3. RTIO(2) - Etc., NRTIO values, must increase in magnitude

C Observed flows to be reconstituted by derivation of runoff or routing coefficients (omit if IDERV (B-7) is zero or negative)

1. QO(1) - Observed flow in cfs (cms) at the end of the first period

2. QO(2) - Etc., NQ (B-3) values

NOTE: When deriving runoff coefficients, the timing must be consistent between the precipitation and the observed flows, i.e., the first precipitation value should be for the period corresponding to the first runoff value.

1 Flow adjustment criteria (omit if IDERV (B-7) is zero or negative)

1. IQ(1) - Sequence number of flow selected to be adjusted

2. RQ(1) - Ratio by which selected flow IQ(1) is temporarily multiplied to aid in reconstitution

3. IQ(2) - Sequence number of other selected flow to be adjusted

4. RQ(2) - Corresponding ratio

Etc., up to 10 values (5 pairs)

D Nonrecording precipitation data for entire region, NSTAN (B-4) cards (Omit if NSTAN is zero or negative). Used to compute basin precipitation.

1. ISTAN - Station identification number (integer)

2. PRCPN - Total storm precipitation in inches, can be omitted if recording station with same number has complete record

3. ANAPN - Normal precipitation for station. Used to compute basin mean precipitation by weighted average of station normal precipitation. Supply 1 if TAREA (G-17) is positive

NOTE: If a recording station is to be used also in the determination of basin precipitation, it must be included in this group of cards.

E Recording precipitation data for entire region, NSTAR (B-5) sets of E and E1 cards (omit if NSTAN (B-5) is zero or negative)

1. ISTAR - Station identification number (integer)

1 Precipitation - Omit if NSTAR (B-5) is zero or negative

1. PRCPR(1) - Precipitation in inches (mm) in first interval, -1 if missing data

2. PRCPR(2) - Etc., NQ (B-3) values of PRCPR

F* Hydrograph specification (all integers). If NPLAN (B-10) is positive, use NPLAN sets of F to T cards, unless ISTAQ is negative, in which case all subsequent plans are identical and F to T cards are not repeated.

1. ISTAQ - Stream station location identification number, precede by minus sign if NPLAN exceeds 1 and if F to T cards are the same at this location for all plans.

2. IHDGR - Positive 1 calls for reading input hydrograph on S cards and G1 to R cards will not be read.

3. NP - Number of precipitation items to be read on H cards, precede by minus sign if values from cards H to L of previous hydrograph (for this job or preceding job) to be used and not to be read, must be zero if hydrograph to be read. Leave blank if NSTN is positive. Must be less than or equal to NQ (B-3) (150 max).

4. NSTN - Number of nonrecording precipitation stations to be used for computing basin precipitation (25 max)

5. NSTR - Number of recording precipitation stations to be used to distribute computed basin precipitation (9 max)

6. NUHGQ - Number of unit hydrograph ordinates to be read on R cards (100 max)

7. NCLRK - Number of time-area ordinates to be read on Q cards for use in computing a unit hydrograph (100 max). Must be zero if unit hydrograph is read in or if synthetic time-area curve is to be used.

8. LOCAL - Positive 1 calls for reading total flow at combination point (on S cards) and subtracting routed hydrographs to compute intermediate runoff. Otherwise zero

9. NCOMB - Number of hydrographs to be combined immediately after the current operation (cards F to T), (zero or more than 1) Hydrographs combined are those most recently computed or read.

10. NEXT - After current operation, next operation will be for hydrograph if -1 (cards F to T), next operation will be for routing if +1 (cards U to U3), end of job if 0

11. IPNT - -1 suppresses printout for computed hydrographs at this location, and -2 also suppresses printout of combined flows; otherwise zero

*Every job requires one set of F cards and an additional set following each hydrograph or routing operation in which NEXT (F-10 or U-10) is -1. If NPLAN (B-10) is positive and NDMG (F-12) is a nonzero integer, these cards must be followed by a single set of frequency-flow-damage cards (V, V1 & V2 cards) if ISTN on V card is negative, otherwise by a single V card and NPLAN sets of V1 and V2 cards.

12. NDMG - Number of damage cards (V2 cards) to be applied to flows computed (and combined if NCOMB (F-9) is positive). These represent different types of damage. NPLAN (B-10) must be positive if this option is used.

13. IBAL - Positive 1 calls for adjusting (balancing) hydrograph to obtain volume-duration relation specified on T card.

14. INRGY - Positive 1 calls for snowmelt by energy budget method and I to L cards will be required.

G Hydrograph data - Always required following each F card.

1. STORM - Total storm basin precipitation in inches (mm), supply only if ratios are to be read on H cards, and if NSTM (B-9) does not exceed 1

2. SPFE - Standard project index precipitation from ER 1110-2-1411

3. PMS - Probably maximum index precipitation from HMS Report 33 (positive value calls for reading G3 card)

4. TRSPC - Storm transposition coefficient. If not given, program will supply from ER 1110-2-27 if IDFRV (B-7) is zero or negative. If IDFRV is positive, TRSPC will not be used.

5. TRSDA - Drainage area in square miles (sq. km.) for which storm is transposed. If hydrograph is to be read in on S cards (IHDGR (F-2) is positive) or if STORM (G-1) is positive, this is drainage area for that hydrograph.

6. STRTL - Initial rainfall loss in inches (mm) (snow-free ground). Supply only if hydrograph to be computed and exponential loss rate function is not to be used.

7. CNSTL - Uniform rainfall loss in inches per hour (mm/hr) (snow-free ground). See item P-5.

8. RTIMP - Ratio of drainage basin that is impervious

9. QRCSN - Flow in cfs (cms) below which hydrograph recession is constrained by RTIOR If negative, this is the ratio of the peak discharge to obtain that flow.

10. RTIOR - Ratio of recession flow to that 10 periods later. Must be equal to or greater than 1.

11. STRTQ - Flow at start of storm in cfs (cms). Will be receded the same manner as QRCSN (G-9)

12. ALSMX - Maximum allowable loss rate in inches per hour (mm/hr). STRTL (G-6) may be overridden unless this value is high enough.

13. TLAPS - Temperature lapse rate in degrees F per 1000-foot elevation zone for snowmelt computations (in degrees C per 300 meters for metric units)

14. RATIO - Ratio by which hydrograph being computed or read in is to be multiplied before further use

15. TP - Snyder's lag in hours. Positive value calls for computing unit hydrograph having specified TP and CP (by successive approximations). Otherwise zero.

16. CP - Snyder's C_p of desired unit hydrograph

17. TAREA - Drainage area in square miles (sq. km.). If area entered here, N and O cards will not be read and ISNOW (B-6) must be zero.

1 Nonrecording station weighting for computing total basin storm precipitation. (omit if IHDGR (F-2) is positive or NSTN (F-4) is zero or negative)

1. ISTN(1) - Precipitation station identification number (integer) Must correspond to one of the identification numbers on the D cards.

2. WTN(1) - Relative weight in any units

3. ISTN(2) -

4. WTN(2) - Etc., NSTN (F-4) pairs

2 Recording station weighting for distributing total basin storm precipitation (omit if IHDGR (F-2) is positive or NSTN (F-4) is zero or negative)

1. ISTR(1) - Precipitation station identification number (integer). Must correspond to one of the identification numbers on the E cards

2. WTR(1) - Relative weight in any units

3. ISTR(2) -

4. WTR(2) - Etc., NSTR (F-5) pairs

3 Probable maximum storm amounts (omit if SPFE (G-2) or IHDGR (F-2) is positive or if PMS (G-3) is zero or negative), NSTM (B-9) cards if NSTM exceeds 1

1. R6 - Maximum 6-hour precipitation in percent of index (G-3) (must be supplied)

2. R12 - Maximum 12-hour percentage of index (must be supplied)

3. R24 - Maximum 24-hour percentage of index (must be supplied)

4. R48 - Maximum 48-hour percentage of index (must be supplied if R72 is)

5. R72 - Maximum 72-hour percentage index (must be supplied if R96 is)

6. R96 - Maximum 96-hour percentage of index (optional)

H Basin precipitation data (omit if IHDGR (F-2), SPFE (G-2) or PMS (G-3) is positive or if NP (F-3) is zero or negative)

1. PRCP(1) - Precipitation (in inches (mm) if STORM (G-1) is zero or as ratio to STORM otherwise) during first interval

2. PRCP(2) - Precipitation (same units) during second interval

3. PRCP(3) - Etc., NP values

I Temperature data (omit if IHDGR (F-2) is positive or ISNOW (B-6) is zero or negative or if NP (F-3) is negative)

1. TMPR(1) - Air temperature in degrees F (deg C) at bottom of lowest elevation zone during first interval

2. TMPR(2) - Air temperature during second interval

3. TMPR(3) - Etc., NQ (B-3) values

J Dew point data (omit if IHDGR (F-2) is positive or ISNOW (B-6) or INRGY (F-14) is zero or negative or if NP (F-3) is negative)

1. DEWPT(1) - Dew point in degrees F (deg C) at bottom of lowest elevation zone during first interval

2. DEWPT(2) - Dew point during second interval

3. DEWPT(3) - Etc., NQ (B-3) values

K Wind data (omit if IHDGR (F-2) is positive or ISNOW (B-6) and INRGY (F-14) is zero or negative or if NP (F-3) is negative)

1. WIND(1) - Wind speed in miles per hour (kph) at 50 feet (15 m) above surface, average for basin during first interval

2. WIND(2) - Wind speed during second interval

3. WIND(3) - Etc., NQ (B-3) values

L Solar radiation data (omit if IHDGR (F-2) is positive or ISNOW (B-6) and INRGY (F-14) is zero or negative or if NP (F-3) is negative)

1. SOL(1) - Short-wave radiation in langleys during first interval

2. SOL(2) - Short-wave radiation during second interval

3. SOL(3) - Etc., NQ (B-3) values

M Snowpack data by 1000-foot (300-meter) elevation zones (omit if IHDGR (F-2) is positive or ISNOW (B-6) is zero or negative)

1. SNO(1) - Average water equivalent in inches (mm) of snowpack at start of storm in Zone 1

2. SNO(2) - Average snowpack at start of storm in Zone 2

3. SNO(3) - Etc., items correspond to N card

N Drainage area data by 1000-foot (300-meter) elevation zones (omit if IHDGR (F-2) or TAREA (G-17) is positive)

1. AREA(1) - Drainage area in square miles (sq. km.) in Zone 1 (lowest zone). Where ISNOW (B-6) and TAREA (G-17) are not positive, entire area should be in this zone.

2. AREA(2) - Drainage area in square miles (sq. km.) in Zone 2

3. AREA(3) - Etc., up to 10 values

O Normal precipitation data (omit if IHDGR (F-2) or TAREA (G-17) is positive)

1. ANAP(1) - Normal precipitation in inches (mm), Zone 1, corresponding to N card

2. ANAP(2) - Normal precipitation in inches (mm), Zone 2, corresponding to N card

3. ANAP(3) - Etc., items correspond to N card

P Runoff computation variables (omit if IHDGR (F-2) is positive)

1. TC - Time of concentration in hours for Clark unit hydrograph. Enter -2 if the ratio R/(TC+R) is to be read in the next field and held constant

2. R - Clark unit hydrograph storage coefficient in hours, or the ratio R/(TC+R) if the first field is -2

3. COEF - Snowmelt coefficient, usually about .07 for degree-day method and 1.0 for energy budget method

4. STRKR - Starting value of loss coefficient on exponential recession curve for rain losses (snow-free ground) Enter -2 if the ratio STRKR/DLTKR is to read in the ninth field and held constant

5. STRKS - Starting value of loss coefficient on exponential recession curve for snowmelt losses. IF CNSTL (G-7) is positive this is constant snowmelt loss in inches per hour (mm/hr)

6. RTIOK - Ratio of snowmelt loss coefficient on exponential recession curve to that corresponding to 10 inches (mm) more of accumulated loss. Not required if CNSTL (G-7) is positive.

7. ERAIN - Exponent of precipitation for rain loss function, often 0.7

8. FRZTP - Index temperature in degrees F (deg C) at bottom of zone for snowmelt, usually 32° F (0° C)

9. DLTKR - Amount of initial accumulated rain loss during which loss coefficient is increased, or the ratio STRKR/DLTKR if the fourth field is -2

10. RTIOL - Ratio of rain loss coefficient on exponential recession curve to that corresponding to 10 inches (mm) more of accumulated loss

NOTE: A value of -1 for any of above 10 variables indicates variable is to be derived if IDERV (B-7) is positive, otherwise that the variable is already in computer from preceding job in same run.

Q Time-area data (omit if IHDGR (F-2) or NUHGQ (F-6) is positive or NCLRK (F-7) is zero or negative). Values are supplied for equal percentages of TC.

1. Q(1) - Area in any units that contributes at time zero (usually area of reservoir, if any, at concentration point)

2. Q(2) - Area that contributes runoff during first of NCLRK equal intervals of any length or time

3. Q(3) - Area that contributes runoff during second such interval

4. Q(4) - Etc., NCLRK (F-7) values

R Unit hydrograph (omit if IHDGR (F-2) is positive or NUHGQ (F-6) is not positive)

1. QUNGR(1) - Unit hydrograph flow in cfs (cms) at end of first interval

2. QUNGR(2) - Unit hydrograph flow in cfs (cms) at end of second interval

3. QUNGR(3) - Etc., NUHGQ (F-6) values

S Hydrograph (omit if IHDGR (F-2) is not positive). Used to supply known runoff data.

1. Q(1) - Flow in cfs (cms) at end of first interval

2. Q(2) - Flow in cfs (cms) at end of second interval

3. Q(3) - Etc., NQ (B-3) values

T Hydrograph balance data (omit if IBAL (F-13) is not positive). Will use as pattern hydrograph either computed hydrograph or hydrograph read on S cards.

1. NQB(1) - Number of flows, shortest duration (integer)

2. SUMB(1) - Sum of flows desired corresponding to the shortest duration, NQB(1)

3. NQB(2) - Number of flows, next duration (integer)

4. SUMB(2) - Sum of flows desired, next duration

5. NQB(3) -

6. SUMB(3) - Etc., up to 5 durations

U# Routing specification (NPLAN (B-10) sets, unless ISTAQ is negative)

1. ISTAQ - Outflow station identification number (integer), precede by minus sign if NPLAN (B-10) exceeds 1 and if routing is identical for all plans (will read one set of U cards only)

2. NSTPS* - Number of routing steps (integer). Supply 1 if routing by straddle-stagger. Supply 1 or more than 1 if routing by Tatum method (equal to Tatum steps) or by Muskingum method (equal to number of reaches), or by modified Puls method.

3. LAG* - Number of intervals hydrograph is to be lagged (integer)

4. IRES - Positive 1 calls for reservoir routing and storage-outflow tables U2 and U3 for each set of U cards (integer). Minus 1 calls for no routing, which is used where NPLAN (B-10) exceeds 1 and a reservoir in one plan does not exist in another.

5. STORA - Initial storage in acre-feet (thousand cubic meters) for modified Puls routing, -1 if inflow equals outflow at start of routing

6. TSK* - Time-of-storage coefficient in hours

7. AMSKK* - Muskingum K coefficient in hours

8. X* - Muskingum X coefficient, between 0 and .5

9. NCOMB - Number of hydrographs to be combined after current routing operation (integer), zero or more than 1.

10. NEXT - After current operation, next operation will be for hydrograph if -1 (cards F to T), next operation will be for routing if +1 (cards U to U3), end of job if 0

11. NSTDL* - Number of ordinates averaged in straddle-stagger routing (integer). Supply 2 if routing by Tatum method.

12. QLOSS - Constant loss in entire routing in cfs (cms)

13. CLOSS - Ratio of remaining flow lost in entire routing

14. AVG - Positive 1 indicates that inflows to be routed are average for period, otherwise zero

#See note on page 4. Cards U to U3 used only when preceding value of NEXT read at F-10 or U-10 is +1.

*A value of -1 indicates variable is to be derived; IDERV (B-7) must be positive

15. NDMG - Number of damage cards (V2 cards) to be applied to flows computed (and combined, if NCOMB (U-9) is positive). These represent different types of damage. NPLAN (B-10) must be positive if this is used.

16. IPNT - -1 suppresses printout for computed hydrographs at this location, and -2 also suppresses printout of combined flows

1 Local inflow pattern hydrograph, which will be adjusted for volume in routing coefficient derivation (omit if IDERV (B-7) is not positive)

1. Q(1) - Local inflow in cfs (cms) at end of first interval

2. Q(2) - Local inflow in cfs (cms) at end of second interval

3. Q(3) - Etc., NQ (B-3) values

2 Storage table (omit if IRES (U-4) is not positive)

1. STOR(1) - Storage in acre-feet (1000's of m^3) corresponding to respective outflow on card U3

2. STOR(2) - Storage in acre-feet (1000's of m^3) corresponding to respective outflow on card U3

3. STOR(3) - Etc., up to 10 values, must remain same or increase successively

3 Outflow table (omit if IRES (U-4) is not positive)

1. OUTFL(1) - Outflow in cfs (cms) corresponding to respective storage on card U2

2. OUTFL(2) - Outflow in cfs(cms) corresponding to respective storage on card U2

3. OUTFL(3) - Etc., values correspond to card U2

NOTE: When storage exceeds last tabulated value, outflow will equal inflow until the inflow recedes below last tabulated value. If storage is less than first value, table will be extended.

V Frequency cards (see footnote, page 4, omit if NPLAN (B-10) is not positive)

1. ISTN - Station identification number. Use minus ISTN if same discharge-damage relation to be used for all plans at this location (one set of V, V1 and V2 cards), otherwise one V card and NPLAN sets of V1 and V2 cards are required.

2. FREQ(1) - Exceedence probability range (frequency per year) associated with each corresponding PEAK & DAMAG value

3. FREQ(2) - Etc., up to 9 values of FREQ

1 Peak flow cards (omit if NPLAN (B-10) is not positive)

1. NFLOD - Number of PEAK discharge values to follow (maximum of 9)

2. PEAK(1) - Peak flow in cfs (cms) corresponding to FREQ(1)

3. PEAK(2) - Peak flow corresponding to FREQ(2)

4. PEAK(3) - Etc., NFLOD items

2 Damage cards (omit if NPLAN (B-10) is zero or negative). NDMG (F-12 or U-15) sets required, one set for each damage category.

1. AVGAN - Average annual damages in thousand dollars (or same units as DAMAG)

2. DAMAG(1) - Damage in thousand dollars (or same units as AVGAN) corresponding to PEAK(1)

3. DAMAG(2) - Damage corresponding to PEAK(2)

4. DAMAG(3) - Etc., NFLOD items

Four blank cards with A in column 1 of first will cause computer to stop.

SUMMARY OF REQUIRED CARDS

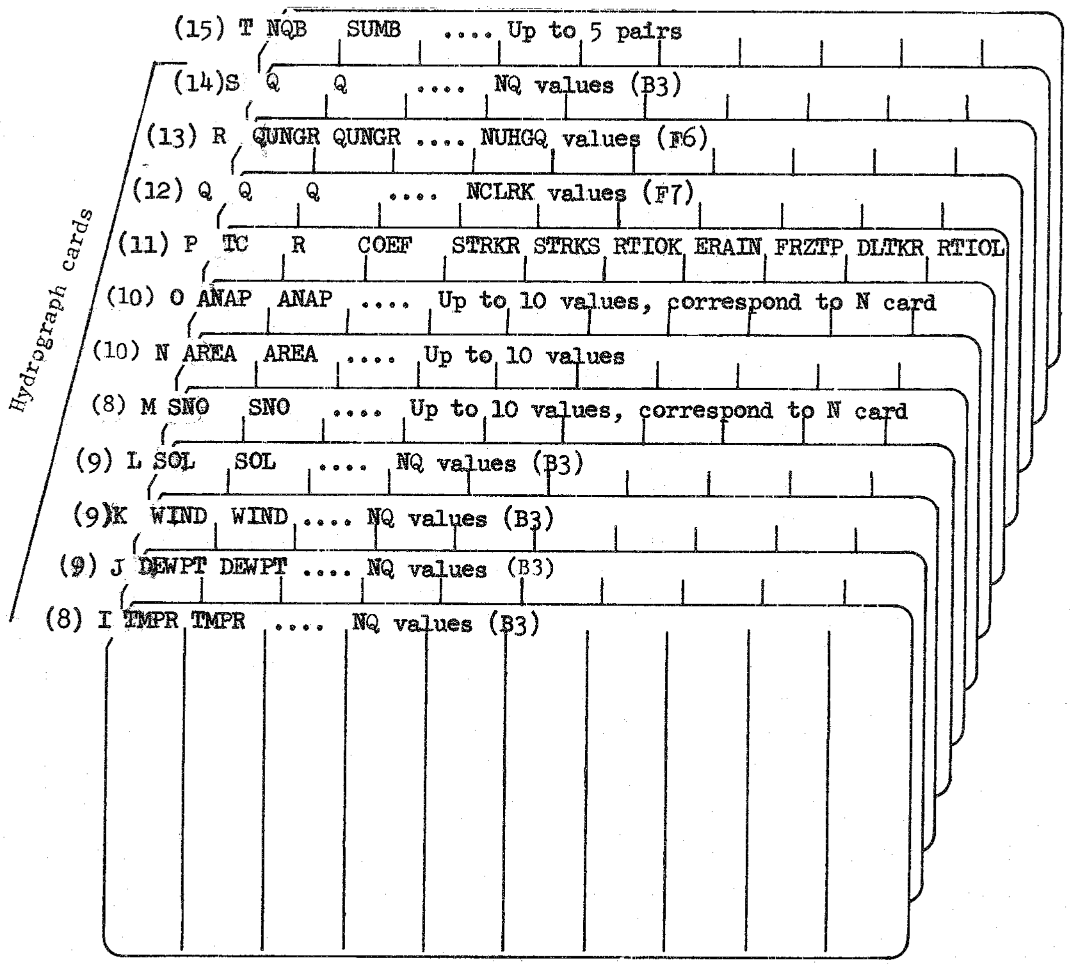
field numbers

		1	2	3	4	5	6	7	8	9	10
Hydrograph cards	(7) H	PRCP	PRCP	....	NP values (F3)						
Hydrograph cards	(6) 3	R6	R12	R24	R48	R72	R96	. . NSTM (B-9) cards			
Hydrograph cards	(5) 2	ISTR	WTR	ISTR	WTR	....	NSTR pairs (F5)				
Hydrograph cards	(4)(5) 1	ISTN	WTN	ISTN	WTN	....	NSTN pairs (F4)				
Hydrograph cards	G	STRTQ	ALSMX	TLAPS	RATIO	TP	CP	TAREA			
Hydrograph cards	G	STORM	SPFE	PMS	TRSPC	TRSDA	STRTL	CNSTL	RTIMP	QRCSN	RTIOR
Hydrograph cards	F	IPNT	NDMG	IBAL	INRGY						
Hydrograph cards	F	ISTAQ	IHDGR	NP	NSTN	NSTR	NUHGQ	NCLRK	LOCAL	NCOMB	NEXT
NSTAR sets	(4) 1	PRCPR	PRCPR	....	NQ values (B3)						
NSTAR sets	(4) E	ISTAR									
	(4) D	ISTAN	PRCPN	ANAPN	....	NSTAN cards (B4)					
	(3) 1	IQ	RQ	IQ	RQ	....	Up to 5 pairs				
	(3) C	QO	QO	....	NQ values (B3)						
	(2) 2	NRTIO	RTIO	RTIO	....	NRTIO values					
	(1) 1	TRDA	STRM	TRDA	STRM	....	NSTM pairs (B9)				
	B	IPRNT	METRC	IDGST	IDAY	IHR	IMIN				
	B	NHR	NMIN	NQ	NSTAN	NSTAR	ISNOW	IDERV	IPLOT	NSTM	NPLAN
	A	Three Title Cards (A in column 1 of first)									

(1) Omit if NSTM (B-9) does not exceed 1.
(2) Omit if NPLAN (B-10) is zero or negative.
(3) Omit if IDERV (B-7) is zero or negative.
(4) Omit if NSTAN (B-4) is zero or negative.
(5) Omit if IHDGR (F-2) is positive or NSTN (F-4) is zero or negative
(6) Omit if SPFE (G-2) or IHDGR (F-2) is positive or if PMS (G-3) is zero or negative.
(7) Omit if IHDGR (F-2), or SPFE (G-2) or PMS (G-3) is positive, or if NP (F-3) is zero or negative.

NOTE: All data use 10 fields of 8 columns each, except that Col. 1 of each card is reserved for identification, so first field of each card is restricted to 7 columns.

EXHIBIT 7



(8) Omit if IHDGR (F-2) is positive or ISNOW (B-6) is zero or negative or if NP (F-3) is negative.

(9) Omit if IHDGR (F-2) is positive or ISNOW (B-6) or INRGY (F-14) is zero or negative or NP (F-3) is negative.

(10) Omit if TAREA (G-17) is positive, or omit if IHDGR (F-2) is positive.

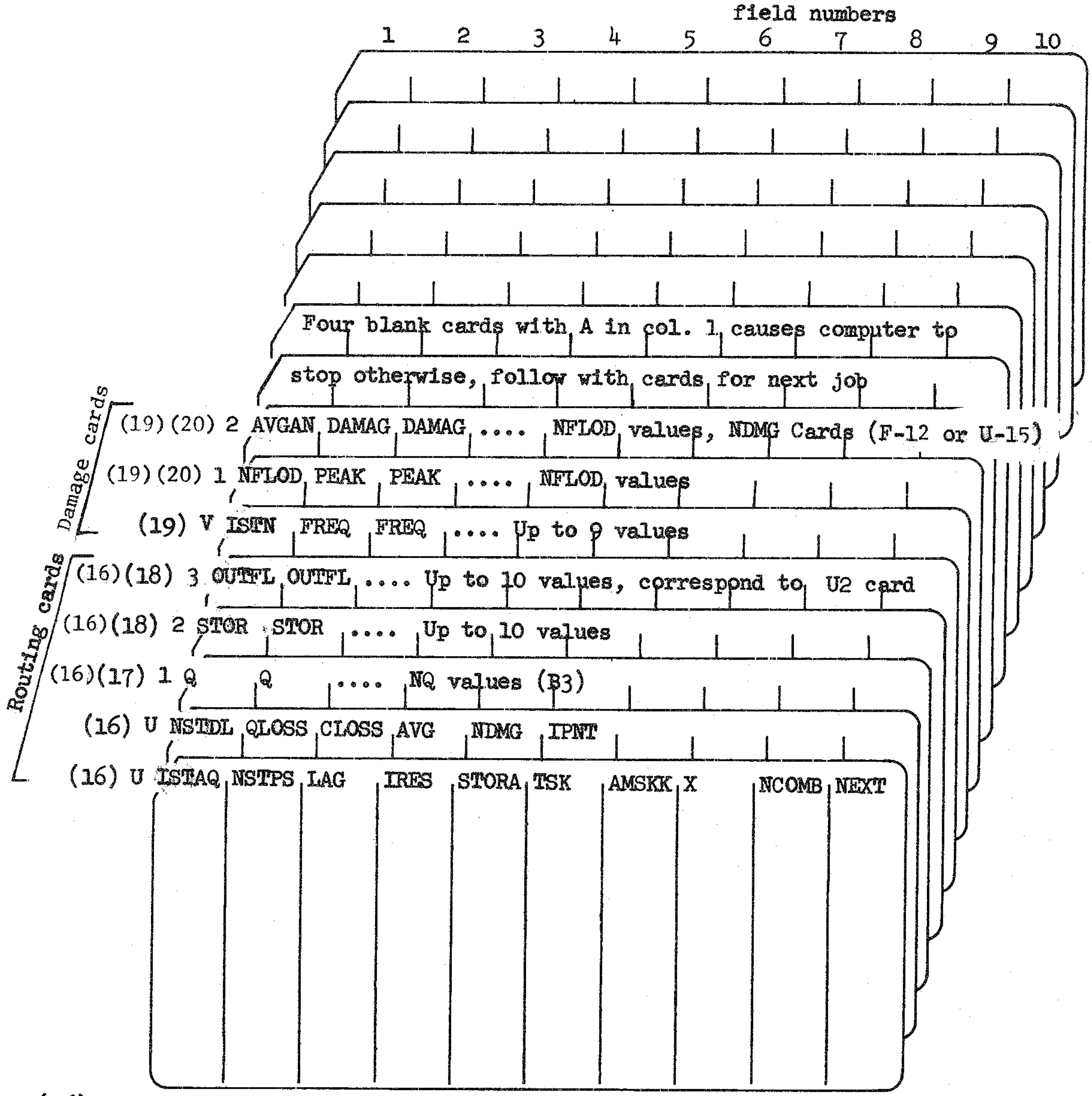
(11) Omit if IHDGR (F-2) is positive.

(12) Omit if IHDGR (F-2) or NUHGQ (F-6) is positive or NCLRK (F-7) is zero or negative.

(13) Omit if IHDGR (F-2) or NUHGQ (F-6) is zero or negative.

(14) Omit if IHDGR (F-2) is not positive.

(15) Omit if IBAL (F-13) is not positive.



(16) Omit if latest value of NEXT (F-10) or (U-10) is not positive.
(17) Omit if IDERV (B-7) is zero or negative.
(18) Omit if IRES (U-4) is not positive.
(19) Omit if NPLAN (B-10) is not positive.
(20) NPLAN (B-10) sets if ISTN (V-1) is positive. Otherwise use one set.

Appendix 2

HEC-2
Water Surface Profiles

COMPUTER PROGRAM 723-X6-L202A
HEC-2 WATER-SURFACE PROFILES

USERS MANUAL

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, U. S. ARMY
609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 449-2105

WATER-SURFACE PROFILES

HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L202A

CONTENTS

CONTENTS (cont'd)

EXHIBITS

WATER-SURFACE PROFILES

THE HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L202A

1. ORIGIN OF PROGRAM

This program is a modification of program 723-G2-L214A, developed in The Hydrologic Engineering Center, Corps of Engineers, 609 Second Street, Davis, California by Bill S. Eichert (1964 version of 723-G2-L214A was from the Tulsa District by same author). The input requirements have been modified to allow the use of many additional options, to provide for future expansion and to simplify input preparation. A supplementary program (723-G1-L202B) is available to convert data from the old program 723-G2-L214A to the new program. Other changes have been made to increase the program's flexibility to handle a wide variety of water surface profile problems. A data edit program (723-G1-L202C) which reads the data cards for program 723-X6-L202A and checks the data for various input errors is also available. The source program, 723-X6-L202A, is shown in exhibit 12.

2. PURPOSE OF PROGRAM

The program computes and plots the water surface profile for river channels of any cross section for either subcritical or supercritical flow conditions. The effects of various hydraulic structures such as bridges, culverts, weirs, embankments, and dams may be considered in the computation. River conditions such as variable channel roughness, islands, bends, levee overflow, river confluences, and waterfalls may also be included. Investigating channel roughness from known high water marks is one of several special program applications. Input may be in either English or Metric units.

3. DESCRIPTION OF EQUIPMENT

The program was written for use in the CDC 6600 computer but may be used with minor modifications on other high-speed computers having four or more magnetic tapes plus input and output units such as the IBM 360, IBM 7094, and GE 625. Various versions of the original program 723-G2-L214A can be used on smaller computers such as the IBM 1620, GE 225, and IBM 1130.

4. DESCRIPTION OF PROGRAM

a. Basic Theory. The computational procedure is similar to Method 1, Backwater Curves in River Channels, Engineering Manual 1110-2-1409, U. S. Army Corps of Engineers, 7 December 1959 (reference d). This method applies Bernoulli's Theorem for the total energy at each cross section and Manning's formula for the friction head loss between cross sections. In the program, average friction slope for a reach between two cross sections is determined in terms of the average of the conveyances at the two ends of the reach (reference f). Other losses are computed using one of several methods. The critical water surface elevation corresponding to the minimum specific energy is computed using an iterative process. Reference (a) describes this method in detail.

b. Subcritical or Supercritical Flow. The computation begins at a control section (location of known water surface elevation) in the river channel and proceeds upstream for subcritical flow or downstream for supercritical flow. The direction of flow is specified by the user on card J1 (first job card) by setting variable IDIR (direction) equal to 1 for superciritical flow or 0 (blank) for subcritical flow. In cases where flow passes from subcritical to supercritical or vice versa, during computations, it is necessary to compute the entire profile twice assuming alternately subcritical and supercritical flow. From the above results **the most likely water surface profile can be determined**

c. Starting Elevation. The water surface elevation for the beginning cross section may be specified in one of three ways: (1) as critical depth, (2) as a known elevation, (3) by the slope area method. By setting the variable STRT on card J1 equal to -1, critical depth will be computed and used as the starting water surface elevation. With variable STRT left blank the starting water surface elevation is specified by variable WSEL on card J1. For beginning by the slope area method STRT is set equal to the estimated slope of the energy grade line (must be a positive value) and WSEL is used as the initial estimate of the water surface elevation. The flows computed for the fixed slope and estimated depth are compared with the starting flow and the initial depth is adjusted until the computed flow is within 1% of the starting flow. The last assumption of initial water surface elevation thus determined is then used as the starting water surface elevation for water surface profile computations.

d. Flow.

(1) The river flow may be specified and altered in several ways. The starting flow is normally specified as variable Q on card J1 when only one flow is anticipated. If it is desired to use different flows for subsequent jobs using the same cross sections, variable INQ and card QT (discharge table) may be used. The flows are input in fields 2 thru 10 on the first QT card and 11 thru 20 on the second. Variable INQ for each job should equal the field number of the flow on card QT to be used for that job. Use of variable INQ and card QT overrides any flow specified for variable Q on card J1. However, variable Q on card J1 will be used until a QT card is encountered.

(2) Where it is desired to change the flow beginning at a certain cross section such as a confluence with another river or stream, variable QNEW on card X2 (second card describing specified cross section) may be used. QNEW permanently changes the flow at any cross section for which this variable is specified.

(3) Where it is necessary to increase or decrease flows specified on cards QT and X2 by a factor, variable FQ on card J1 is available. When a value

for FQ is entered, all flows on cards QT and X2 are multipled by this value and the resulting flows are used in the subsequent calculations.

e. Manning's "n".

(1) Since Manning's coefficient of roughness "n" depends on such factors as type and amount of vegetation, channel configuration and stage, several options are available to vary "n". When three "n" values are sufficient to describe the channel and overbank roughness, the first three fields of card NC ("n" value change) are used. Any of the "n" values may be permanently changes at any cross section by using another NC card. Often three values are not enough to adequately describe the lateral roughness variation in the overbanks in which case card NH ("n" value - horizontal) is used. The number of "n" values used to describe the overbank roughness is entered as variable NUMNH in the first field, and the "n" values and corresponding cross section stations are entered in subsequent fields. These "n" values will be used for all subsequent cross sections unless changed by another NH card or NC card. The "n" values specified on card NH apply only to the overbanks and the stations must correspond with overbank stations on card GR (ground profile). The value used for the channel roughness is the value entered on the last NC card.

(2) Data indicating the variation of Manning's "n" with river stage may be used in the program. Manning's "n" and the corresponding stage elevation (beginning with the lowest elevation) are entered on card NV ("n" value - vertical) beginning in the second and third field, respectively. Variable NUMNV in field 1 is the number of "n" values input on the NV cards. This option applies only to the channel area.

(3) If for subsequent runs of the same job it is desired to multiply the "n" values specified on cards NC, NH, and NV by a multiplier, variable FN on card J2 may be used. The desired multiplier is simply entered as variable FN for each job. If the variable is left blank, all "n" values will be multiplied by one. If the value of FN is negative then the factor is multiplied by the channel "n" on the NC card but the overbank "n" is not changed.

f. Solving for Manning's "n".

(1) To determine Manning's "n" from known high water marks along the river reach, the discharge, relative ratios of the "n" values for the channel and overbanks, and the water surface elevation at each cross section must be known. The "best estimate" of "n" for the first cross section must be entered on card NC since it is not possible to compute an "n" value for this cross section. The relative ratio of "n" between channel and overbank is set by the first cross section and will be used for all subsequent cross sections unless another NC card is used to change this ratio. High water marks are used for the computed water surface elevation by setting variable

NINV on card J1 equal to 1 and entering the known water surface elevation as variable WSELK on card X2 for each cross section. When an adverse slope is encountered, computations restart using n-values from the previous section, but WTN computations continue.

(2) Another method is to specify the discharge and an assumed set of "n" values, and have the program compute a water surface profile which can be compared with the high water profile. For this method WSELK may be input on card X2, without entering the computations, so that it can be easily compared with the computed water surface elevation on the output.

g. Multiple Stream Profiles. The water surface profile computations may be computed up both forks of a river or throughout a whole river basin for single or multiple profiles in a single computer run. The profile is first computed for reach 1 from the most downstream point to the end of one tributary. The data for a second tributary (reach 2), whose starting water surface elevation was determined when reach 1 was calculated, follows the data for reach 1 except that the first field of the X1 card (section number) is negative and is equal to the section number in reach 1 where the starting water surface elevation for reach 2 was determined. When a negative section number is encountered, the program will search its memory for the computed water surface elevation that corresponds to the negative section number. It will then start computing the profile for reach 2 with the previously determined water surface elevation.

h. Storage-Outflow Data. Punched cards can be obtained from HEC-2 for stream routing by the Modified Puls Method using program HEC-1. The cards punched are U,2 and 3 cards (see program description for HEC-1). This option can be used only if multiple profiles are computed from the same cross sectional data and if the summary printout is requested. Interpolated cross sections determined by the computer may be used. Routing reach sections may not be interpolated sections. However, it may not be wise to use interpolated cross sections since a different number of cross sections might be interpolated between two given cross sections for different magnitudes of discharge which could cause inconsistencies in the incremental storage volumes. The ability to repeat the previous cross section by using only an X1 card (i.e., field 2 on the X1 card is blank) can be used where additional cross sections are needed at the ends of routing reaches and in place of the interpolated cross sections. The J4 card calls for this option.

i. Critical Depth Computation. Critical depth will not be computed for all cross sections in this program unless that option is requested on the J2 card, since this takes about half of the computation time. However, the program will check each cross section to see if the depth is close to critical. If the depth is near critical, it will calculate critical depth using subroutine DC by determining the point of minimum specific energy using a discharge weighted velocity head. Critical depth will always be computed for supercritical profile and it will be determined for low flow for the cross section upstream of a special bridge. This low flow critical depth is calculated by subroutine YCRIT for a trapezoidal section.

j. <u>River Cross Sections</u>.

(1) Cross sections are required at representative locations throughout the river reach. These are locations where changes occur in slope, cross sectional area, or channel roughness; locations where levees begin or end; and at bridges. In general, for rivers of flat slope and fairly uniform section (drop of three or four feet per mile) cross sections should be taken at least every mile. For steeper slopes and very irregular cross sections four or five cross sections per mile may be necessary. Where an abrupt change occurs in the cross section, several cross sections should be used to describe the change regardless of the distance. Every effort should be made to obtain cross sections that accurately represent the river geometry.

(2) Each cross section in the reach is identified and described using cards X1 (first card for a cross section) and GR. Variable SECNO on card X1 is the cross section <u>number</u> which may correspond to stationing along the channel, mile points, or any fictitious numbering system, since it is only used to identify output and is not used in the computations. Each point in the cross section is given a station number corresponding to the horizontal distance from the first point on the left. The station number and corresponding elevation of each point are input as variables STA(I) and EL(I) on card GR. Up to 100 points may be used. Cross sections may be oriented looking either upstream or downstream since the program considers the left side to be the lowest station number and the right side the highest. The left and right stations separating the channel from the overbank areas are specified as variables STCHL and STCHR on card X1. End points of a cross section that are too low (below the computed water surface elevation) will automatically be extended vertically by the program and a message giving the vertical distance extended will be printed.

(3) There are times when the user wishes to use the previous cross section as the current one (for uniform channels), with or without a modification, or to modify the current cross section (perhaps the surveyed cross section is moved upstream or downstream). To do this, variables NUMST, PXSECR and PXSECE on card X1 are available. A zero or blank for variable NUMST indicates that the previous cross section will be used for the current one, i.e., GR cards are omitted. When the GR cards are read in NUMST must equal the number of stations on the GR cards. When the horizontal dimensions of the previous (NUMST = 0) or current (NUMST = +) cross section are to be increased or decreased by a factor, the value of the factor is entered as variable PXSECR. All cross section stations except the first will then be multiplied by the factor. If the elevations of the previous or current cross sections are to be raised or lowered by a constant, the value is entered as variable PXSECE. During normal usage, when cross section data are read, NUMST will equal the number of stations on cards GR and PXSECR and PXSECE will be blank.

(4) Channel encroachments may be included in the analysis by using variables on card X3 (third card for cross section). ENCFP is used to specify a width between encroachment areas which is centered in the channel midway between the left and right bank stations. This width will be used for each cross section until another value of ENCFP is entered. Another method for specifying encroachments is to enter the station and elevation of the encroachment as variables STENCL and ELENCL on the left and STENCR and ELENCR on the right. If only the station is required the elevation should be omitted and it will be assumed to be very high.

(5) The existing cross section as described by the GR cards can be modified due to the excavation of a trapezoidal channel by the use of subroutine CHIMP which is called by the CI card. The GR points are modified due to the excavation, but no fill is used. The bank elevations and stations are modified if the channel daylights outside the original bank stations. If the alignment of the excavated channel is such that two separate channels exist, the division between overbank and channel will be based on the excavated channel, and the old channel will be considered as overbank (no fill). It may be necessary to change the reach lengths for this case.

k. Multiple Profiles. Where it is desired to compute several profiles using the same cross sectional data, variable NPROF on card J2 is used. For the first profile, NPROF is set equal to 1 and all cross section cards are read in. For all remaining profiles NPROF equals the profile number, i.e., 2, 3, 4 ...., and only cards T1, T2, T3, J1 and J2 are required (cards NC through EJ are omitted). If NPROF is set equal to 15 for the last of two or more profiles, a summary printout is called for which will provide a concise summary of results for all profiles for each cross section. For a single job NPROF can be left blank, or, if the summary printout format for the single job is desired, set equal to -1.

l. Cross Sections with Levees.

(1) Levees require special consideration in computing water surface profiles because of possible overflow into areas outside the main channel. Normally the computations are based on the assumption that all area below the water surface elevation is effective in passing the discharge (IEARA = 0). However, if the water surface elevation is less than the top of levee elevation, and if the water cannot enter the overbanks upstream or downstream of that cross section, then all flow area in these overbanks should not be used in the computations. Variable IEARA on card X3 is used for this condition. By setting IEARA equal to 10 the program will consider only flow confined by the levees, unless the water surface elevation is above the top of one or both sides of the levee, in which case flow area or areas outside the levee will be included. When the water surface elevation is close to the top of the levee, it may not be possible to balance the assumed and computed water surface elevations due to the changing assumptions of flow area when just above and below the levee. When this condition occurs a note will be printed that states that the assumed and computed water surface elevations for the cross section

cannot be balanced. A water surface elevation equal to the elevation which came closest to balancing (plus 0.1 ft.) will be adopted. It is then up to the program user to determine the appropriateness of the assumed water surface elevation and start the computation over again at that cross section if required.

(2) It is important for the user to study carefully the flow pattern of the river where levees exist. If, for example, a levee were open at both ends and flow passed behind the levee without overtopping it, IEARA equals 0 or blank should be used. Also, assumptions regarding effective flow areas may change with changes in flow magnitude. Where cross section elevations outside the levee are considerably lower than the channel bottom it may be necessary to set IEARA equal to 10 to confine the flow to the channel.

m. Interpolated Cross Sections. Sometimes it is necessary to insert cross sections between those specified on the GR cards because the change in velocity heads between cross sections is too great to accurately determine the hydraulic gradient. Variable HVINS on card J1 is used to specify when interpolated cross sections should be used. This variable specifies the maximum change in velocity head allowed between cross sections. If this value is exceeded, up to three interpolated cross sections will be generated between given cross sections (depending on the magnitude of $\Delta HV/HVINS - 1$). If HVINS is left blank or equal to zero the computer will use 0.5 feet for the limiting value. This value of 0.5 feet was selected based on experience with channels of various slopes. Should it be desired to suppress interpolated cross sections, HVINS should be set to -1. Interpolated cross sections should be omitted when computing several profiles on the same stream in order to use exactly the same cross sections. Interpolated cross sections are identified on the output by section numbers of 1.01, 1.02, 1.03, etc.

n. Distance Between Cross Sections. It was pointed out previously that the cross section number, SENCO on card X1, is used for identification purposes only. The actual distance between cross sections used in the computation is specified on card X1 as variables XLOBL, XLOBR and XLCH for the left overbank, right overbank, and channel, respectively. Normally these three values will be equal. There are however, conditions where they will differ, such as at river bends, or where the channel meanders considerably and the overbanks are straight. Where the distance between cross sections for channel and overbanks are different, a weighted distance is automatically computed based on the flow and corresponding distance in the channel and overbanks.

o. Transition Losses. Expansion or contraction of flow due to changes in the channel cross section is a common cause of energy losses within a reach. Whenever this occurs the loss may be computed by specifying on card NC the expansion and contraction coefficients as variables CEHV and CCHV respectively. The coefficients are multiplied by the absolute difference in velocity heads between the cross sections to give the energy loss caused by the transition. Where the change in river cross section is small, coefficients CEHV and CCHV are on the order of 0.3 and 0.1, respectively. When the change in cross sections is abrupt such as at bridges, CEHV and CCHV may be as high as 1.0 and 0.6. These values may be changed at any cross section by inserting a new NC card, however, these new values will be used until changed again by another NC card.

p. Bridge Losses.

(1) Energy losses caused by structures such as bridges and culverts are computed in two parts. First, the losses due to expansion and contraction of the cross section on the upstream and downstream sides of the structure are computed (see exhibits 3 and 4 for required cross sections). Variables CEHV and CCHV discussed in the previous section are used to specify the expansion and contraction coefficients. Secondly, the loss through the structure itself is computed by either the normal bridge routine or the special bridge routine.

(2) The normal routine handles the cross section at the bridge just as it would any river cross section with the exception that the area of the bridge below the water surface is subtracted from the total area and the wetted perimeter is increased where the water surface elevation exceeds the low chord. The bridge deck is described by entering the elevation of the top of roadway and low chord as variables ELTRD and ELLC respectively on card X2 or by specifying a table of roadway elevation and station and corresponding low chord elevations (BT cards). When only ELLC and ELTRD are used, these elevations are extended horizontally until they intersect the ground line. Pier losses are accounted for by the increased wetted perimeter of the piers as described on card GR. The normal routine is particularly applicable for bridges without piers, bridges under high submergence, and for low flow through circular and arch culverts. Whenever flow crosses critical depth in a structure, the special bridge routine should be used. The normal bridge is automatically used by the computer, even though data was prepared for the special bridge routine, for bridges without piers and under low flow control.

(3) The special bridge routine computes losses through the structure for low flow, weir flow and pressure flow or for any combination of these. The type of flow is determined by a series of comparisons as shown on exhibit 1 and as described below. First, the energy grade line elevations are computed assuming alternately low flow and pressure flow control. The higher energy grade line elevation determines the appropriate type of flow. If pressure flow appears to control and the energy grade line is above the minimum top of roadway elevation, then a combination of pressure flow and weir flow exists. If the energy gradient is below the minimum top of roadway then pressure flow alone controls. If low flow appears to control, and the corresponding energy

gradient elevation is above the minimum top of roadway elevation, then a combination of low flow under the bridge and weir flow over the roadway approach exists; if the energy elevation is below the minimum top of roadway, then low flow controls.

(4) Low flow is further classified as Class A, B and C depending on whether subcritical, critical, or supercritical flow occurs between bridge piers.

(a) Class A flow, identified by procedures explained in later paragraph, is solved from Yarnell's energy equation shown on sheet 010-6 of the WES Hydraulic Design Charts:

$$H_3 = 2K\,(K + 10\omega - 0.6)(\alpha + 15\alpha^4)\,V_3^2/2g \quad \text{where,}$$

H_3 = drop in water surface in feet from upstream to downstream sides of the bridge

K = pier shape coefficient (see exhibit 2)

ω = ratio of velocity head to depth downstream from the bridge

$\alpha = \dfrac{\text{obstructed area}}{\text{total unobstructed area}}$

V_3 = velocity downstream from the bridge in feet per second

The computed upstream water surface elevation is simply H_3 plus the downstream water surface elevation.

(b) Class B and C flows are handled by employing the following momentum relations proposed by Koch and Carstanjen in reference (b):

$$m_1 - m_{p1} + \frac{Q^2}{g(A_1)^2}\left(A_1 - A_{p1}\right) = m_2 + \frac{Q^2}{gA_2} = m_3 - (m_p)_3 + \frac{Q^2}{gA_3}$$

where,

m_1, m_2, m_3 = $A_1\bar{y}_1$, $A_2\bar{y}_2$ and $A_3\bar{y}_3$, respectively

m_{p1}, m_{p3} = $A_{p1}\bar{y}_{p1}$ and $A_{p3}\bar{y}_{p3}$, respectively

A_1, A_3 = unobstructed (gross) area at upstream and downstream sections, respectively

A_2 = flow area (gross area - area of piers) at a section within constricted reach

A_{p1}, A_{p3} = obstructed areas at upstream and downstream sections, respectively

$\bar{y}_1$, $\bar{y}_2$, $\bar{y}_3$ = vertical distance from water surface to center of gravity of A_1, A_2, and A_3, respectively

$\bar{y}_{p1}$, $\bar{y}_{p2}$ = vertical distance from water surface to center of gravity of A_{p1} and A_{p3}, respectively

Q = discharge

g = gravitational acceleration

(c) The three parts of the momentum equation represent the total momentum flux in the constriction expressed in terms of the channel properties and flow depths upstream, within and downstream of the constricted section, respectively. If each part of this equation is plotted as a function of the water depth, three curves are obtained, representing the total momentum flux in the constriction for various depths at each location. The desired solutions (water depths) are then readily available for any class of flow. If the water surface profile has been computed to the section at the downstream end of the pier, as is the usual case for subcritical flow, then the downstream depth is known. If the momentum flux for the constriction based on this downstream depth is greater than the momentum flux for the constriction based on critical depth, and the downstream depth is above critical depth, the flow is Class A, and the upstream depth is determined by the use of Yarnell's energy equation since the momentum method does not take into account an exit loss. The depth within the constricted section is determined by solving for the depth of flow which will provide a momentum flux equal to the downstream momentum flux. If the downstream momentum flux is less than the momentum flux for the constriction at critical depth, and the downstream depth is above critical, the flow is Class B, and the water surface elevation in the constriction is at critical depth. A new downstream depth (below critical) and the upstream depth (above critical) can be determined by finding the depths whose corresponding momentum fluxes equal the momentum flux at the constriction for critical depth. If the upstream depth is known, as is usually true for supercritical flow, and the momentum flux for the constricted section based on the upstream depth is greater than the momentum flux for the constricted section at critical depth, and the upstream depth is less than critical, the flow is Class C, and the downstream depth and the depth within the bridge section are found by determining depths corresponding to a momentum flux in the constriction based on the upstream depth. If, however, the computed momentum flux for the constricted section based on the upstream depth is less than the momentum flux for the constricted section at critical depth, the flow is Class B and the upstream depth is the depth (above critical) corresponding to the momentum flux for the constricted section at critical depth. The water surface profile must be recomputed with the upstream depth thus found as a control depth and proceeding in an upstream direction. The downstream depth (less than critical) is determined by finding the depth corresponding to the momentum flux for the constricted section at critical depth. The downstream depth thus found is used as a control depth to continue water surface computation in the downstream direction as far as downstream flow conditions permit.

(5) Weir flow is computed by the weir equation:

$Q = CLH^{3/2}$ where,

C = coefficient of discharge (see exhibit 2)

L = effective length of weir controlling flow

H = difference between the energy grade line elevation and the roadway crest elevation

Q = total flow over the weir

The approach velocity is included by using the energy grade line elevation in lieu of the upstream water surface elevation for computing the head, H. The coefficient of discharge "C" should not be greater than 3.1 for critical depth control, and in actual practice should be around 2.5 to allow for losses caused by bridge railings, etc. Where submergence by tailwater exists the coefficient "C" is reduced by the computer program according to the method indicated in reference (c). The total flow, Q, is computed by dividing the weir flow into subareas, computing L, H and Q for each subarea and summing all subareas.

(6) Pressure flow computations use the orifice flow equation of U. S. Army Engineering Manual 1110-2-1602, "Hydraulic Design of Reservoir Outlet Structures", August 1963 (reference e):

$Q = A\sqrt{\frac{2gH}{K}}$ where,

H = difference between the energy gradient elevation upstream and tailwater elevation downstream

K = total loss coefficient (see exhibit 2)

A = area of the orifice

g = gravitational acceleration

Q = total orifice flow

The total loss coefficient K, representing losses between the cross sections immediately upstream and downstream of the bridge, is equal to the sum of loss coefficients for intake, intermediate piers, friction, exit and other minor losses. See exhibit 2 for values of the loss coefficients.

(7) Often combinations of these three basic types of flow occur. In these cases a trial and error procedure is used with the equations just described to determine the amount of each type of flow. The procedure consists of assuming energy elevations and computing the total discharge until the computed discharge equals, within one percent, the discharge desired.

(8) To use the special bridge routine, variable IBRID on card X2 is set equal to 1. Variables on card SB (Special Bridge) specifiy bridge geometry and coefficients for the weir and orifice equations. Where the length of roadway for the weir equation is assumed constant for any depth of flow, variable RDLEN is set equal to that length. In cases where the length varies with depth it is necessary to input a table of roadway stations and elevations on card BT. In this case RDLEN is left blank. For some structures the user may desire to input a previously computed or estimated change in water surface elevation in which case the change is entered as variable BLOSS on card X2. When BLOSS is specified, no computations are performed for structure loss and the value entered for BLOSS is simply added to the water surface elevation for the previous cross section.

(9) Losses through culverts are handled in the same way as bridges where the culvert top (BT cards) and bottom elevation (GR cards) must be at the same horizontal stations.

(10) The special bridge routine can be used for any bridge but should be used for trapezoidal bridges with piers where low flow occurs, for pressure flow through circular or arch culverts, and whenever flow passes through critical when going through a structure. The computer program will automatically shift from the special bridge routine to the normal bridge routine when there are no piers and low flow controls.

(11) Examples of input preparation for a bridge and a culvert are shown in exhibits 5 and 6. Test problems F, G, K, L, M, N, O, P, Q, R, and S of exhibit 8 involve bridges.

q. Cross Section Plot. Plots on the printer of any or all of the river cross sections to any scale may be requested by using cards J2 and X1. If all cross sections are to be plotted, set variable IPLOT on card J2 equal to 1 or 10. If only certain cross sections are desired, IPLOT on card J2 should be left blank and variable IPLOT on card X1 set equal to 1 or 10 for each individual cross section to be plotted. Vertical and horizontal scales of the plot may be specified constant for all cross sections in the job by using variables XSECV and XSECH on card J2. If the scale is not specified, the largest scale which is a multiple of 1, 2 or 5 that produces three pages of output or less will be used. For some deep river cross sections, flow may occupy only a small portion of the total cross section. In this case it may be desirable to enlarge the scale and to print only the cross section points up to the water surface elevation. This may be done by using a value of 10 for IPLOT instead of 1.

r. Profile Plot. This plot includes not only the water surface elevation, but the critical water surface elevation, energy grade line, channel invert, left and right bank elevations, and the maximum elevation of the cross section for which hydraulic properties can be computed. The vertical scale of the profile may be determined by the user using the variable PRFVS (which allows breaking the profile before the plot runs off the sheet) or by the computer (no break in the profile) if left blank. Profiles are plotted automatically for jobs using more than five cross sections. Profile plots may be suppressed by inputting a negative value for PRFVS.

s. Program Trace.

(1) It is sometimes useful to print out important variables as they are computed by the program to aid in checking, debugging and understanding the program. Two program traces are available for this purpose. The major trace prints values of variables used in the following computations:

(a) Interpolated cross sections

(b) Manning's "n" from known water surface elevations

(c) Computed water surface elevation

(d) Weir flow

(e) Critical water surface elevation

(2) The minor trace prints values of variables used in the computation of the hydraulic properties of each subarea of a cross section.

(3) ITRACE on cards J2 and X2 are used to specify the desired trace. The major trace may be called separately, ITRACE = 1, or in combination with the minor trace, ITRACE = 10. If all cross sections are to be traced, card J2 is used. If only individual cross sections are to be traced, card X2 is used.

5. INPUT

a. General. The various types of cards used for input (see exhibits 10 and 11) are identified by two characters in card columns 1 and 2. These characters are read by the computer to identify the card and corresponding variables. Exhibit 10 contains a description of each card type. Since some cards have similar purposes, it is helpful to discuss them together.

b. Data Comment Cards. These cards are optional and are used to print out description of cross sections in the data.

c. 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. Card columns 9-32 on the third title card (card T3) are reserved for the river name, which will be printed to title the cross section and profile plots.

d. Job Cards - J1, J2, J3, & J4. These cards are used to specify starting conditions, i.e., Q, water surface elevation, direction of flow, and various options for each job. Card J2, J3 and J4 are used only when the options or variables on the card apply. Cards J1 and J2 are used for each profile while cards J3 and J4 are used only on the first profile in a multiple profile run but apply to all.

e. Change Cards - NC, QT, NH, NV, CI, & ET. Card NC is required at the start of a job to initialize Manning's "n" values, and expansion and contraction coefficients. It may also be used to change these values at any cross section within a job. When the initial values are changed, they remain changed for the remainder of the job unless another change card is entered. Cards QT, NH, NV, CI and ET are also used to change starting conditions within a job. When the starting conditions are changed, the new value is used for all subsequent cross sections unless another card is used to make another change. Each change begins at the next cross section described by card X1 except for the CI card which is placed between the X1 and GR cards where the change occurs.

f. Cross Section Cards - X1, X2, X3, X4, & GR. Cards X1 and GR are required for each cross section unless NPROF on card J2 is 2 or greater, in which case the cross section data read for the previous job would be used. Cards X2, X3 and X4 provide additional options that apply to the current cross section and can be used or omitted as desired. The purpose of these cross section cards is to completely describe each river cross section which is representative of the reach, and to specify program options for that cross section.

g. Bridge Cards - SB & BT. Card SB is required whenever the special bridge routine is used (IBRID = 1 on card X2). Card BT is included when stations and elevations of the top of roadway and low chord are to be read for either the normal or special bridge routines. The GR cards before and after Card SB must describe the constricted cross sections (effective section should be changed where weirflow occurs, see exhibit 3) immediately adjacent to the bridge to account for transition losses between the river cross section and the bridge. The special bridge routine computes only the losses through the bridge.

h. End of Job Card - EJ. Each job that contains any of the cards NC through GR must be ended with an end of job card, which signifies the end of input data.

i. End of Run Card - ER. Following the last card (EJ or J2) of the last job, 3 blank cards and card ER should be included. When card ER is read, control is transferred from the program by ending on a STOP.

j. Single Job. The minimum required cards for a single job using one cross section would be cards T1, T2, T3, J1, NC, X1, GR, EJ, 3 blanks and ER. The other cards are optional and would only be included if they applied.

k. Multiple Jobs. Where several jobs are to be computed during the same run (stacked jobs), the same cards are required as for a single run, except that the card following card EJ would be card T1 for the next job, and so on. Where it is desired to use the same cross sections for other jobs, variable NPROF on card J2 would be used. In this case the only cards required would be cards T1, T2, T3, J1, and J2. This option could only be used after the cross sections have been read in on the first job.

l. Card Format. Each data card is layed out in ten fields of eight columns each. One variable is used for each field except the first field, where the first two card columns are used for the card identification characters. The format specification for each data card is A2, F6.0, and 9F8.0. If decimal points are not punched in the data, all numbers must be right justified within the field. Where the user desires to punch a decimal point it may appear anywhere within the field. All blank fields are read as zeros. Minus one (-1) and plus one (1) are used in the program to specify certain program options. Any number without a sign is considered positive.

m. Tapes. All data cards are read at the beginning of the program and stored on tape 6. The tape is then rewound and the data cards are read from tape 6 individually. Tape 7 is used to store the plotted cross sections and tape 8 is used to store information used for plotting the profile. Tape 9 is used to store comment card for later printout.

6. OUTPUT

a. Cross Section Data. The first three lines of the output is the job description contained on the three title cards. Following the titles, input data on cards J1 and J2, J3, J4 (if used) are printed. The next output is four lines of variable names used to identify the output data for each cross section. A description of each variable is summarized in exhibit 9. Four lines of corresponding data follow the four lines of variables. When the normal or special bridge routines are used, a note will be printed identifying the routine, together with variable names applicable to the bridge section. These variable names are also described in exhibit 9. Following variable names for the bridge section is the corresponding bridge data. When data for the last cross section has been printed, a plot of the profile is printed.

b. Special Notes. Special notes are printed at various locations in the output to inform the user of various assumptions or options that have been used during the computation. These notes are summarized in exhibit 7.

c. Summary Data. When several jobs use the same cross section data (NPROF is equal to or greater than 2), summary data is printed to aid in comparing differences. Also differences between the water surface elevations are printed out to facilitate checking the answers. Negative differences point out trouble areas where the discharges are in increasing order.

d. Tapes. Normal output is on the printer. Additional output for the cross section plot is from tape 7.

7. EXAMPLE PROBLEMS

Listings of input and output data for several example problems are shown as exhibit 8.

8. UNITS

Water surface profiles may be computed using either the English or Metric system. English units are feet, square feet and cubic feet per second (cfs), where as the Metric system calls for meters, square meters, and cubic meters per second (cms). The only constants changed in the program are the constant in Manning's formula and the gravitational acceleration. Coefficients for computing losses through bridges and transitions are dimensionless. The only exception is in the weir flow equation, $Q = CLH^{3/2}$. The discharge coefficient "C" is a function of the square root of the gravitational acceleration. Since "C" is read as variable COFQ on card SB it may be input as a metric coefficient. In English units "C" ranges from 2.5 to 3.1. For Metric units a comparable range would be 1.39 to 1.72. Table 1 below summarizes the conversion used between English and Metric units.

TABLE 1

ITEM	ENGLISH	METRIC
Length Conversion	3.28 feet	1 meter
Area Conversion	10.76 square feet	1 square meter
	1 acre	4046.86 square meter
Flow Conversion	35.31 cubic ft/sec	1 cubic meter/second
Manning's Constant	1.49	1.00
Gravitational Acceleration (g)	32.2 ft/sec^2	9.82 m/sec^2
Coefficient "C" in Weir Formula	2.5 to 3.1	1.39 to 1.72
Coefficient of Contraction	.1 to .3	.1 to .3
Coefficient of Expansion	.3 to .5	.3 to .5

9. SUPPLEMENTAL MATERIAL

The following supporting publications and illustrations are available from HEC for computer program HEC-2, Water Surface Profiles:

a. HEC-2, Water Surface Profiles, Programmers Manual, 1971.

b. HEC Training Document, Water Surface Profiles (1969).

c. HEC Technical Paper #11, Survey of Programs for Water Surface Profiles (1968) by Bill S. Eichert. (Published in the Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY 2, February 1970.)

d. HEC Technical Paper #20, Computer Determination of Flow Through Bridges (1970) by Bill S. Eichert and John Peters. (Published in the Journal of the Hydraulics Division, ASCE, Vol. 96, No. HY7, July.)

e. "Backwater Curves in River Channels", Engineering Manual 1110-2-1409, U. S. Army Corps of Engineers, 7 December 1959.

f. Examples of Input Requirements for HEC-2.

g. Examples of Input Requirements for HEC-2 Normal Bridge.

10. REFERENCES

a. Eichert, Bill S., "Critical Water Surface by Minimum Specific Energy Using the Parabolic Method", Hydrologic Engineering Center, U. S. Army Corps of Engineers.

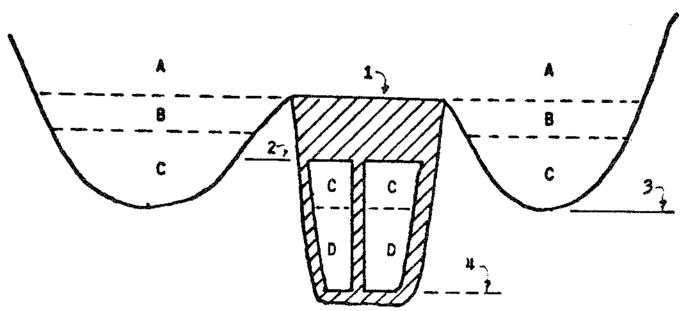
b. Koch-Carstanjen, "Von der Bewegung des Wassers und Den Dabei Auftretenden Kraften, Hydrodynamik", Berlin, 1926. A partial translation appears in appendix I, "Report on Engineering Aspects of Flood of March 1938," U. S. Engineer Office, Los Angeles, May 1939.

c. "Hydraulic Design of Spillways", Engineering Manual 1110-2-1603, U. S. Army Corps of Engineers, 31 March 1965, Plate 33.

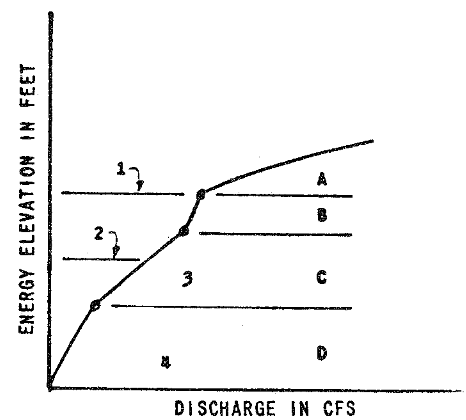
d. "Backwater Curves in River Channels", Engineering Manual 1110-2-1409, U. S. Army Corps of Engineers, 7 December 1959.

e. "Hydraulic Design of Reservoir Outlet Structures", Engineering Manual 1110-2-1602, U. S. Army Corps of Engineers, 1 August 1963.

f. "Evaluating Friction Loss in the Standard Step Method," William A. Thomas and John C. Peters.



BRIDGE CROSS SECTION



BRIDGE RATING CURVE

ELEVATIONS

1 Top of Roadway

2 Low Chord

3 Roadway Approach

4 Channel Invert

FLOW CONDITION

A - Combined pressure under bridge, weir in over banks, weir over bridge

B - Combined pressure under bridge, weir in overbanks

C - Combined low flow under bridge, weir in overbanks

D - Low flow under bridge

ILLUSTRATION OF BRIDGE FLOW TYPES

EXHIBIT 1

EXHIBIT 2

LOSS COEFFICIENTS

I. Pier Shape Coefficient, "K"

For use in Yarnell's energy equation for Class A flow

$$H_3 = 2K\ (K + 10\omega - 0.6)(\alpha + 15\alpha^4)\ V_3^{\ 2}/2g$$

Pier Shape	K
Semicircular nose and tail	0.90
Twin - Cylinder piers with connecting diaphragm	0.95
Twin - Cylinder piers without diaphragm	1.05
90° trangular nose and tail	1.05
Square nose and tail	1.25

II. Loss Coefficient, "K"

This coefficient is used in the orifice flow equation, $Q = A\sqrt{2g\ H/K}$ and is equal to the sum of the loss coefficients, k, applicable at the structure. Shown below are typical values for a bridge.

Description	k
Intake	.10
Intermediate piers	.05
Friction	k_f
Exit loss	1.0
Total =	$1.15 + k_f$

The loss coefficient for friction, k_f, should be computed using Manning's equation where $k_f = \dfrac{29.1\ n^2 L}{R^{4/3}}$ (English) or $\dfrac{19.6\ n^2 L}{R^{4/3}}$ (Metric).

Multiple Culverts:

$$Q = \sqrt{2gH} \cdot AT \sqrt{1/K_{equiv}}$$, where AT = Total Area

$$K_{equiv} = \frac{AT^2}{\left(\Sigma \sqrt{\frac{A_i}{K_i}}\right)^2}$$

III. Coefficient of Discharge, "C"

Under free flow conditions (discharge independent of tailwater) the coefficient of discharge, "C", ranges from 2.5 to 3.1 (1.39 - 1.72 Metric) depending primarily upon the gross head of the crest ("C" increases with head) and resistance to flow caused by obstructions such as bridge railings, curbs, and other barriers. When submerged flow (discharge affected by tailwater) occurs the coefficient "C" should be reduced. This is done automatically by the computer program using Waterways Experiment Station Design Chart 111-4.

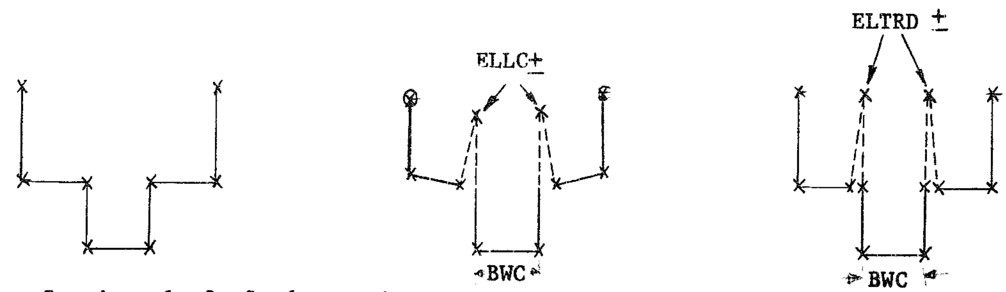
IV. Expansion and Contraction Coefficients

These coefficients are used to compute losses caused by changes in the river cross sections. For long gradual transitions the coefficients are small. For short abrupt transitions they are large. The transition loss is computed as the coefficient times the difference in velocity head between cross sections.

	Coefficient	
	Expansion	Contraction
No transition	0.0	0.0
Gradual transitions	0.3	0.1
Abrupt transitions	0.8	0.6

REQUIRED CROSS SECTIONS FOR SPECIAL BRIDGE ROUTINE

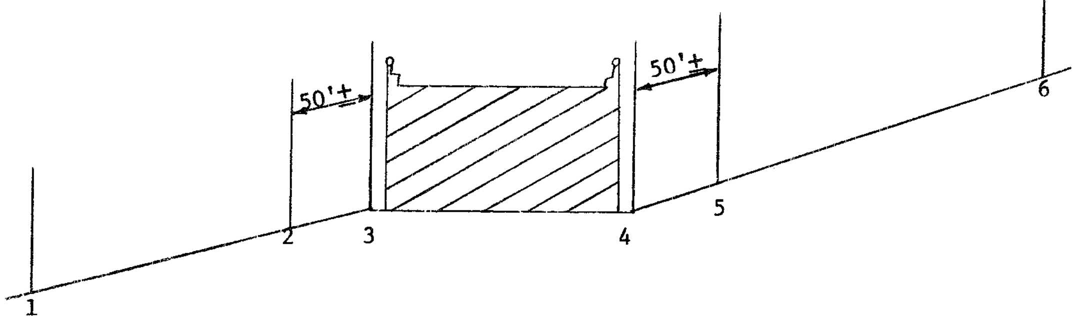
The cross sections below show the points required on cards GR when using the special bridge routine. Cross sections 1, 2, 5, 6 are taken in the river channel upstream and downstream from the bridge and should represent the full cross section unaffected by the bridge. Cross section 3 is adjacent to the bridge on the downstream side and includes the elevations and stations of an artificial levee whose top is about equal to the low chord elevation (ELLC). The points defining the artificial levee can be omitted if the elevations where the effective area changes are shown on the X3 card (eighth and ninth fields), thus cross section 3 could resemble cross sections 1 and 2. Cross section 4 is adjacent to the bridge on the upstream side and includes the elevation and station of an artificial levee (or an X3 card with elevations in eighth and ninth fields) whose top elevation is approximately equal to the top of roadway elevation (ELTRD). No cross section is provided through the bridge, but data describing the bridge are entered on cards SB, X2 and BT (optional). Therefore, when using the special bridge routine cross sections 3 and 4 should describe the channel cross section (excluding any roadway embankment) immediately downstream and upstream from the bridge. The top of roadway embankment should be described on card X2 or BT.



Cross Sections 1, 2, 5, 6
Full natural river cross sections

Cross Section 3
Immediately downstream of bridge embankment

Cross Section 4
Immediately upstream of bridge embankment

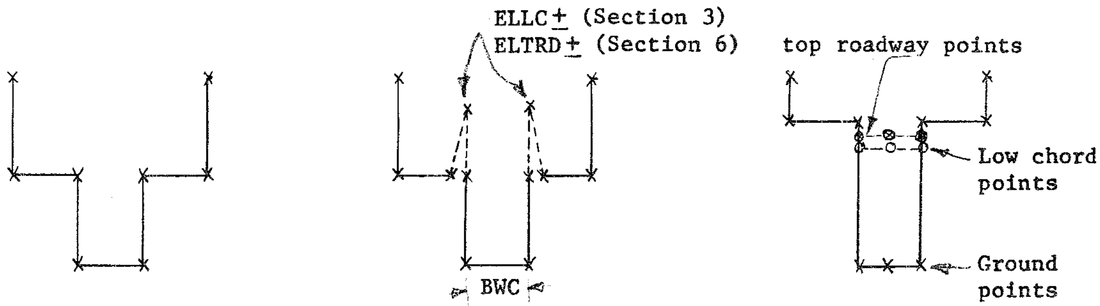


The artificial levees (or the elevations on the X3 card) are included in the cross section points in order to confine the flow to the channel area when the water flows under the bridge low chord and to allow the use of the overbank flow area for flows over the road. The left and right bank stations must be equal to stations at the top of the artificial levees. Variable IEARA on card X3 must equal 10 for this condition.

EXHIBIT 4

REQUIRED CROSS SECTIONS FOR NORMAL BRIDGE ROUTINE*

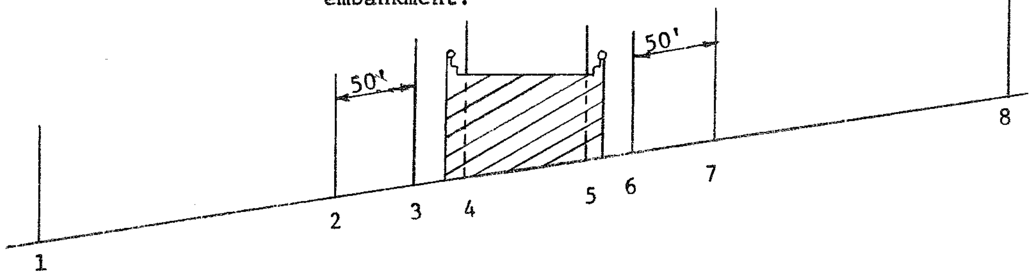
The cross sections below show the points required on cards GR when using the normal bridge routine. Cross sections 1, 2, 7, 8 describe the natural river channel. Cross sections 3 and 6 are adjacent to the bridge on the downstream and upstream sides respectively and include elevations and stations of an artificial levee whose top is approximately equal to the low chord elevation (ELLC) and top of roadway elevation (ELTRD) respectively. The artificial levee is included in the cross section points to confine the flow to the channel area (bridge area) when the water flows under the low chord, and to allow the overbank area to be used for flows over the roadway. The left and right bank stations must be equal to the station at the top of the artificial levees.



Cross Sections 1, 2, 7, 8
Full natural cross sections

Cross Sections 3 and 6
Immediately downstream and upstream of bridge embankment.

Cross Sections 4 and 5
within bridge



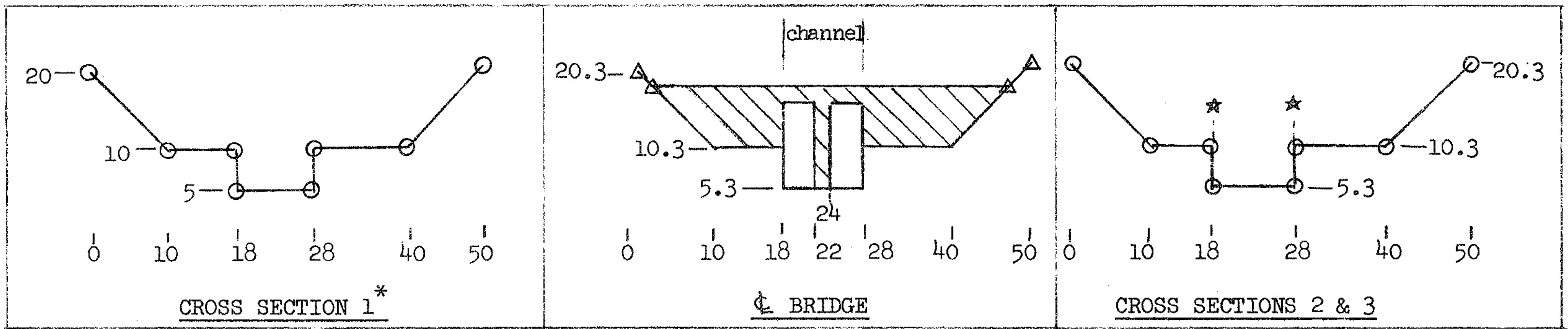
Variable IEARA on card X3 must equal 10 for cross sections 3 and 6. Cross sections 4 and 5 are within the bridge and BT (or X2) cards are used to describe the low chord and top or roadway points. All stations used on the BT cards should also appear on the GR cards.

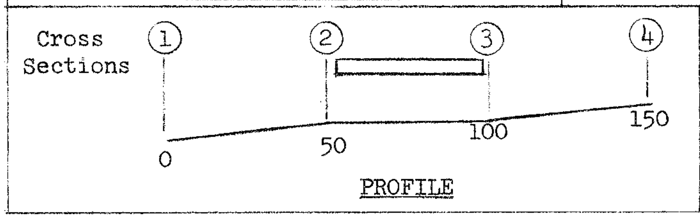
---

*The points defining the artificial levee can be omitted if the elevations where the effective area changes are shown on the X3 cards (eighth and ninth fields). Thus cross sections 3 and 6 could resemble cross sections 2 and 7.

EXAMPLE INPUT PREPARATION

FOR A BRIDGE





NOTES

* Cross section 4 is .6 ft above no. 1

⊙ GR Card points

△ BT Card - top of roadway elevation

★ Top of artificial levees

	1	2	3	4	5	6	7	8	9	10
T1		EXAMPLE INPUT PREPARATIØN - SPECIAL BRIDGE RØUTINE								
T2		TWØ FØØT BRIDGE PIER								
T3		ARTIFICIAL LEVEES BY X3 CARD								
J1	-1			0	0		-1	700	14	
NC	.043	.043	.043	.3	.5					
X1	1	8	18	28	0	0	0			
GR	20	0	10	10	10	18	5	18	5	28
GR	10	28	10	40	20	50				
X1	2	0	0	0	50	50	50	1	.3	
X3	10							16	16	
SB	.9	1.5	2.5	0	10	2	85.6	0		
X1	3	0	0	0	50	50	50	1	0	
X2			1	16	18	0				
X3	10							18	18	
BT	4	0	20.3		2.3	18		47.3	18	
BT	50	20.3								
X1	4	0	0	0	50	50	50	1	3	
EJ										

GENERAL PURPOSE DATA FORM

(8 COLUMN FIELDS)

PROGRAM HEC 2 WATER SURFACE PROFILES DATE

REQUESTED BY PREPARED BY BSE CHECKED BY PAGE OF

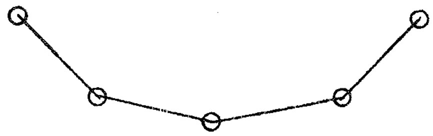
Card	1	2	3	4	5	6	7	8	9	10
T1		EXAMPLE INPUT PREPARATIØN - NØRMAL BRIDGE RØUTINE - HEC 2								
T2										
T3										
J1										
NC										
X1	1		SAME AS FOR SPECIAL BRIDGE ROUTINE							
GR										
GR										
X1	2									
X3	10									
NC	.015	.015	.015	.3	.5					
X1	2.1	12	18	28	1	1	1			
X2				16	18					
GR	20.3	0	18	2.3	18	18	5.3	18	5.3	22
GR	18	22	18	24	5.3	24	5.3	28	18	28
GR	18	47.3	20.3	50						
X1	2.9	0	0	0	48	48	48	1	0	
X2				16	18					
NC	.043	.043	.043	.3	.5					
X1	3	8	18	20	1	1	1	1	0	
X3	10							18	18	
GR	20.3	0	10.3	10	10.3	18	5.3	18	5.3	28
GR	10.3	28	10.3	40	20.3	50				
X1	4	0						1	.3	
EJ										

SPK Form 321
1 Jul 66

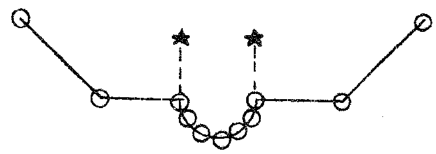
(Previous editions are obsolete)

EXAMPLE INPUT PREPARATION

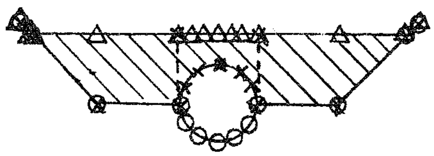
FOR A CULVERT



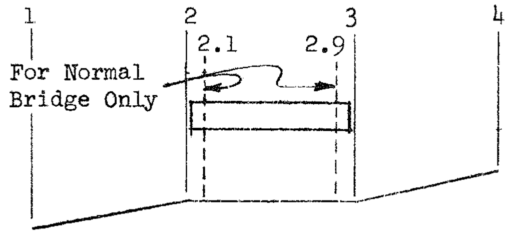
CROSS SECTIONS 1 & 4



CROSS SECTION 2



CROSS SECTION 3*



PROFILE

*Note: Also sections 2.1 and 2.9 for normal bridge routine.

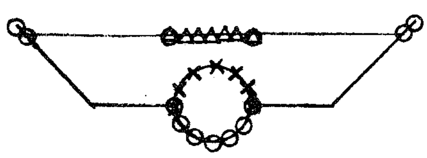
LEGEND

- ⊙ GR Card points
- × BT Card - low chord elevation
- △ BT Card - top of roadway elevation
- ★ Top of artificial levees

SPECIAL BRIDGE ROUTINE (and Normal Bridge Routine for Low Flow)				
	CARDS	FIELD 1	FIELD 2	COMMENTS
Cross Section	T1			
	T2			
	T3			
	J1			
	NC			
#1	X1	1	5	5 Points
	GR			
#2	X1	2	11	11 Points
	X3	10		Use 8th and 9th fields
	GR			
	GR			
	GR			
	SB			
#3	X1	3	0	Use previous X sect's GR Cards
	X2			**Use 4th and 5th fields**
	X3	10		Use 8th and 9th fields
	X4	2		Points at top of roadway
	BT	13		Thirteen points
	BT			
	BT			
	BT			
#4	X1	4	5	5 Points
	GR			
	EJ			

NORMAL BRIDGE ROUTINE (only)				
	CARD	FIELD 1	FIELD 2	COMMENTS
Cross Sections	T1			
	T2			
	T3			
	J1			
	NC			
#1	X1	1	5	Same as Special Bridge
	GR			
#2	X1	2	11	
	X3	10		
	GR			
	GR			
	GR			
	NC			Use n for concrete
#2.1	X1	2.1	0	Use previous GR Cards
	X4	2		Points at top roadway
	BT	13		
	BT			Same as Special Bridge
	BT			
	BT			
#2.9	X1	2.9	0	Use previous GR Cards
	X2			Repeat Bridge
	NC			Change n back
#3	X1	3	0	Use previous GR Cards
	X3	10		Use 8th and 9th fields
#4	X1	4	5	
	GR			Same as Special Bridge
	EJ			

ALTERNATE CROSS SECTION
FOR NORMAL BRIDGE (ONLY)



No. of GR Card points = 13
No. of BT Card points = 7

EXHIBIT 7

SPECIAL NOTES

This exhibit explains special notes which are not explained as part of the normal output. The special notes should be carefully reviewed to assure an accurate profile. If these notes are not satisfactorily explained, the job should be rerun obtaining intermediate printout (ITRACE = 1). If the reason is still not evident, please contact The Hydrologic Engineering Center.

Statement Number	Notes and Remarks
1340	CARD NOT RECOGNIZED. First two columns of input card read did not correspond to any of the standard alphabetic characters used to identify cards.
1362	XKOR INCREASED TO 1.2. The orifice coefficient was zero or minus and was therefore changed to 1.2 since 1.0 is the minimum value.
1365	SB CARD, BWP = 0. On the special bridge routine card SB, the pier width is omitted. If there is no intermediate pier this is satisfactory.
1366	SB CARD, BAREA = 0. On the special bridge routine card SB, the area of the bridge when flowing full is omitted and therefore this job has been terminated.
1400	CCHV =, CEHV = . A change in contraction and expansion losses have been made.
1415	INQ EXCEEDS NUMQ. The field of the QT cards to be used for the current Q, specified by variable INQ, contained no flow data.
1445	Q EXCEEDS 19. The number of discharges on card QT exceeded the maximum allowable number of 19.
1452	NV CARDS EXCEED 4. The number of items specified on the NV card exceeded the allowable.
1455	NV CARD USED. A table of Manning's "n" value and corresponding elevation was used in the channel.
1481	EL(N) DON'T INCREASE. The elevations on the NV cards must increase when the channel roughness is varied with elevation and therefore the job has been terminated.

Statement Number	Notes and Remarks
1490	NH CARD USED. Manning's "n" value varied horizontally in accordance with values on NH card.
1518	NH CARD STATIONS NOT INCREASING. The stations on the NH card specifying changes in Manning's roughness must increase and therefore the job has been terminated.
1525	NH VALUES EXCEED 20. Manning's roughness coefficient specified on the NH card exceeded the allowable number.
1535	Q = 0. The discharge was not specified on the J1 card.
1537	START TRIB COMP. Since a negative section number was used, the profile is to be computed on a tributary starting with the water surface elevation which was computed for the same section number on the main stem.
1553	STARTING NC CARD OMITTED. The starting values on the NC card were not given. The roughness values assumed were very small (.00001).
1645	INT SEC ADDED BY RAISING SEC X, Y, FT AND MULTIPLYING BY Z. An intermediate cross section was calculated by the computer and inserted between two cross sections specified by input data. This interpolated cross section was calculated by all horizontal stations, and hence the cross sectional area, by Y.
1707	STCHL OR X, GREATER THAN Y. The station of the left bank was given larger than the station of the right bank and therefore was assumed equal to the first station.
1807	BT CARDS EXCEED 50 PTS. Number of points describing the bridge (Card BT) exceeded allowable.
1857	BT CARD, STA DON'T INCREASE. The roadway station on the BT card should increase. Data should be corrected.
1860	SLCEL OF X, EXCEEDS RDEL OF Y. The low chord elevation of X exceeds the corresponding value of the top of roadway Y. Data should be corrected.
1912	GR CARDS, STATIONS CON'T INCREASE. The ground profile points don't increase in horizontal station. The data should be corrected.
2020	NUMBER EL, STA, PTS EXCEED 100. The number of points used to describe the ground profile for the current cross section exceeded the allowable.

Statement Number	Notes and Remarks
2096	WSEL NOT GIVEN, AVG OR MAX, MIN USED. The starting water surface elevation wasn't given and therefore has been assumed as halfway between the maximum and minimum elevation in the cross section.
2725	WSEL EXCEEDS LIMITS OF TABLE FOR MANNING'S "n". An assumed water surface elevation fell outside the elevation limits which specified Manning's "n" values on NV cards. Table values were extrapolated for "n" value.
2620	NO IMPROVEMENT MADE TO THIS SECTION. The subroutine CHIMP has been requested by the CF card and the excavation described will not cut the existing cross section.
2750	NUMBER OF COMPUTED POINTS EXCEED 100. The number of points added by subroutine CHIMP have caused the total to exceed 100. Reduce the number of points on the GR card.
3073	NEGATIVE SLOPE, WSEL = , EG = , PCWSE = , XEG = , WLEN = RESTART COMPUTATIONS AT SECNO = , USING N-VALUES COMPUTED FOR SECNP = . A negative slope of the energy gradient has been computed while trying to calculate roughness values that will exactly duplicate the observed high water mark. Due to this condition, the computations will start over again using the previous section's roughness values.
3235	SLOPE TOO STEEP, EXCEEDS X. The computed slope of the energy grade line exceeded X, and critical depth has probably been crossed. If this cross section is a bridge, the special bridge routine should be used in lieu of the normal bridge.
3265	DIVIDED FLOW. The area below the computed water surface elevation is divided into two or more segments by high ground. If this condition occurs for three or more cross sections consecutively, then separate profiles should be run up each leg of the divided flow as the water surfaces are not necessarily the same elevation across the cross section.
3280	CROSS SECTION EXTENDED X FEET. The cross sections ends have been projected vertically 50 feet in order to calculate the hydraulic properties of the cross section. Exactly X feet of this extension were used. If this vertical assumption could produce unreasonable results, the input data should be corrected.

Statement Number	Notes and Remarks
3301	HV CHANGED MORE THAN HVINS. The differences between velocity heads computed for the current and previous cross sections exceeded the allowable specified by input as HVINS (or .5 feet if HVINS = -1).
3370	NORMAL BRIDGE, NRD = X, MIN ELTRD = Y, MAX ELLC = Z. The normal bridge routine was used for this cross section. The number of point used in describing the bridge deck are given as X, the minimum top of roadway elevation is Y and the maximum low chord elevation is Z.
3377	BLOSS READ IN. The diffenence in water surface elevation between the previous and current cross section was given by input data.
3420	BRIDGE W.S. = X, BRIDGE VELOCITY = Y. The water surface elevation under the bridge is specified by X and the velocity through the bridge is Y.
3470	ENCROACHMENT STATIONS = X, Y. The left bank encroachment station is specified by X and the right bank encroachment station is specified by Y. Only the flow area between X and Y is considered effective.
3495	OVERBANK AREA ASSUMED NONEFFECTIVE, XLBEL = X, RBEL = Y. The effective area option (IEARA) was used and the computed water surface elevation was below at least one of the bank elevations specified by X and Y and therefore this flow area was assumed noneffective.
3685	20 TRIALS USED WSEL, CWSEL. The number of trials in balancing the assumed and computed water surface elevations for the normal step procedure of backwater has exceeded 20. Check the assumed water elevation for reasonableness.
3693	PROBABLE MINIMUM SPECIFIC ENERGY. This note is similar to 7185 except it is not certain (only probable), that critical depth has been crossed. It is known that no depth of flow assumed in any of the trials produced an energy grade line elevation as high as the minimum energy at critical depth.
3710	ESEL ASSUMED BASED ON MIN DIFF =.1. At the conclusion of 30 trials the assumed water surface elevation will be made equal to .1 of a foot above the elevation that came the closest to balancing. This condition usually occurs near the top of banks when IEARA = 10. Check results for reasonableness.

Statement Number	Notes and Remarks
3720	ASSUMED CRITICAL DEPTH. Critical depth has been assumed for this cross section. This assumption should be verified by inspection of channel properties. Additional cross sections may need to be inserted in order to preserve the assumption of gradually varying flow.
3790	DATA ERROR. JOB DUMPED. The computer detected an error in input and terminated that particular job (profile), but continued on with the next job of the input data.
3800	PREVIOUS ST GREATER THAN CURRENT. Either an input error caused the stations of the GR card to not increase or a programming error has been found.
3810	HT IS -. The height (HT), determined by subtracting the ground elevation from the assumed water surface elevation, has been found to be negative. Corrections for bridge deck (ELTRD - ELLC) used in normal bridge routine will have caused this note if any ELLC is greater than the corresponding ELTRD. If this is not the case a program error has been found, and a trace should be run to determine the source of the error.
3820	STA(N) GREATER STMAX. One of the stations of the points on the current ground profile cards (GR) was greater than the maximum station for this profile.
3830	AROB OR ALOB IS -. A negative area in the left or right overbank has been computed. A program error probably has been detected. A trace should be run.
3840	SECTION NOT HIGH ENOUGH. The computed water surface elevation exceeds the maximum specified on input cards, therefore, the cross section ends have been vertically raised 50 feet.
3875	SUMMARY PRINTOUT FOR MULTIPLE PROFILES.
3956	VOL NOT ON J3 CARD. The J3 and J4 cards have both been used. The J4 card requires that variable VOL and TIME be requested on the J3 card.
3959	TIME NOT ON J3 CARD. Same as note 3956.
3965	REACH OF - NOT EQUAL TO SECNO OF -. The J4 card has been used to specify routing reaches which must be equal to the section numbers (SECNO) on the first field of the X1 card. The section numbers must also be in increasing order.

Statement Number	Notes and Remarks
4020	80 TRIALS NOT ENOUGH FOR CRITICAL DEPTH. This note indicates a data error or program error has been detected. If no data error is detected, job should be rerun, with ITRACE equal to one, in order to obtain reason for failure of parabolic optimization process.
4575	CRITICAL DEPTH ASSUMED BELOW ELLC OF - EGLC = - EGC = - WSEL = -. Critical depth is being computed in a bridge section and the minimum energy below the low chord is less than the minimum energy above the top of the bridge.
5020	SPECIAL BRIDGE. The input has specified that the bridge routine to be used for this cross section is a special bridge routine.
5070	VARIABLE ELCHU OR ELCHD ON CARD SB NOT SPECIFIED. The elevations of the channel upstream and downstream of the bridge are not specified on input fields and have therefore been assumed equal to the previous cross sections minimum elevation.
5227	DOWNSTREAM ELEV IS X, NOT Y, HYDRAULIC JUMP OCCURS DOWNSTREAM. The upstream momentum is so great that the water downstream of the bridge is supercritical and not subcritical.
5920	UPSTREAM ELEVATION IS X NOT Y, NEW BACKWATER REQUIRED. Since supercritical flow was assumed by input and since the bridge obstruction drowns out the supercritical flow upstream of the bridge, new backwater is required, from the bridge upstream.
5470	ERROR DS DEPTH WRONG SIDE CRITICAL. The calculated depth in the low-flow routine was determined on the wrong side of critical depth. If this error occurs, a programming error has been discovered. Run with ITRACE = 1 and determine the cause.
6070	LOW FLOW BY NORMAL BRIDGE. When the pier width is specified as zero for the special bridge routine and when low flow controls, the friction loss for the bottom and sides of the channel are computed using the normal bridge routine instead of the special bridge routine.
6110	EGLWC OF X LESS THAN XEG OF Y. The energy gradient elevation for the controlling low flow is less than the previous cross section's energy gradient indicating negative losses. The energy gradient elevation for the current cross section is therefore assumed equal to the previous energy gradient (no loss) and the run has been continued.

Statement Number	Notes and Remarks
6400	TRIAL AND ERROR FOR CHANNEL Q FAILED. For the low flow and weir flow combination, the discharge through the channel must be determined. In trying to determine the discharge through the channel by an iterative process, the assumed and computed discharges do not agree in 50 trials. The allowable error which is specified in statement 6340, .3 of 1 percent is too severe for the computation or a programming inadequacy has been detected.
6790	20 TRIALS OF EG NOT ENOUGH. In determining the energy grade line elevation for a combination of weir flow and low flow or valance the discharge computed for an assumed energy grade line elevation with the actual discharge to be used in the water surface profile determination. When this condition occurs the job should be rerun using the trace feature and the cause of this failure determined.
6840	FLOW IS BY WEIR AND LOW FLOW. The minimum top of roadway in one or both overbank dips below the low chord over the bridge and the resulting water surface elevation, which is below the low chord over the bridge, was computed using Class A low flow under the bridge and weir flow in the low overbanks.
6870	D.S. ENERGY OF X HIGHER THAN COMPUTED ENERGY OF Y. The previous cross section's downstream energy grade line elevation of X is higher than the current cross section's computed energy grade line elevation of Y. The current energy grade line elevation was computed for a combination of weir and low flow or weir and pressure flow. The energy grade line elevation for this cross section has been assumed equal to the previous energy elevation in order to eliminate negative losses. The weir coefficients used apparently were too efficient.
7185	MIN SPECIFIC ENERGY. The computer determined that it was impossible to procede from the previous cross section to the current cross section without crossing critical depth and therefore, critical depth has been assumed for the current cross section. In other words, maximum losses cannot produce an energy elevation as high as the minimum energy at critical depth. If this note occurs for several consecutive cross sections, it is apparent that the wrong type of flow (IDIR) has been assumed for this segment of the profile. The cross section should be reversed, IDIR changed and the profile run.

Statement Number	Notes and Remarks
7230	SLOPE-AREA TRIALS EXCEED 100. In determining the starting water surface elevation using the slope of the energy grade line from input, 100 trials were not sufficient to balance the calculated discharge with the actual discharge (Q). If this condition occurs, an error in the input data or a programming error has been encountered. Rerun with trace feature if input data appears satisfactory.
8190	PLOTTED POINTS (BY PRIORITY). - - - ETC. This note gives the priority for plotting the values for the cross section. If two or more points are close enough together that a single space of the printer cannot distinguish between them then only the last point plotted will be seen on the output. For instance, the energy gradient elevation (E) will hide the water surface elevation (W) for very small velocity heads.
8560	XSEC POINT - , X, EL, ST - Y, Z. The subscript computed for the current point was too low or too high to be plotted and is therefore not shown on the cross section plot. The X indicates the type of point being plotted (X for ground point). The elevation and station of this point are printed out as Y and Z.
8930	RDST NOT ON GR CARD. The roadway station printed out here does not appear on the ground profile card (GR). For the normal bridge routine all stations on the BT card must also appear on the BR card. This note can be ignored for the special bridge routine.

EXHIBIT 8

TEST PROBLEMS

Test	Description	Page
A	Normal backwater - starting depth less than critical depth - 3 interpolated cross sections. North Buffalo Creek	3
B	N values vary by horizontal table (NH cards) - start at critical depth, GR cards omitted for cross section 150, cross section modified by (X1.8-X1.9). Discharge varied by X2 card for single profile, no interpolated cross sections.	5
C	N values vary with elevation in channel, NV card used. Davis Creek	6
D	Start by slope area method. Desired energy slope and estimated elevation given. Davis Creek	7
E	Supercritical flow profile - starting depth above critical, GR points from cross section 1180 repeated for cross sections 1380-1580, profile plot suppressed - change in velocity head fixed - Salt Lake City streams.	8
F	Flow through a circular culvert - 4 ft. diameter, 5 percent slope, supercritical flow - start at critical depth.	10
G	Special bridge routine - data for weir flow only (no X3 cards), input and output in metric units, no interpolated cross sections. North Buffalo Creek	12
H	Encroachment tests (1) encroachment width given, (2) stations given, (3) stations and elevations given, (4) encroachment width repeated from previous sections ENCFP (X3.3).	14
I	Channel improvement (subroutine CHIMP). 1st profile is natural (IBW-8), (BW-.01). Discharge read from 12th field (INQ) of QT cards. Catalpa Creek	15

Test	Description	Page
J	Second profile using channel improvement (IBW-0, BW-10). Summary printout for multiple profiles. Catalpa Creek	17
K	Special bridge routine - effective area option, two foot bridge piers, artificial levees by ELLEA and ELREA.	19
L	Special bridge - class A low flow controlling, rectangular channel, printout of input data. Flat Creek	21
M	Special bridge - class B low flow controlling, rectangular channel. Flat Creek	22
N	Special bridge - pressure flow controlling, rectangular channel. Flat Creek	23
O	Special bridge - weir and pressure flow controlling, top of roadway and low cord read from BT cards, cross sections plotted. Flat Creek	24
P	Special bridge - class C and B low flow controlling, supercritical flow, no interpolated cross sections, (2 bridge piers skewed), profile plotted. Upper Rio Hondo River	27
Q	Special bridge - class C low flow controlling, supercritical flow. Flat Creek	32
R	Special bridge - weir and low flow controlling, low bridge approaches for overbank (weir flow) from BT cards. Small Creek	34
S	Normal bridge routine - critical depth above top of bridge, roadway cross sections 27975 and 27997. Big Cottonwood Creek	36

```
*
T1      TEST A NORMAL BACKWATER-GIVEN STARTING DEPTH LESS THAN CRITICAL DEPTH-
T2      3 INTERPOLATED CROSS SECTIONS
T3      NORTH BUFFALO CREEK

J1  ICHECK     INQ       NINV      IDIR       STRT      METRIC    HVINS      Q        WSEL       FQ

       -1.       -0.       -0.       -0.   -.000000     -.00      -.0     7570.   674.000     -.000

NC          .100      .100      .050      .300      .400     -.000     -.000     -.000     -.000     -.000

X1       109.000     8.000   480.000   520.000     -.000     -.000     -.000     -.000     -.000     -.000
GR       690.000      .000   680.000   120.000   670.500   480.000   661.400   485.000   661.400   515.000
GR       670.500   520.000   680.000  1150.000   690.000  1330.000     -.000     -.000     -.000     -.000

X1       112.000    12.000   185.000   255.000  1520.000  1520.000  2100.000     -.000     -.000     -.000
GR       695.000      .000   693.000    20.000   686.700    70.000   676.800   135.000   675.500   185.000
GR       662.700   200.000   663.400   240.000   673.800   255.000   677.700   490.000   680.800   520.000
GR       687.100   570.000   695.000   670.000     -.000     -.000     -.000     -.000     -.000     -.000
EJ         -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                   *** PROFILE COMPUTATIONS ***
*INPUT DATA FOR EACH TEST PROBLEM IS PRINTED AHEAD OF THE PROFILE COMPUTATIONS.  THE PRINTING OF INPUT DATA IS ACHIEVED BY SPECIFYING -1
 FOR VARIABLE ICHECK (J1,1).

CCHV=     .300 CEHV=     .400

3720 ASSUMED CRITICAL DEPTH

    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

    109.00     12.90    674.30    674.30    674.00    676.24      1.95      .00       .00    670.50
     7570.      598.     5926.     1046.      273.      470.      478.       0.        0.    670.50
       .00      2.19     12.60      2.19      .100      .050      .100     .000    661.40    336.13
   .009234      -0.       -0.       -0.         0         7         1      .00    435.64    771.77


1645 INT SEC ADDED BY RAISING SEC    112.00,   -.975FT AND MULTIPLYING BY    .751


3301 HV CHANGED MORE THAN HVINS

      1.01     16.42    678.15       .00       .00    679.12       .97      2.59      .29    674.52
     7570.      210.     6207.     1153.      125.      714.      604.      14.       3.     672.82
       .02      1.68      8.69      1.91      .100      .050      .100     .053    661.72     89.89
   .003312      380.      525.      380.         3         0         1      .00    288.43    378.33


1645 INT SEC ADDED BY RAISING SEC      1.01,    .325FT AND MULTIPLYING BY    1.111

      1.02     17.79    679.84       .00       .00    680.34       .50      1.08      .14    674.85
     7570.      317.     5683.     1571.      218.      873.      960.      31.       6.     673.15
       .04      1.45      6.51      1.64      .100      .050      .100     .053    662.05     92.39
   .001582      380.      525.      380.         3         0         1      .00    338.73    431.13
```

1645 INT SEC ADDED BY RAISING SEC 1.02, .325FT AND MULTIPLYING BY 1.100

1.03	18.28	680.65	.00	.00	681.01	.36	.63	.04	675.17
7570.	351.	5527.	1692.	274.	991.	1175.	54.	10.	673.47
.07	1.28	5.58	1.44	.100	.050	.100	.053	662.37	98.62
.001080	380.	525.	380.	2	0	1	.00	379.51	478.14

1645 INT SEC ADDED BY RAISING SEC 1.03, .325FT AND MULTIPLYING BY 1.091

112.00	18.51	681.21	.00	.00	681.49	.29	.46	.02	675.50
7570.	364.	5467.	1739.	317.	1097.	1342.	80.	13.	673.80
.11	1.15	4.98	1.30	.100	.050	.100	.054	662.70	106.06
.000828	380.	525.	380.	2	0	1	.00	417.18	523.24

```
T1      TEST 8 N VALUES VARY BY HOR TABLE(NH CARDS)-START AT CRITICAL (J1.5)-
T2      GR CARDS OMITTED FOR XSEC 150,XSEC MODIFIED BY(X1.8-X1.9)
T3      DISCHARGE VARIED BY X2 CARD(X2.1) FOR SINGLE PROFILE-NO INTER XSEC(J1.7)

J1   ICHECK     INQ       NINV      IDIR       STRT      METRIC    HVINS      Q        WSEL       FQ

       -1.        -0.        -0.        -0. -1.000000     -.00      -1.0    12000.   110.000     -.000

NC        .015      .015      .015      .100      .300     -.000     -.000     -.000     -.000     -.000

X1     100.000     4.000   150.000   250.000     -.000     -.000     -.000     -.000     -.000     -.000
GR     149.500      .000    99.500   150.000    99.500   250.000   149.500   400.000     -.000     -.000
NC        .020      .020      .010     -.000     -.000     -.000     -.000     -.000     -.000     -.000

X1     150.000      .000      .000      .000    50.000    50.000    50.000      .900      .250     -.000
X2    5000.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000
NH       6.000      .010    20.000      .015    40.000      .030    60.000      .040    80.000      .015
NH      90.000      .010   100.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

X1     200.000    10.000      .000      .000    50.000    50.000    50.000     -.000     -.000     -.000
GR     115.000      .000   100.000      .000   100.000    25.000   100.000    40.000   100.000    60.000
GR     100.000    80.000   100.000    90.000   100.000   100.000   115.000   100.000   115.000   100.010
EJ       -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                   *** PROFILE COMPUTATIONS ***


3720 ASSUMED CRITICAL DEPTH


CCHV=    .100 CEHV=    .300
    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN     SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID    ENDST


   100.00      7.18    106.68    106.68    110.00    109.82      3.15       .00       .00     99.50
   12000.      695.    10611.      695.       77.      718.       77.        0.        0.     99.50
      .00      8.99     14.78      8.99      .015      .015      .015      .000     99.50    128.47
  .001608       -0.       -0.       -0.         0        13         1       .00    143.06    271.53


3301 HV CHANGED MORE THAN HVINS
   150.00      9.98    109.73       .00       .00    110.11       .37       .01       .28     99.75
    5000.      207.     4586.      207.      134.      898.      134.        1.        0.     99.75
      .00      1.54      5.11      1.54      .020      .010      .020      .010     99.75    108.07
  .000055       50.       50.       50.         3         0         1       .00    143.86    251.93

1490 NH CARD USED
   200.00      9.71    109.71       .00       .00    110.12       .41       .01       .01    115.00
    5000.        0.        0.     5000.        0.        0.      971.        2.        0.    100.00
      .01       .00       .00      5.15      .020      .010      .020      .010    100.00       .00
  .000251       50.       50.       50.         2         0         1       .00    100.00    100.00
```

```
T1       TEST C   -N VALUES VARY WITH ELEVATION IN CHANNEL-
T2       NV CARD USED
T3       DAVIS CREEK

J1  ICHECK      INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

       -1.       -0.       -0.       -0.  -.000000      -.00      -.0    5000.    65.000    -.000

NC        .050      .060      .030      .000      .000     -.000     -.000     -.000     -.000     -.000
NV       4.000      .010    40.000      .020    50.000      .030    60.000      .040    70.000     -.000

X1       1.000     8.000    50.000   200.000     -.000     -.000     -.000     -.000     -.000     -.000
GR     100.000      .000    50.000      .000    50.000    50.000    40.000   100.000    40.000   150.000
GR      50.000   200.000    50.000   250.000   100.000   250.000     -.000     -.000     -.000     -.000

X1       2.000      .000      .000      .000   100.000   100.000   100.000     1.000     2.000     -.000
EJ       -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                  *** PROFILE COMPUTATIONS ***


1455 NV CARD USED
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

     1.00     25.00     65.00       .00     65.00     65.02       .02       .00       .00     50.00
    5000.      447.     4180.      373.      750.     3250.      750.        0.        0.     50.00
      .00       .60      1.29       .50      .050      .035      .060      .000     40.00       .00
  .000015       -0.       -0.       -0.         0         0         1       .00    250.00    250.00

     2.00     23.00     65.00       .00       .00     65.02       .03       .00       .00     52.00
    5000.      427.     4218.      356.      650.     2950.      650.       10.        1.     52.00
      .02       .66      1.43       .55      .050      .035      .060      .035     42.00       .00
  .000022      100.      100.      100.         2         0         1       .00    250.00    250.00
```

```
T1       TEST D START BY SLOPE-AREA METHOD
T2       DESIRED ENERGY SLOPE(J1.5) ESTIMATED ELEV.(J1.9)
T3       DAVIS CREEK

J1   ICHECK       INQ        NINV        IDIR        STRT      METRIC     HVINS       Q         WSEL        FQ

        -1.        -0.         -0.         -0.     .000400      -.00       -.0    20000.   1020.000     -.000

NC         .055        .055        .025        .100        .300       -.000       -.000       -.000       -.000       -.000

X1     670.720      39.000    5600.000    6360.000        .000        .000        .000       -.000       -.000       -.000
GR    1100.000        .000    1080.000     200.000    1060.000     500.000    1040.000     900.000    1030.000    4100.000
GR    1025.000    4150.000    1020.000    4200.000    1015.000    4230.000    1010.000    4260.000    1005.000    4290.000
GR    1000.000    4320.000     995.000    4960.000     990.000    5220.000     988.400    5600.000     985.800    5640.000
GR     986.600    5680.000     979.400    5870.000     978.400    6000.000     981.200    6160.000     978.500    6270.000
GR     990.000    6360.000     995.000    6410.000     995.000    7210.000    1000.000    7420.000    1004.000    7680.000
GR    1000.000    7940.000    1000.000    9070.000     995.000    9890.000    1000.000   10430.000    1005.000   10730.000
GR    1010.000   10820.000    1015.000   10970.000    1020.000   11090.000    1025.000   11170.000    1030.000   11260.000
GR    1040.000   11290.000    1060.000   11690.000    1080.000   12490.000    1100.000   13290.000       -.000       -.000

X1     672.000      34.000    1600.000    2270.000    7200.000    5000.000    6760.000       -.000       -.000       -.000
GR    1100.000        .000    1080.000     200.000    1060.000     400.000    1040.000    1200.000    1030.000    1420.000
GR    1025.000    1460.000    1020.000    1500.000    1015.000    1520.000    1010.000    1540.000    1005.000    1560.000
GR    1000.000    1580.000     995.700    1600.000     978.400    1630.000     983.400    1800.000     988.600    1990.000
GR     990.400    2090.000     989.500    2260.000     995.600    2270.000     995.000    2400.000    1000.000    3000.000
GR    1002.000    3680.000    1000.000    4050.000    1000.000    4600.000    1005.000    4640.000    1005.000    8670.000
GR    1010.000    8870.000    1015.000    9500.000    1020.000    9600.000    1025.000    9720.000    1030.000    9820.000
GR    1040.000   10150.000    1060.000   10750.000    1080.000   11400.000    1100.000   12250.000       -.000       -.000
EJ       -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000

                                         *** PROFILE COMPUTATIONS ***

CCHV=      .100 CEHV=      .300
   SECNO      DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL       OLOSS    BANK ELEV
   Q          QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA     LEFT/RIGHT
   TIME       VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN       SSTA
   SLOPE      XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID      ENDST

   670.72      9.63    988.03       .00   1020.00    988.30       .27       .00       .00    988.40
   20000.        0.    20000.        0.        0.     4828.        0.        0.        0.    990.00
      .00       .00      4.14       .00      .055      .025      .055      .000    978.40   5605.64
  .000398        0.        0.        0.         0         0         9       .00    738.97   6344.61

   672.00     13.35    991.75       .00       .00    992.22       .47      3.86       .06    995.70
   20000.        0.    20000.        0.        0.     3628.        0.      656.      108.    995.60
      .34       .00      5.51       .00      .055      .025      .055      .025    978.40   1606.85
  .000889     7200.     6760.     5000.         4         0         1       .00    656.84   2263.69
```

```
T1      TEST E SUPERCRITICAL FLOW PROFILE(J1.4)-STARTING DEPTH ABOVE CRITICAL-
T2      GR POINTS FROM XSEC1180 REPEATED FOR XSECS 1380-1580*PRO SUPRESSED(J2.3)
T3      SALT LAKE CITY STREAMS-CHANGE IN VELOCITY HEAD FIXED(J1.7)

J1  ICHECK    INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

      -1.       -0.       -0.        1.  -.000000     -.00      50.0      900.  5889.000     -.000

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     -.000     -.000    -1.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

NC       .012      .012      .012      .100      .300     -.000     -.000     -.000     -.000     -.000

X1   1000.000     9.000      .000    18.000    30.000    30.000    30.000     -.000     -.000     -.000
GR   5889.000      .000  5884.000      .000  5884.000     8.000  5889.000     8.000  5889.000    10.000
GR   5884.000    10.000  5884.000    18.000  5889.000    18.000  5889.000    20.000     -.000     -.000

X1   1030.000     9.000      .000    18.000     2.000     2.000     2.000     -.000     -.000     -.000
GR   5889.000      .000  5875.720      .000  5875.720     8.000  5889.000     8.000  5889.000    10.000
GR   5875.700    10.000  5875.720    18.000  5889.000    18.000  5889.000    20.000     -.000     -.000

X1   1032.000     5.000      .000    18.000   148.000   148.000   148.000      .000     -.000     -.000
GR   5889.000      .000  5875.170      .000  5875.170    18.000  5889.000    18.000  5889.000    20.000

X1   1180.000     5.000      .000     6.000   200.000   200.000   200.000     1.000      .320     -.000
GR   5889.000      .000  5834.000      .000  5834.000     6.000  5889.000     6.000  5889.000    20.000

X1   1380.000      .000      .000      .000   200.000   200.000   200.000     1.000   -55.200     -.000

X1   1580.000      .000      .000      .000    25.000    25.000    25.000     1.000   -55.200     -.000
EJ      -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                  *** PROFILE COMPUTATIONS ***


CCHV=    .100 CEHV=    .300

3720 ASSUMED CRITICAL DEPTH


3265 DIVIDED FLOW

    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


  1000.00      4.61   5888.61   5888.61   5889.00   5890.92      2.31       .00       .00   5889.00
     900.        0.      900.        0.        0.       74.        0.        0.        0.   5889.00
      .00       .00     12.19       .00      .012      .012      .012      .000   5884.00       .00
  .003511        0.        0.        0.         0        12         1       .00     16.00     18.00


3265 DIVIDED FLOW
```

1030.00	2.04	5877.74	5880.32	.00	5889.71	11.97	.24	.97	5889.00
900.	0.	900.	0.	0.	32.	0.	0.	0.	5889.00
.00	.00	27.77	.00	.012	.012	.012	.012	5875.70	.00
.033884	30.	30.	30.	8	5	1	.00	16.00	18.00
1032.00	1.75	5876.92	5879.42	.00	5889.58	12.66	.07	.07	5889.00
900.	0.	900.	0.	0.	32.	0.	0.	0.	5889.00
.00	.00	28.56	.00	.012	.012	.012	.011	5875.17	.00
.031934	2.	2.	2.	8	11	1	.00	18.00	18.00
1180.00	2.89	5837.21	5843.16	.00	5878.85	41.64	7.83	2.90	5889.32
900.	0.	900.	0.	0.	17.	0.	0.	0.	5889.32
.00	.00	51.78	.00	.012	.012	.012	.012	5834.32	.00
.104261	148.	148.	148.	9	17	1	.00	6.00	6.00
1380.00	2.29	5781.41	5787.97	.00	5848.28	66.88	28.04	2.52	5834.12
900.	0.	900.	0.	0.	14.	0.	0.	0.	5834.12
.00	.00	65.63	.00	.012	.012	.012	.012	5779.12	.00
.198504	200.	200.	200.	6	5	1	.00	6.00	6.00
1580.00	2.12	5726.04	5732.77	.00	5803.43	77.38	43.81	1.05	5778.92
900.	0.	900.	0.	0.	13.	0.	0.	0.	5778.92
.00	.00	70.59	.00	.012	.012	.012	.012	5723.92	.00
.242942	200.	200.	200.	7	5	1	.00	6.00	6.00

```
T1      TEST F FLOW THROUGH A CIRCULAR CULVERT
T2      4 FT. DIAMETER, 5 PERCENT SLOPE-SUPERCRITICAL FLOW(J1.4)-
T3      START AT CRITICAL DEPTH(J1.5)

J1  ICHECK     INQ       NINV       IDIR       STRT      METRIC     HVINS      Q         WSEL       FQ

       -1.       -0.       -0.        1. -1.000000     -.00      -1.0      100.      -.000      -.000

NC         .015       .015       .015      -.000      -.000      -.000      -.000      -.000      -.000      -.000

X1        1.000      7.000      1.000      5.000      -.000      -.000      -.000      -.000      -.000      -.000
BT        7.000      1.000    120.000    102.000      1.200    120.000    103.000      2.100    120.000    103.800
BT        3.000    120.000    104.000      3.900    120.000    103.800      4.700    120.000    103.000      5.000
BT      120.000    102.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000
GR      102.000      1.000    101.000      1.200    100.200      2.100    100.000      3.000    100.200      4.000
GR      101.000      4.800    102.000      5.000      -.000      -.000      -.000      -.000      -.000      -.000

X1        2.000      -.000      -.000      -.000      5.000      5.000      5.000      -.000      -.250      -.000
X2        -.000      -.000      -.000      -.000      -.000      -.000      1.000      -.000      -.000      -.000

X1        3.000      -.000      -.000      -.000     10.000     10.000     10.000      -.000      -.250      -.000
X2        -.000      -.000      -.000      -.000      -.000      -.000      1.000      -.000      -.000      -.000

X1        4.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.500      -.000
X2        -.000      -.000      -.000      -.000      -.000      -.000      1.000      -.000      -.000      -.000
EJ        -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

                                        *** PROFILE COMPUTATIONS ***


3720 ASSUMED CRITICAL DEPTH

2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED
3280 CROSS SECTION      1.00 EXTENDED       .96 FEET

    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

NORMAL BRIDGE,NRD= 7 MIN ELTRD=  120.00 MAX ELLC=  104.00

      1.00      2.96    102.96    102.96      -.00    104.61      1.65       .00       .00    102.00
      100.        0.      100.        0.        0.       10.        0.        0.        0.    102.00
       .00       .00     10.31       .00      .015      .015      .015      .000    100.00      1.00
   .008500        0.        0.        0.         0        19         1      -.34      4.00      5.00

3280 CROSS SECTION      2.00 EXTENDED       .51 FEET


3301 HV CHANGED MORE THAN HVINS
```

NORMAL BRIDGE,NRD= 7 MIN ELTRD= 120.00 MAX ELLC= 104.00

2.00	2.50	102.25	102.71	.00	104.61	2.36	.00	.00	101.75
100.	0.	100.	0.	0.	8.	0.	0.	0.	101.75
.00	.00	12.32	.00	.015	.015	.015	.000	99.75	1.00
.012285	-0.	-0.	-0.	7	19	1	-.10	4.00	5.00

3280 CROSS SECTION 3.00 EXTENDED .38 FEET

NORMAL BRIDGE,NRD= 7 MIN ELTRD= 120.00 MAX ELLC= 104.00

3.00	2.37	101.87	102.46	.00	104.55	2.67	.07	.00	101.50
100.	0.	100.	0.	0.	8.	0.	0.	0.	101.50
.00	.00	13.12	.00	.015	.015	.015	.011	99.50	1.00
.014753	5.	5.	5.	6	22	1	-.08	4.00	5.00

3280 CROSS SECTION 4.00 EXTENDED .21 FEET

NORMAL BRIDGE,NRD= 7 MIN ELTRD= 120.00 MAX ELLC= 104.00

4.00	2.21	101.21	101.95	.00	104.38	3.17	.17	.00	101.00
100.	0.	100.	0.	0.	7.	0.	0.	0.	101.00
.00	.00	14.28	.00	.015	.015	.015	.013	99.00	1.00
.018933	10.	10.	10.	5	16	1	-.04	4.00	5.00

```
T1      TEST G SPECIAL BRIDGE ROUTINE-DATA FOR WEIR FLOW ONLY(NO X3 CARDS)-
T2      INPUT/OUTPUT IN METRIC UNITS(J1.6) - NO INTERPOLATED XSEC(J1.7)-
T3      NORTH BUFFALO CREEK

J1   ICHECK     INQ      NINV      IDIR      STRT     METRIC    HVINS      Q       WSEL       FQ

        -1.      -0.       -0.       -0.  -.000000     1.00     -1.0     214.   205.440    -.000

NC      .100      .100      .050      .300      .400     -.000     -.000     -.000     -.000     -.000

X1   109.000     8.000   146.300   158.500     -.000     -.000     -.000     -.000     -.000     -.000
GR   210.310      .000   207.270    36.580   204.370   146.300   201.600   147.830   201.600   156.970
GR   204.370   158.500   207.270   350.520   210.310   405.380     -.000     -.000     -.000     -.000

X1   112.000    12.000    56.390    77.720   463.300   463.300   640.080     -.000     -.000     -.000
GR   211.840      .000   211.230     6.100   209.310    21.340   206.290    41.150   205.890    56.390
GR   201.990    60.960   202.210    73.150   205.380    77.720   206.560   149.350   207.510   158.500
GR   209.430   173.740   211.840   204.220     -.000     -.000     -.000     -.000     -.000     -.000
SB     1.250     1.250     1.390   121.920    17.370     1.220    79.530      .000   202.080   202.080

X1   114.000    10.000   114.300   131.060    60.960    60.960    60.960      .000     -.000     -.000
X2     -.000     -.000     1.000   206.960   207.420     -.000     -.000     -.000     -.000     -.000
GR   211.840      .000   209.610    30.480   207.170    91.440   205.560   114.300   202.540   115.820
GR   202.510   128.020   205.040   131.060   205.190   164.590   206.660   193.550   211.840   213.360
EJ     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                   *** PROFILE COMPUTATIONS ***


CCHV=    .300 CEHV=    .400

3720 ASSUMED CRITICAL DEPTH

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN       SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


   109.00     3.93    205.53    205.53    205.44    206.12       .59       .00       .00    204.37
     214.      17.      168.       29.       25.       44.       44.        0.        0.    204.37
      .00      .67      3.84       .67      .100      .050      .100      .000    201.60    102.57
  .009244      -0.       -0.       -0.         0         7         1       .00    132.46    235.03

   112.00     5.50    207.49       .00       .00    207.59       .10      1.32       .15    205.89
     214.       9.      159.       45.       26.       99.      113.        2.        1.    205.38
      .13      .36      1.61       .40      .100      .050      .100      .054    201.99     33.31
  .000973     463.      640.      463.         5         0         1       .00    124.96    158.27


SPECIAL BRIDGE

SB  XK         XKOR       COFQ      RDLEN      BWC        BWP       BAREA     SS        ELCHU      ELCHD
    1.25       1.25       1.39     121.92     17.37       1.22      79.53      .00     202.08     202.08
```

PRESSURE AND WEIR FLOW

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
207.95	207.60	.01	39.	175.	80.	206.96	207.42	30.00

114.00	5.20	207.71	205.73	.00	207.79	.08	.21	.00	205.56
214.	12.	128.	74.	35.	81.	141.	2.	2.	205.04
.14	.35	1.58	.53	.100	.050	.100	.053	202.51	77.82
.000938	61.	61.	61.	2	18	3	.00	119.76	197.58

```
T1       TEST H ENCROACHMENT TEST (1) ENCROACHMENT WIDTH GIVEN (X3.3)
T2       (2)STATIONS GIVEN(X3.4+X3.6) (3)STATIONS AND ELEVATIONS GIVEN(X3.4-X3.7)
T3       (4)ENCROACHMENT WIDTH REPEATED FROM PREVIOUS SECTION(X3.3)

J1   ICHECK      INQ       NINV      IDIR       STRT      METRIC    HVINS       Q        WSEL        FQ

        -1.       -0.       -0.       -0.   -.000000      -.00       -.0     5000.    65.000     -.000

NC         .050      .050      .030      .100      .300     -.000     -.000     -.000     -.000     -.000

X1        1.000    10.000    50.000   200.000     -.000     -.000     -.000     -.000     -.000     -.000
X3        -.000     -.000   200.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000
GR      100.000      .000    50.000      .000    50.000    25.000    50.000    50.000    40.000   100.000
GR       40.000   150.000    50.000   200.000    50.000   225.000    50.000   250.000   100.000   250.000

X1        2.000      .000      .000      .000    50.000    50.000    50.000     1.000     2.000     -.000
X3        -.000     -.000   200.000    10.000      .000   240.000      .000     -.000     -.000     -.000

X1        3.000    12.000    50.000   200.000    50.000    50.000    50.000     -.000     -.000     -.000
X3        -.000     -.000   200.000    25.000    55.000   225.000    55.000     -.000     -.000     -.000
GR      100.000      .000    50.000      .000    50.000    24.000    50.000    25.000    50.000    50.000
GR       40.000   100.000    40.000   150.000    50.000   200.000    50.000   225.000    50.000   226.000
GR       50.000   250.000   100.000   250.000     -.000     -.000     -.000     -.000     -.000     -.000

X1        4.000      .000      .000      .000    50.000    50.000    50.000     1.000     2.000     -.000
EJ        -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                        *** PROFILE COMPUTATIONS ***


CCHV=     .100 CEHV=     .300
    SECNO    DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL       OLOSS    BANK ELEV
    Q        QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA    LEFT/RIGHT
    TIME     VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN       SSTA
    SLOPE    XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID      ENDST


3470 ENCROACHMENT STATIONS=       25.0     225.0   ELEVATIONS=  100000.00  100000.00
      1.00     25.00     65.00       .00     65.00     65.03       .03       .00       .00     50.00
     5000.      246.     4507.      246.      375.     3250.      375.        0.        0.     50.00
       .00       .66      1.39       .66      .050      .030      .050      .000     40.00     25.00
   .000013       -0.       -0.       -0.         0         0         1       .00    200.00    225.00


3470 ENCROACHMENT STATIONS=       10.0     240.0   ELEVATIONS=  100000.00  100000.00
      2.00     23.00     65.00       .00       .00     65.03       .03       .00       .00     52.00
     5000.      348.     4303.      348.      520.     2950.      520.        5.        0.     52.00
       .01       .67      1.46       .67      .050      .030      .050      .029     42.00     10.00
   .000017       50.       50.       50.         2         0         1       .00    230.00    240.00


3470 ENCROACHMENT STATIONS=       25.0     225.0   ELEVATIONS=      55.00      55.00
      3.00     25.01     65.01       .00       .00     65.03       .02       .00       .00     50.00
     5000.      333.     4333.      333.      625.     3251.      625.        9.        1.     50.00
       .02       .53      1.33       .53      .050      .030      .050      .029     40.00       .00
   .000012       50.       50.       50.         2         0         1       .00    250.00    250.00


3470 ENCROACHMENT STATIONS=       25.0     225.0   ELEVATIONS=  100000.00  100000.00
      4.00     23.00     65.00       .00       .00     65.03       .03       .00       .00     52.00
     5000.      230.     4541.      230.      325.     2950.      325.       14.        1.     52.00
       .03       .71      1.54       .71      .050      .030      .050      .029     42.00     25.00
   .000019       50.       50.       50.         2         0         1       .00    200.00    225.00
```

```
T1      TEST I CHANNEL IMPROVEMENT, SUBROUTINE CHIMP
T2      1ST PROFILE IS NATURAL (IBW=8,J2.8),(BW=.01,CI.8)
T3      CATALPA CREEK - DISCHARGE READ FROM 12TH FIELD(INQ)OF QT CARDS(J1.2)

J1  ICHECK     INQ       NINV       IDIR       STRT       METRIC     HVINS     Q          WSEL       FQ

      -1.        12.       -0.        -0.   -.000000      -.00      -1.0       -0.    168.100     -.000

J2  NPROF      IPLOT     PRFVS      XSECV      XSECH      FN         ALLDC      IBW        CHNIM      ITRACE

     1.000      -.000    -1.000      -.000      -.000      -.000      -.000     8.000     30.000      -.000

J3       1.000       2.000       4.000       6.000       7.000      14.000      17.000       -.000       -.000       -.000
J3  VAR(I),I=1,10

         1.         2.         4.         6.         7.     14.       17.        -0.        -0.       -.00
NC       .120        .120        .037        .100        .300       -.000       -.000       -.000       -.000       -.000
QT     11.000     450.000     600.000     900.000    1200.000    1500.000    2300.000    5000.000    6700.000    9400.000
QT  15000.000   25000.000      -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000

X1      1.050      38.000   18150.000   18448.000      -.000       -.000       -.000       1.000       -.850       -.000
GR    200.000   12000.000     180.000   12200.000     170.000   13000.000     170.000   13200.000     170.000   13500.000
GR    170.000   14000.000     170.000   14400.000     165.000   14500.000     170.000   14600.000     170.000   15950.000
GR    165.000   18149.000     165.000   18150.000     165.000   18151.000     165.000   18168.000     160.000   18179.000
GR    149.000   18188.000     155.000   18201.000     158.000   18209.000     159.800   18229.000     159.900   18234.000
GR    159.900   18237.000     160.000   18255.000     157.500   18259.000     157.000   18260.000     145.000   18282.000
GR    144.800   18308.000     144.800   18309.000     145.000   18310.000     145.000   18324.000     150.000   18341.000
GR    155.000   18353.000     162.000   18364.000     163.000   18429.000     164.000   18447.001     167.000   18448.000
GR    172.800   18449.000     180.000   19250.000     200.000   20600.000      -.000       -.000       -.000       -.000

X1      1.550      -.000       -.000       -.000    1200.000    1300.000    3684.000       1.000       3.140       -.000
CI  18300.000     147.090        .025       3.000       3.000      10.000      20.000        .010       -.000       -.000

X1      1.820      -.000       -.000       -.000    1400.000    1250.000    1450.000       1.000       1.700       -.000
CI     -1.000     -1.000        .025       3.000       3.000      10.000      20.000        .010       -.000       -.000

X1      2.100      -.000       -.000       -.000    1400.000    1250.000    1450.000       1.000       1.760       -.000
EJ      -.000      -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000       -.000

                                    *** PROFILE COMPUTATIONS ***


CCHV=    .100 CEHV=    .300

3265 DIVIDED FLOW

  SECNO      DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
  Q          QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
  TIME       VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
  SLOPE      XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

    1.05      24.15    168.10       .00    168.10    168.64       .54       .00       .00    164.15
  25000.      2194.    22806.        0.     3747.     3682.        0.        0.        0.     166.15
     .00        .59      6.19       .11      .120      .037      .120      .000    143.95  14421.00
 .000901        -0.       -0.       -0.         0         0         1       .00   2194.54  18448.34
```

3265 DIVIDED FLOW

1.55	24.14	171.23	.00	.00	171.78	.55	3.13	.00	167.29
25000.	2178.	22822.	0.	3719.	3677.	0.	414.	77.	169.29
.17	.59	6.21	.11	.120	.037	.120	.039	147.09	14421.29
.000906	1200.	3684.	1300.	2	0	1	.00	2187.47	18448.33

3265 DIVIDED FLOW

1.82	23.79	172.58	.00	.00	173.19	.61	1.39	.02	168.99
25000.	1819.	23181.	0.	3100.	3575.	0.	644.	145.	170.99
.23	.59	6.48	.10	.120	.037	.120	.039	148.79	14428.15
.001026	1400.	1450.	1250.	2	0	1	.00	2023.04	18448.27

3265 DIVIDED FLOW

2.10	23.55	174.10	.00	.00	174.75	.65	1.55	.01	170.75
25000.	1580.	23420.	0.	2700.	3504.	0.	855.	209.	172.75
.30	.59	6.68	.10	.120	.037	.120	.038	150.55	14432.95
.001121	1400.	1450.	1250.	2	0	1	.00	1907.81	18448.23

```
T1      TEST J SECOND PROFILE USING CHANNEL IMPROVEMENT (IBW=0,BW=10)
T2      SUMMARY PRINTOUT FOR MULTIPLE PROFILES(J2.1)
T3      CATALPA CREEK

J1  ICHECK     INQ      NINV      IDIR      STRT     METRIC    HVINS      Q        WSEL      FQ

      -0.      12.      -0.       -0.   -.000000    -.00      -1.0      -0.    168.100    -.000

J2  NPROF     IPLOT     PRFVS     XSECV     XSECH      FN      ALLDC     IBW      CHNIM     ITRACE

    15.000    -.000    -1.000     -.000     -.000     -.000     -.000    -.000    30.000     -.000


CCHV=     .100 CEHV=     .300

3265 DIVIDED FLOW

    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN       SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


      1.05     24.15    168.10       .00    168.10    168.64       .54       .00       .00    164.15
    25000.     2194.    22806.        0.     3747.     3682.        0.        0.        0.    166.15
       .00       .59      6.19       .11      .120      .037      .120      .000    143.95  14421.00
   .000901       -0.       -0.       -0.         0         0         1       .00   2194.54  18448.34


CHIMP CLSTA=  18300.00 CELCH=     147.09 BW=     10.00 STCHL=  18150.00 STCHR=  18448.00
2136 NH VALUES       .120   18120.001        .025   18478.000        .120   20600.010

3265 DIVIDED FLOW

      1.55     23.16    170.25       .00       .00    170.80       .55      2.16       .00    167.29
    25000.     3345.    21655.        0.     2108.     3400.        0.      380.       71.    169.29
       .16      1.59      6.37       .01      .120      .025      .120      .027    147.09  14440.76
   .000483     1200.     3684.     1300.         2         0         1       .00   1720.43  18448.17


CHIMP CLSTA=  18299.00 CELCH=     148.79 BW=     10.00 STCHL=  18150.00 STCHR=  18448.00
2136 NH VALUES       .120   18120.001        .025   18478.000        .120   20600.010

3265 DIVIDED FLOW

      1.82     22.13    170.92       .00       .00    171.77       .86       .88       .09    168.99
    25000.     1358.    23642.        0.      893.     3095.        0.      536.      119.    170.99
       .22      1.52      7.64       .00      .120      .025      .120      .027    148.79  14461.46
   .000786     1400.     1450.     1250.         2         0         1       .00   1223.54  18447.98


CHIMP CLSTA=  18299.00 CELCH=     150.55 BW=     10.00 STCHL=  18150.00 STCHR=  18448.00
2136 NH VALUES       .120   18120.001        .025   18478.000        .120   20600.010

3265 DIVIDED FLOW

      2.10     21.51    172.06       .00       .00    173.13      1.07      1.30       .06    170.75
    25000.      560.    24440.        0.      416.     2913.        0.      657.      154.    172.75
       .27      1.35      8.39       .00      .120      .025      .120      .026    150.55  14473.72
   .001026     1400.     1450.     1250.         2         0         1       .00    929.26  18447.77
```

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

CATALPA CREEK

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	TOPWID	TIME	VOL	QCH	K*XNCH
1.05	-.00	.00	.00	143.95	25000.00	168.10	.00	2194.54	.00	.00	22806.34	37.00
1.05	-.00	.00	.00	143.95	25000.00	168.10	.00	2194.54	.00	.00	22806.34	37.00
1.55	3684.00	.00	.00	147.09	25000.00	171.23	.00	2187.47	.17	414.03	22822.25	37.00
1.55	3684.00	.00	.00	147.09	25000.00	170.25	.00	1720.43	.16	380.09	21655.42	25.00
1.82	1450.00	.00	.00	148.79	25000.00	172.58	.00	2023.04	.23	644.33	23181.33	37.00
1.82	1450.00	.00	.00	148.79	25000.00	170.92	.00	1223.54	.22	536.41	23642.38	25.00
2.10	1450.00	.00	.00	150.55	25000.00	174.10	.00	1907.81	.30	855.36	23419.54	37.00
2.10	1450.00	.00	.00	150.55	25000.00	172.06	.00	929.26	.27	657.43	24440.27	25.00

SECTION NUMBER	DISCHARGE CFS	CWSEL	CWSEL DIFF EACH Q	CWSEL DIFF EACH SECTION
1.050	25000.000	168.100	.000	.000
1.050	25000.000	168.100	-.000	.000
1.550	25000.000	171.231	.000	3.131
1.550	25000.000	170.253	-.978	2.153
1.820	25000.000	172.583	.000	1.352
1.820	25000.000	170.916	-1.667	.663
2.100	25000.000	174.103	.000	1.520
2.100	25000.000	172.064	-2.039	1.148

```
T1      TEST K SPECIAL BRIDGE ROUTINE - EFFECTIVE AREA (X3.1)-
T2      TWO FOOT BRIDGE PIERS(SB.6)
T3      ARTIFICAL LEVEES BY ELLEA AND ELREA(X3.8+X3.9)

J1  ICHECK     INQ       NINV       IDIR       STRT      METRIC     HVINS       Q        WSEL        FQ

       -1.       -0.       -0.        -0.    -.000000      -.00       -1.0      700.     14.000      -.000

NC        .043       .043       .043       .300       .500      -.000      -.000      -.000      -.000      -.000

X1       1.000      8.000     18.000     28.000       .000       .000       .000      -.000      -.000      -.000
GR      20.000       .000     10.000     10.000     10.000     18.000      5.000     18.000      5.000     28.000
GR      10.000     28.000     10.000     40.000     20.000     50.000      -.000      -.000      -.000      -.000

X1       2.000       .000       .000       .000     50.000     50.000     50.000      1.000       .300      -.000
X3      10.000      -.000      -.000      -.000      -.000      -.000      -.000     16.000     16.000      -.000
SB        .900      1.500      2.500       .000     10.000      2.000     85.600       .000      -.000      -.000

X1       3.000       .000       .000       .000     50.000     50.000     50.000      1.000       .000      -.000
X2       -.000      -.000      1.000     16.000     18.000       .000      -.000      -.000      -.000      -.000
X3      10.000      -.000      -.000      -.000      -.000      -.000      -.000     18.000     18.000      -.000
BT       4.000       .000     20.300      -.000      2.300     18.000      -.000     47.300     18.000      -.000
BT      50.000     20.300      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

X1       4.000       .000       .000       .000     50.000     50.000     50.000      1.000       .300      -.000
EJ       -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

                                       *** PROFILE COMPUTATIONS ***

CCHV=     .300 CEHV=     .500
  SECNO    DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS   BANK ELEV
  Q        QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA    LEFT/RIGHT
  TIME     VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN      SSTA
  SLOPE    XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID     ENDST

    1.00     9.00    14.00      .00    14.00    14.22      .22      .00      .00    10.00
    700.     136.     368.     196.      40.      90.      56.       0.       0.    10.00
     .00     3.40     4.09     3.51     .043     .043     .043     .000     5.00     6.00
 .001881       0.       0.       0.        0        0        1      .00    38.00    44.00

3301 HV CHANGED MORE THAN HVINS

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=      16.00 ELREA=      16.00

    2.00     8.47    13.77      .00      .00    14.83     1.06      .18      .42    10.30
    700.       0.     700.       0.       0.      85.       0.       0.       0.    10.30
     .00      .00     8.27      .00     .043     .043     .043     .042     5.30    18.00
 .010339      50.      50.      50.        2        0        1      .00    10.00    44.00

SPECIAL BRIDGE
```

SB XK	XKOR	COFQ	RDLEN	BWC	BWP	BAREA	SS	ELCHU	ELCHD
.90	1.50	2.50	.00	10.00	2.00	85.60	.00	5.30	5.30

CLASS A LOW FLOW

BRIDGE W.S.= 12.25 BRIDGE VELOCITY= 12.59

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
.00	15.34	.66	0.	700.	86.	16.00	18.00	1.00

OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA= 18.00 ELREA= 18.00

3.00	9.13	14.43	.00	.00	15.34	.91	.52	.00	10.30
700.	0.	700.	0.	0.	91.	0.	0.	0.	10.30
.00	.00	7.67	.00	.043	.043	.043	.042	5.30	18.00
.008345	50.	50.	50.	0	0	1	.00	10.00	44.00

3301 HV CHANGED MORE THAN HVINS

4.00	9.93	15.53	.00	.00	15.69	.16	.12	.23	10.60
700.	151.	332.	217.	52.	99.	71.	0.	0.	10.60
.01	2.93	3.34	3.04	.043	.043	.043	.042	5.60	5.06
.001099	50.	50.	50.	2	0	1	.00	39.87	44.94

```
T1      TEST L SPECIAL BRIDGE-CLASS A LOW FLOW CONTROLLING-
T2      RECTANGULAR CHANNEL  **PRINTOUT OF INPUT DATA (J1.1)**
T3      FLAT CREEK

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

      -1.       -0.       -0.       -0.   -.000000     -.00      -.0    16000.  1215.000     -.000

NC        .015      .015      .015      .100      .300      .000     -.000     -.000     -.000     -.000

X1       1.000     4.000     -.000   100.000     -.000     -.000     -.000     -.000     -.000     -.000
GR    1300.000     -.000  1200.000     -.000  1200.000   100.000  1300.000   100.000     -.000     -.000
SB        .900     1.250     3.100   100.000   100.000    10.000  1350.000      .000  1200.000  1200.000

X1       2.000     4.000     -.000   100.000     -.000     -.000     -.000     -.000     -.000     -.000
X2       -.000     -.000     1.000  1220.000  1225.000     -.000     -.000     -.000     -.000     -.000
GR    1230.000     -.000  1200.000     -.000  1200.000   100.000  1230.000   100.000     -.000     -.000
EJ       -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                              *** PROFILE COMPUTATIONS ***


CCHV=     .100 CEHV=    .300
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

     1.00     15.00   1215.00       .00   1215.00   1216.77      1.77       .00       .00   1300.00
   16000.        0.    16000.        0.        0.     1500.        0.        0.        0.   1300.00
      .00       .00     10.67       .00      .015      .015      .015      .000   1200.00       .00
  .000445       -0.       -0.       -0.         0         0         1       .00    100.00    100.00


SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
      .90      1.25      3.10    100.00    100.00     10.00   1350.00       .00   1200.00   1200.00

CLASS A LOW FLOW

BRIDGE W.S.=   1214.35  BRIDGE VELOCITY=     12.39

  EGPRS     EGLWC     H3        QWEIR     QPR       BAREA     ELLC      ELTRD     CLASS

      .00   1217.14      .48        0.    16000.     1350.   1220.00   1225.00      1.00

     2.00     15.48   1215.48       .00       .00   1217.14      1.66       .37       .00   1230.00
   16000.        0.    16000.        0.        0.     1548.        0.        0.        0.   1230.00
      .00       .00     10.34       .00      .015      .015      .015      .000   1200.00       .00
  .000404       -0.       -0.       -0.         0         0         1       .00    100.00    100.00
```

```
T1       TEST M SPECIAL BRIDGE-CLASS B LOW FLOW CONTROLLING-
T2       RECTANGULAR CHANNEL
T3       FLAT CREEK

J1   ICHECK      INQ       NINV       IDIR       STRT      METRIC     HVINS       Q        WSEL        FQ

        -1.       -0.        -0.        -0.   -.000000      -.00       -.0    16000.  1210.000     -.000

NC       .015       .015       .015       .100       .300       .000      -.000      -.000      -.000      -.000

X1      1.000      4.000      -.000    100.000      -.000      -.000      -.000      -.000      -.000      -.000
GR   1230.000      -.000   1200.000      -.000   1200.000    100.000   1230.000    100.000      -.000      -.000
SB       .900      1.250      3.100    100.000    100.000     10.000   1350.000       .000   1200.000   1200.000

X1      2.000      4.000      -.000    100.000      -.000      -.000      -.000      -.000      -.000      -.000
X2      -.000      -.000      1.000   1215.000   1225.000      -.000      -.000      -.000      -.000      -.000
GR   1230.000      -.000   1200.000      -.000   1200.000    100.000   1230.000    100.000      -.000      -.000
EJ      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

                                           *** PROFILE COMPUTATIONS ***


CCHV=     .100 CEHV=     .300
    SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
    Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA   LEFT/RIGHT
    TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN       SSTA
    SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID      ENDST


     1.00     10.00   1210.00       .00   1210.00   1213.98      3.98       .00       .00   1230.00
   16000.        0.    16000.        0.        0.     1000.        0.        0.        0.    1230.00
      .00       .00     16.00       .00      .015      .015      .015      .000   1200.00       .00
  .001544       -0.       -0.       -0.         0         0         1       .00    100.00    100.00


SPECIAL BRIDGE

5227 DOWNSTREAM ELEV IS    1207.25 ,NOT    1210.00 HYDRAULIC JUMP OCCURS DOWNSTREAM (IF LOW FLOW CONTROLS)

SB  XK        XKOR      COFQ      RDLEN      BWC       BWP      BAREA      SS        ELCHU     ELCHD
      .90      1.25      3.10    100.00    100.00     10.00   1350.00       .00   1200.00   1200.00

3301 HV CHANGED MORE THAN HVINS

CLASS B LOW FLOW

BRIDGE W.S.=    1209.94  BRIDGE VELOCITY=      17.89

  EGPRS     EGLWC       H3       QWEIR      QPR       BAREA      ELLC      ELTRD     CLASS

      .00   1215.54       .00        0.    16000.     1350.   1215.00   1225.00      2.00

     2.00     13.29   1213.29       .00       .00   1215.54      2.25      1.57       .00   1230.00
   16000.        0.    16000.        0.        0.     1329.        0.        0.        0.    1230.00
      .00       .00     12.04       .00      .015      .015      .015      .000   1200.00       .00
  .000642       -0.       -0.       -0.         0         0         1       .00    100.00    100.00
```

```
T1       TEST N SPECIAL BRIDGE-PRESSURE FLOW CONTROLLING-
T2       RECTANGULAR CHANNEL
T3       FLAT CREEK

J1  ICHECK     INQ        NINV       IDIR       STRT       METRIC     HVINS     Q         WSEL       FQ

       -1.        -0.        -0.        -0.  -.000000       -.00       -.0   16000.  1215.000      -.000

NC        .015       .015       .015       .100       .300       .000      -.000      -.000      -.000      -.000

X1       1.000      4.000      -.000    100.000      -.000      -.000      -.000      -.000      -.000      -.000
GR    1230.000      -.000   1200.000      -.000   1200.000    100.000   1230.000    100.000      -.000      -.000
SB        .900      1.250      3.100    100.000    100.000     10.000    900.000       .000   1200.000   1200.000

X1       2.000      4.000      -.000    100.000      -.000      -.000      -.000      -.000      -.000      -.000
X2       -.000      -.000      1.000   1210.000   1225.000      -.000      -.000      -.000      -.000      -.000
GR    1230.000      -.000   1200.000      -.000   1200.000    100.000   1230.000    100.000      -.000      -.000
EJ       -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

                                        *** PROFILE COMPUTATIONS ***


CCHV=     .100 CEHV=     .300
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST


     1.00     15.00   1215.00       .00   1215.00   1216.77      1.77       .00       .00   1230.00
   16000.        0.    16000.        0.        0.     1500.        0.        0.        0.   1230.00
      .00       .00     10.67       .00      .015      .015      .015      .000   1200.00       .00
  .000445       -0.       -0.       -0.         0         0         1       .00    100.00    100.00


SPECIAL BRIDGE

SB  XK         XKOR       COFQ       RDLEN      BWC        BWP        BAREA      SS         ELCHU      ELCHD
       .90       1.25       3.10     100.00     100.00      10.00     900.00        .00    1200.00    1200.00

3301 HV CHANGED MORE THAN HVINS

PRESSURE FLOW

  EGPRS     EGLWC      H3        QWEIR      QPR        BAREA     ELLC      ELTRD     CLASS

  1221.13   1217.14       .48        0.     16000.       900.   1210.00   1225.00     10.00


     2.00     20.16   1220.16   1209.23       .00   1221.13       .98      4.37       .00   1230.00
   16000.        0.    16000.        0.        0.     2015.        0.        0.        0.   1230.00
      .00       .00      7.94       .00      .015      .015      .015      .000   1200.00       .00
  .000184       -0.       -0.       -0.         3        20         1       .00    100.00    100.00
```

```
T1      TEST 0 SPECIAL BRIDGE-WEIR AND PRESSURE FLOW CONTROLLING-
T2      TOP OF ROADWAY AND LOW CHORD READ FROM BT CARDS
T3      FLAT CREEK TEST 0        ***CROSS SECTIONS PLOTTED (J2.2)***
```

NOTE: CROSS SECTIONS ARE PRINTED AT THE END OF THE LAST JOB ON TAPE 7. THEY HAVE BEEN MOVED FOR THIS EXHIBIT FOR READABILITY.

```
J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

      -1.      -0.       -0.       -0.    -.000000     -.00      -.0     16000.  1215.000    -.000

J2  NPROF      IPLOT     PRFVS     XSECV     XSECH     FN        ALLDC     IBW       CHNIM     ITRACE

     -.000     1.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

NC       .015      .015      .015      .100      .300      .000     -.000     -.000     -.000     -.000

X1      1.000     4.000     -.000   100.000     -.000     -.000     -.000     -.000     -.000     -.000
GR   1230.000     -.000  1200.000     -.000  1200.000   100.000  1230.000   100.000     -.000     -.000
SB       .900     1.250     3.100   100.000   100.000    10.000   900.000      .000  1200.000  1200.000

X1      2.000     4.000     -.000   100.000     -.000     -.000     -.000     -.000     -.000     -.000
X2      -.000     -.000     1.000  1210.000  1212.000     -.000     -.000     -.000     -.000     -.000
BT      6.000      .000  1230.000  1210.000   100.000  1218.000  1210.000   200.000  1215.000  1210.000
BT    300.000  1212.000  1210.000   400.000  1215.000  1210.000   500.000  1230.000  1210.000     -.000
GR   1230.000     -.000  1200.000     -.000  1200.000   100.000  1230.000   100.000     -.000     -.000
EJ      -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                              *** PROFILE COMPUTATIONS ***

CCHV=    .100 CEHV=     .300
   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

     1.00     15.00   1215.00      .00   1215.00   1216.77      1.77      .00       .00   1230.00
   16000.        0.    16000.       0.        0.     1500.        0.       0.        0.   1230.00
      .00       .00     10.67      .00      .015      .015      .015     .000   1200.00       .00
  .000445       -0.       -0.      -0.         0         0         1      .00    100.00    100.00

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
      .90      1.25      3.10    100.00    100.00     10.00    900.00       .00   1200.00   1200.00

PRESSURE AND WEIR FLOW

  EGPRS     EGLWC      H3        QWEIR     QPR       BAREA     ELLC      ELTRD     CLASS

  1221.13   1217.14       .48     5613.    10479.      900.   1210.00   1212.00     30.00

     2.00     16.10   1216.10   1209.23      .00   1217.63      1.53      .86       .00   1230.00
   16000.        0.    16000.       0.        0.     1610.        0.       0.        0.   1230.00
      .00       .00      9.94      .00      .015      .015      .015     .000   1200.00       .00
  .000359       -0.       -0.      -0.         2        20         2      .00    100.00    100.00
```

```
CROSS SECTION       1.00
RIVER  FLAT CREEK TEST 0
DISCHARGE=     16000.

PLOTTED POINTS (BY PRIORITY)-B=BOTTOM BRIDGE,T=TOP BRIDGE,X=GROUND,W=WATER SUR,E=ENERGY GRADIENT,C=CRITICAL WSEL

ELEV 1200.     1205.     1210.     1215.     1220.     1225.     1230.     1235.     1240.     1245.     1250.     1255.

    STA-FEET

 3    0. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX          .         .         .         .         .     BANK.
      2. X         .         .         W   E     .         .         .         .         .         .         .         .         .
      4. X         .         .         W   E     .         .         .         .         .         .         .         .         .
      6. X         .         .         W   E     .         .         .         .         .         .         .         .         .
      8. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     10. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     12. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     14. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     16. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     18. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     20. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     22. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     24. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     26. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     28. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     30. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     32. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     34. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     36. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     38. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     40. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     42. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     44. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     46. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     48. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     50. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     52. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     54. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     56. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     58. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     60. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     62. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     64. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     66. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     68. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     70. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     72. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     74. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     76. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     78. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     80. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     82. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     84. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     86. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     88. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     90. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     92. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     94. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     96. X         .         .         W   E     .         .         .         .         .         .         .         .         .
     98. X         .         .         W   E     .         .         .         .         .         .         .         .         .
 5  100. XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX          .         .         .         .         .     BANK.

NRD=        0 ELLC=  9999999.00 ELTRD=  9999999.00

  EL(I),STA(I)
    1230.00        -.00      1200.00          .00     1200.00       100.00     1230.00       100.00
```

```
CROSS SECTION      2.00
RIVER  FLAT CREEK TEST 0
DISCHARGE=     16000.

PLOTTED POINTS (BY PRIORITY)-B=BOTTOM BRIDGE,T=TOP BRIDGE,X=GROUND,W=WATER SUR,E=ENERGY GRADIENT,C=CRITICAL WSEL

ELEV 1200.      1205.      1210.      1215.      1220.      1225.      1230.      1235.      1240.      1245.      1250.      1255.

    STA-FEET

3   0. XXXXXXXXXXXXXXXXXXXXBXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXT                                                       BANK.
    2. X         .       C B         . W  E    .         .         T         .         .         .         .         .         .
    4. X         .       C B         . W  E    .         .        T.         .         .         .         .         .         .
    6. X         .       C B         . W  E    .         .        T.         .         .         .         .         .         .
    8. X         .       C B         . W  E    .         .       T .         .         .         .         .         .         .
   10. X         .       C B         . W  E    .         .       T .         .         .         .         .         .         .
   12. X         .       C B         . W  E    .         .      T  .         .         .         .         .         .         .
   14. X         .       C B         . W  E    .         .      T  .         .         .         .         .         .         .
   16. X         .       C B         . W  E    .         .     T   .         .         .         .         .         .         .
   18. X         .       C B         . W  E    .         .     T   .         .         .         .         .         .         .
   20. X         .       C B         . W  E    .         .    T    .         .         .         .         .         .         .
   22. X         .       C B         . W  E    .         .    T    .         .         .         .         .         .         .
   24. X         .       C B         . W  E    .         .   T     .         .         .         .         .         .         .
   26. X         .       C B         . W  E    .         .   T     .         .         .         .         .         .         .
   28. X         .       C B         . W  E    .         .  T      .         .         .         .         .         .         .
   30. X         .       C B         . W  E    .         .  T      .         .         .         .         .         .         .
   32. X         .       C B         . W  E    .         . T       .         .         .         .         .         .         .
   34. X         .       C B         . W  E    .         . T       .         .         .         .         .         .         .
   36. X         .       C B         . W  E    .         .T        .         .         .         .         .         .         .
   38. X         .       C B         . W  E    .         .T        .         .         .         .         .         .         .
   40. X         .       C B         . W  E    .         T         .         .         .         .         .         .         .
   42. X         .       C B         . W  E    .         T         .         .         .         .         .         .         .
   44. X         .       C B         . W  E    .        T.         .         .         .         .         .         .         .
   46. X         .       C B         . W  E    .        T.         .         .         .         .         .         .         .
   48. X         .       C B         . W  E    .       T .         .         .         .         .         .         .         .
   50. X         .       C B         . W  E    .       T .         .         .         .         .         .         .         .
   52. X         .       C B         . W  E    .       T .         .         .         .         .         .         .         .
   54. X         .       C B         . W  E    .      T  .         .         .         .         .         .         .         .
   56. X         .       C B         . W  E    .      T  .         .         .         .         .         .         .         .
   58. X         .       C B         . W  E    .     T   .         .         .         .         .         .         .         .
   60. X         .       C B         . W  E    .     T   .         .         .         .         .         .         .         .
   62. X         .       C B         . W  E    .    T    .         .         .         .         .         .         .         .
   64. X         .       C B         . W  E    .    T    .         .         .         .         .         .         .         .
   66. X         .       C B         . W  E    .   T     .         .         .         .         .         .         .         .
   68. X         .       C B         . W  E    .   T     .         .         .         .         .         .         .         .
   70. X         .       C B         . W  E    .  T      .         .         .         .         .         .         .         .
   72. X         .       C B         . W  E    .  T      .         .         .         .         .         .         .         .
   74. X         .       C B         . W  E    . T       .         .         .         .         .         .         .         .
   76. X         .       C B         . W  E    . T       .         .         .         .         .         .         .         .
   78. X         .       C B         . W  E    .T        .         .         .         .         .         .         .         .
   80. X         .       C B         . W  E    .T        .         .         .         .         .         .         .         .
   82. X         .       C B         . W  E    T         .         .         .         .         .         .         .         .
   84. X         .       C B         . W  E    T         .         .         .         .         .         .         .         .
   86. X         .       C B         . W  E   T.         .         .         .         .         .         .         .         .
   88. X         .       C B         . W  E   T.         .         .         .         .         .         .         .         .
   90. X         .       C B         . W  E  T .         .         .         .         .         .         .         .         .
   92. X         .       C B         . W  E  T .         .         .         .         .         .         .         .         .
   94. X         .       C B         . W  E T  .         .         .         .         .         .         .         .         .
   96. X         .       C B         . W  E T  .         .         .         .         .         .         .         .         .
   98. X         .       C B         . W  ET   .         .         .         .         .         .         .         .         .
5 100. XXXXXXXXXXXXXXXXXXXX XXXXXXXXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXX          .         .         .         .         .    BANK.
NRD=       8 ELLC=     1210.00 ELTRD=      1212.00

      .00    1210.00    1230.00     100.00    1210.00    1218.00     200.00    1210.00    1215.00
   300.00    1210.00    1212.00     400.00    1210.00    1215.00     500.00    1210.00    1230.00
  EL(I),STA(I)
    1230.00         -.00       1200.00          .00      1200.00       100.00      1230.00       100.00
```

```
T1      TEST P SPECIAL BRIDGE-CLASS C+B LOW FLOW CONTROLLING-
T2      SUPER CRITICAL FLOW (J1.4),NO INTERPOLATED CROSS SECTIONS (J1.7)
T3      UPPER RIO HONDO RIVER   (2 BRIDGE PIERS SKEWED) *PROFILE PLOTTED*

J1  ICHECK     INQ       NINV      IDIR      STRT      METRIC    HVINS     Q         WSEL      FQ

      -1.      -0.       -0.        1.     -.000000    -.00      -1.0     31000.    15.620    -.000

NC        .014           .014      .014      -.000     -.000     -.000     -.000     -.000     -.000     -.000

X1   70936.000          4.000      .000    190.000      .000      .000    86.000     -.000     -.000     -.000
GR      25.000           .000     5.000     45.000     5.000   145.000    25.000   190.000     -.000     -.000

X1   70850.001          4.000      .000    190.000     -.000     -.000    50.000     -.000     -.000     -.000
GR      24.750           .000     4.750     45.000     4.750   145.000    24.750   190.000     -.000     -.000

X1   70800.000          4.000      .000    200.000     -.000     -.000    50.000     -.000     -.000     -.000
GR      24.610           .000     4.610     45.000     4.610   155.000    24.610   200.000     -.000     -.000

X1   70750.000          4.000      .000    210.000     -.000     -.000    50.000     -.000     -.000     -.000
GR      24.470           .000     4.470     45.000     4.470   165.000    24.470   210.000     -.000     -.000

X1   70700.000          4.000      .000    220.000     -.000     -.000   110.000     -.000     -.000     -.000
GR      24.330           .000     4.330     45.000     4.330   175.000    24.330   220.000     -.000     -.000

X1   70590.001          4.000      .000    220.000     -.000     -.000    50.000     -.000     -.000     -.000
GR      24.010           .000     4.010     45.000     4.010   175.000    24.010   220.000     -.000     -.000
SB        .900          2.040     3.000    300.000   130.000     9.100  3320.000     2.250     4.010     3.860

X1   70540.000          4.000      .000    220.000     -.000     -.000    35.000     -.000     -.000     -.000
X2       -.000          -.000     1.000     20.000    22.000     -.000     -.000     -.000     -.000     -.000
GR      23.860           .000     3.860     45.000     3.860   175.000    23.860   220.000     -.000     -.000

X1   70505.000          4.000      .000    220.000     -.000     -.000      .000     -.000     -.000     -.000
X2       -.000          -.000     -.000     20.000    22.000     -.000     -.000     -.000     -.000     -.000
GR      23.760           .000     3.760     45.000     3.760   175.000    23.760   220.000     -.000     -.000
SB        .900          2.040     3.000    300.000   130.000     9.100  3320.000     2.250     3.760     3.640

X1   70455.001          4.000      .000    220.000     -.000     -.000    50.000     -.000     -.000     -.000
X2       -.000          -.000     1.000     20.000    22.000     -.000     -.000     -.000     -.000     -.000
GR      23.620           .000     3.620     45.000     3.620   175.000    23.620   220.000     -.000     -.000

X1   70019.000          4.000      .000    220.000     -.000     -.000   436.000     -.000     -.000     -.000
GR      22.350           .000     2.350     45.000     2.350   175.000    22.350   220.000     -.000     -.000
EJ       -.000          -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                   *** PROFILE COMPUTATIONS ***

  SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
  Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA     LEFT/RIGHT
  TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
  SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

 70936.00    10.62     15.62     17.94     15.62     24.24      8.62       .00       .00     25.00
   31000.       0.    31000.        0.        0.     1316.        0.        0.        0.     25.00
      .00      .00     23.56       .00      .014      .014      .014      .000      5.00     21.11
  .002779       0.        0.        0.         0        10         1       .00    147.79    168.89
```

```
 70850.00     10.63    15.38    17.70       .00    24.00     8.62      .24      .00    24.75
   31000.        0.   31000.       0.        0.    1316.       0.       3.       0.     24.75
      .00       .00    23.56      .00      .014     .014     .014     .014     4.75    21.11
  .002780        0.      86.       0.         3        5        1      .00   147.78   168.89
```

3301 HV CHANGED MORE THAN HVINS

```
 70800.00      9.39    14.00    16.97       .00    23.84     9.84      .16      .00    24.61
   31000.        0.   31000.       0.        0.    1231.       0.       4.       0.     24.61
      .00       .00    25.17      .00      .014     .014     .014     .014     4.61    23.87
  .003586       -0.      50.      -0.         7        8        1      .00   152.26   176.13
```

3301 HV CHANGED MORE THAN HVINS

```
 70750.00      8.50    12.97    16.27       .00    23.65    10.68      .20      .00    24.47
   31000.        0.   31000.       0.        0.    1182.       0.       5.       1.     24.47
      .00       .00    26.22      .00      .014     .014     .014     .014     4.47    25.88
  .004306       -0.      50.      -0.         6        8        1      .00   158.24   184.12
```

3301 HV CHANGED MORE THAN HVINS

```
 70700.00      7.79    12.12    15.61       .00    23.42    11.29      .23      .00    24.33
   31000.        0.   31000.       0.        0.    1149.       0.       7.       1.     24.33
      .00       .00    26.97      .00      .014     .014     .014     .014     4.33    27.47
  .004984       -0.      50.      -0.         6        8        1      .00   165.06   192.53

 70590.00      7.89    11.90    15.26       .00    22.88    10.98      .54      .00    24.01
   31000.        0.   31000.       0.        0.    1166.       0.      10.       1.     24.01
      .00       .00    26.59      .00      .014     .014     .014     .014     4.01    27.24
  .004771       -0.     110.      -0.         4        5        1      .00   165.51   192.76
```

SPECIAL BRIDGE

```
SB  XK        XKOR     COFQ     RDLEN      BWC      BWP     BAREA      SS     ELCHU    ELCHD
     .90      2.04     3.00    300.00   130.00     9.10   3320.00     2.25     4.01     3.86
```

3301 HV CHANGED MORE THAN HVINS

CLASS C LOW FLOW

BRIDGE W.S.=   13.45 BRIDGE VELOCITY=   22.88

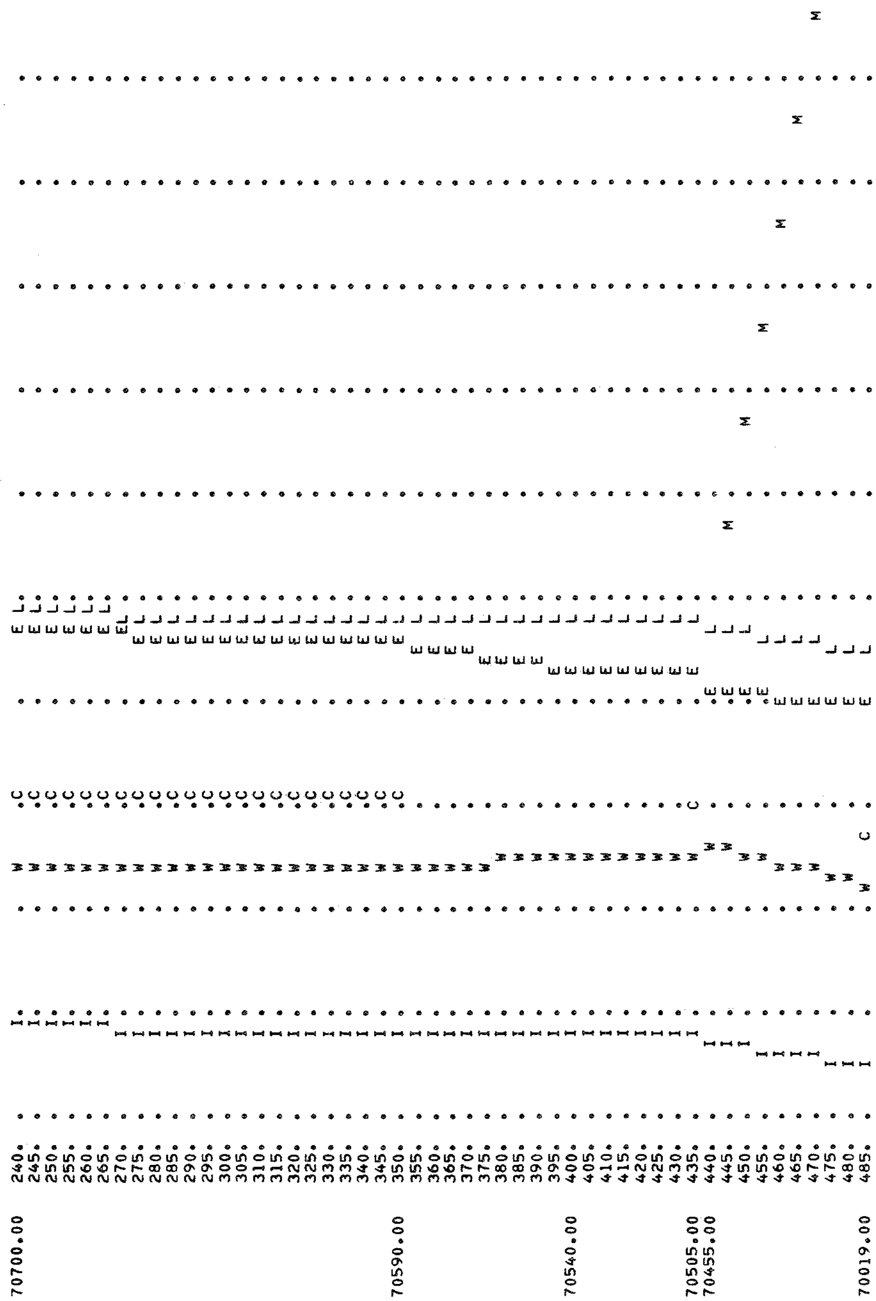
```
  EGPRS     EGLWC      H3      QWEIR      QPR      BAREA     ELLC     ELTRD    CLASS

     .00    21.47      .00       0.     31000.    3320.     20.00    22.00     3.00
```

```
 70540.00     8.63    12.49      .00      .00    21.47     8.98     1.41      .00    23.86
  31000.        0.    31000.       0.       0.    1289.       0.      11.       1.     23.86
     .00       .00    24.04      .00     .014     .014     .014     .014     3.86    25.59
 .003511       -0.      50.      -0.        0        0        1      .00   168.83   194.41

  SECNO     DEPTH    CWSEL    CRIWS    WSELK    EG       HV       HL       OLOSS    BANK ELEV
  Q         QLOB     QCH      QROB     ALOB     ACH      AROB     VOL      TWA    LEFT/RIGHT
  TIME      VLOB     VCH      VROB     XNL      XNCH     XNR      WTN      ELMIN      SSTA
  SLOPE     XLOBL    XLCH     XLOBR    ITRIAL   IDC      ICONT    CORAR    TOPWID     ENDST


NORMAL BRIDGE,NRD= 0 MIN ELTRD=    22.00 MAX ELLC=    20.00

 70505.00     8.65    12.41    15.00      .00    21.34     8.94      .12      .00    23.76
  31000.        0.    31000.       0.       0.    1292.       0.      12.       2.     23.76
     .00       .00    23.99      .00     .014     .014     .014     .014     3.76    25.55
 .003487       -0.      35.      -0.        3       19        1      .00   168.91   194.45


SPECIAL BRIDGE

5290 UPSTREAM ELEV IS      18.14 ,NOT     12.41 NEW BACKWATER REQUIRED

SB  XK        XKOR      COFQ      RDLEN      BWC        BWP      BAREA       SS        ELCHU      ELCHD
      .90      2.04      3.00    300.00    130.00       9.10   3320.00      2.25       3.76       3.64

3301 HV CHANGED MORE THAN HVINS

CLASS B LOW FLOW

BRIDGE W.S.=      15.45  BRIDGE VELOCITY=      17.91

  EGPRS     EGLWC       H3       QWEIR      QPR        BAREA     ELLC     ELTRD    CLASS

      .00     20.30       .00        0.     31000.     3320.     20.00     22.00     2.00

 70455.00     9.55    13.17      .00      .00    20.30     7.13     1.04      .00    23.62
  31000.        0.    31000.       0.       0.    1447.       0.      12.       2.     23.62
     .00       .00    21.43      .00     .014     .014     .014     .014     3.62    23.51
 .002476       -0.       0.      -0.        0        0        1      .00   172.98   196.49

3840 SECTION NOT HIGH ENOUGH     74.698     72.350     2.350     72.350     12.396        2
3301 HV CHANGED MORE THAN HVINS

 70019.00     8.49    10.84    13.60      .00    20.15     9.31      .15      .00    22.35
  31000.        0.    31000.       0.       0.    1266.       0.      14.       2.     22.35
     .01       .00    24.49      .00     .014     .014     .014     .014     2.35    25.90
 .003711       -0.      50.      -0.        5       20        1      .00   168.21   194.10
```

PROFILE FOR RIVER UPPER RIO HONDO RIVER

PLOTTED POINTS (BY PRIORITY)-E-ENERGY GRADIENT,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-MAXIMUM

```
ELEVATION-FT-    0.        5.        10.       15.       20.       25.       30.       35.       40.       45.       50.

   SECNO  CUMDIS-FT

70936.00     0.  .         I         .         .W    C   .       E L         .         .         .         .         .
             5.  .         I         .         .W    C   .       E L         .         .         .         .         .
            10.  .         I         .         .W    C   .       E L         .         .         .         .         .
            15.  .         I         .         .W    C   .       E L         .         .         .         .         .
            20.  .         I         .         .W    C   .       E L         .         .         .         .         .
            25.  .         I         .         .W    C   .       E L         .         .         .         .         .
            30.  .         I         .         .W    C   .       E L         .         .         .         .         .
            35.  .         I         .         .W    C   .       E L         .         .         .         .         .
            40.  .         I         .         .W    C   .       E L         .         .         .         .         .
            45.  .         I         .         .W    C   .       E L         .         .         .         .         .
            50.  .         I         .         .W    C   .       E L         .         .         .         .         .
            55.  .         I         .         .W    C   .       E L         .         .         .         .         .
            60.  .         I         .         .W    C   .       E L         .         .         .         .         .
            65.  .         I         .         .W    C   .       E L         .         .         .         .         .
            70.  .         I         .         .W   C    .       E L         .         .         .         .         .
            75.  .         I         .         .W   C    .       E L         .         .         .         .         .
            80.  .         I         .         .W   C    .       E L         .         .         .         .         .
            85.  .         I         .         .W   C    .       E L         .         .         .         .         .
70850.00    90.  .         I         .         .W   C    .       E L         .         .         .         .         .
            95.  .        I.         .         W    C    .       EL.         .         .         .         .         .
           100.  .        I.         .         W    C    .       EL.         .         .         .         .         .
           105.  .        I.         .         W    C    .       EL.         .         .         .         .         .
           110.  .        I.         .         W    C    .       EL.         .         .         .         .         .
           115.  .        I.         .        W.    C    .       EL.         .         .         .         .         .
           120.  .        I.         .        W.    C    .       EL.         .         .         .         .         .
           125.  .        I.         .        W.   C     .       EL.         .         .         .         .         .
           130.  .        I.         .        W.   C     .       EL.         .         .         .         .         .
           135.  .        I.         .       W .   C     .       EL.         .         .         .         .         .
70800.00   140.  .        I.         .       W .   C     .       EL.         .         .         .         .         .
           145.  .        I.         .       W .   C     .       EL.         .         .         .         .         .
           150.  .        I.         .       W .   C     .       EL.         .         .         .         .         .
           155.  .        I.         .      W  .   C     .       EL.         .         .         .         .         .
           160.  .        I.         .      W  .  C      .       EL.         .         .         .         .         .
           165.  .        I.         .      W  .  C      .      E L.         .         .         .         .         .
           170.  .        I.         .      W  .  C      .      E L.         .         .         .         .         .
           175.  .        I.         .      W  .  C      .      E L.         .         .         .         .         .
           180.  .        I.         .     W   .  C      .      E L.         .         .         .         .         .
           185.  .        I.         .     W   .  C      .      E L.         .         .         .         .         .
70750.00   190.  .        I.         .     W   .  C      .      E L.         .         .         .         .         .
           195.  .        I.         .     W   . C       .      E L.         .         .         .         .         .
           200.  .        I.         .     W   . C       .      E L.         .         .         .         .         .
           205.  .        I.         .    W    . C       .      E L.         .         .         .         .         .
           210.  .        I.         .    W    . C       .      E L.         .         .         .         .         .
           215.  .        I.         .    W    . C       .      E L.         .         .         .         .         .
           220.  .        I.         .    W    . C       .      E L.         .         .         .         .         .
           225.  .        I.         .    W    . C       .      E L.         .         .         .         .         .
           230.  .        I.         .    W    .C        .      E L.         .         .         .         .         .
           235.  .        I.         .   W     .C        .      E L.         .         .         .         .         .
```


240. 245. 250. 255. 260. 265. 270. 275. 280. 285. 290. 295. 300. 305. 310. 315. 320. 325. 330. 335. 340. 345. 350. 355. 360. 365. 370. 375. 380. 385. 390. 395. 400. 405. 410. 415. 420. 425. 430. 435. 440. 445. 450. 455. 460. 465. 470. 475. 480. 485.
70700.00
70590.00
70540.00
70505.00
70455.00
70019.00

```
T1       TEST Q SPECIAL BRIDGE-CLASS C LOW FLOW CONTROLLING-
T2       SUPERCRITICAL FLOW
T3       FLAT CREEK

J1  ICHECK     INQ       NINV      IDIR       STRT      METRIC    HVINS      Q        WSEL      FQ

      -1.        -0.       -0.        1.   -.000000     -.00     -1.0    19000.     9.630    -.000

NC        .012       .012       .012      -.000      -.000      -.000      -.000      -.000      -.000      -.000

X1   72300.000      4.000       .000    240.000      -.000      -.000     97.000      -.000      -.000      -.000
GR      25.000       .000      5.000     40.000      5.000    200.000     25.000    240.000      -.000      -.000

X1   72203.001      4.000       .000    240.000      -.000      -.000     50.000      -.000      -.000      -.000
GR      24.640       .000      4.640     40.000      4.640    200.000     24.640    240.000      -.000      -.000
SB        .900      2.040      3.000    300.000    160.000     18.000   3204.000      2.000      4.640      4.440

X1   72153.001      4.000       .000    240.000      -.000      -.000    452.000      -.000      -.000      -.000
X2       -.000      -.000      1.000     18.000     20.000      -.000      -.000      -.000      -.000      -.000
GR      24.450       .000      4.450     40.000      4.450    200.000     24.450    240.000      -.000      -.000

X1   71701.001      4.000       .000    240.000      -.000      -.000       .000      -.000      -.000      -.000
GR      22.770       .000      2.720     40.000      2.770    200.000     22.770    240.000      -.000      -.000
EJ       -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000      -.000

                                   *** PROFILE COMPUTATIONS ***

   SECNO     DEPTH     CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS    BANK ELEV
   Q         QLOB      QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

 72300.00     4.63      9.63     12.33      9.63     18.76      9.13       .00       .00     25.00
   19000.       0.    19000.        0.        0.      784.        0.        0.        0.     25.00
      .00      .00     24.24       .00      .012      .012      .012      .000      5.00     30.74
  .005420       0.        0.        0.         0        13         1       .00    178.52    209.26

 72203.00     4.68      9.32     11.98       .00     18.24      8.93       .52       .00     24.64
   19000.       0.    19000.        0.        0.      792.        0.        2.        0.     24.64
      .00      .00     23.98       .00      .012      .012      .012      .012      4.64     30.64
  .005230      -0.       97.       -0.         5         5         1       .00    178.72    209.36

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN     BWC       BWP       BAREA     SS        ELCHU     ELCHD
       .90      2.04      3.00    300.00    160.00     18.00   3204.00      2.00      4.64      4.44

3301 HV CHANGED MORE THAN HVINS

CLASS C LOW FLOW
```

BRIDGE W.S.= 11.07 BRIDGE VELOCITY= 18.76

EGPRS	EGLWC	H3	QWEIR	QPR	BAREA	ELLC	ELTRD	CLASS
.00	16.41	.00	0.	19000.	3204.	18.00	20.00	3.00

72153.00	5.42	9.87	.00	.00	16.41	6.54	1.83	.00	24.45
19000.	0.	19000.	0.	0.	926.	0.	3.	1.	24.45
.00	.00	20.52	.00	.012	.012	.012	.012	4.45	29.16
.003190	-0.	50.	-0.	0	0	1	.00	181.68	210.84

3840 SECTION NOT HIGH ENOUGH 75.445 72.770 2.720 72.770 9.340 2

71701.00	5.32	8.04	10.09	.00	14.91	6.87	1.50	.00	22.77
19000.	0.	19000.	0.	0.	903.	0.	12.	2.	22.77
.01	.00	21.03	.00	.012	.012	.012	.012	2.72	29.38
.003448	-0.	452.	-0.	6	20	1	.00	181.16	210.54

```
T1        TEST R SPECIAL BRIDGE-WEIR FLOW AND LOW FLOW CONTROLLING-
T2        LOW BRIDGE APPROACHES FOR OVERBANK (WEIR FLOW) FROM BT CARDS
T3        SMALL CREEK

J1   ICHECK     INQ       NINV       IDIR      STRT      METRIC    HVINS      Q        WSEL       FQ

        -1.       -0.       -0.        -0.   -.000000      -.00      -.0    12000.    80.000     -.000

NC        .080      .080      .030       .100      .300     -.000     -.000     -.000     -.000     -.000

X1       1.000     8.000   200.000    300.000     -.000     -.000     -.000     -.000     -.000     -.000
GR     150.000      .000    60.000    100.000    95.000   200.000    50.000   200.000    50.000   300.000
GR      95.000   300.000    60.000    400.000   150.000   500.000     -.000     -.000     -.000     -.000
SB        .900     2.040     2.700       .000   100.000     5.000  4000.000      .000    50.000    50.000

X1       2.000     -.000     -.000      -.000     -.000     -.000     -.000     1.000     -.000     -.000
X2       -.000     -.000     1.000     90.000    60.000     -.000     -.000     -.000     -.000     -.000
BT       6.000      .000   150.000    150.000   100.000    60.000    60.000   200.000    95.000    90.000
BT     300.000    95.000    90.000    400.000    60.000    60.000   500.000   150.000   150.000     -.000

X1       3.000     -.000     -.000      -.000     -.000     -.000     -.000     1.000     -.000     -.000
EJ       -.000     -.000     -.000      -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                   *** PROFILE COMPUTATIONS ***


CCHV=     .100 CEHV=     .300

3265 DIVIDED FLOW

   SECNO     DEPTH     CWSEL     CRIWS     WSELK      EG        HV        HL       OLOSS   BANK ELEV
   Q         QLOB      QCH       QROB      ALOB       ACH       AROB      VOL      TWA    LEFT/RIGHT
   TIME      VLOB      VCH       VROB      XNL        XNCH      XNR       WTN      ELMIN     SSTA
   SLOPE     XLOBL     XLCH      XLOBR     ITRIAL     IDC       ICONT     CORAR    TOPWID    ENDST

     1.00     30.00     80.00      .00      80.00     80.18       .18       .00       .00     95.00
   12000.      645.    10711.     645.       794.     3000.      794.        0.        0.     95.00
      .00       .81      3.57      .81       .080      .030      .080      .000     50.00     77.78
  .000104       -0.       -0.      -0.          0         0         1       .00    258.73    422.22

SPECIAL BRIDGE

SB  XK        XKOR      COFQ      RDLEN      BWC       BWP       BAREA      SS       ELCHU     ELCHD
      .90      2.04      2.70       .00    100.00      5.00    4000.00      .00     50.00     50.00

6840,FLOW IS BY WEIR AND LOW FLOW

3265 DIVIDED FLOW

BRIDGE W.S.=      80.01  BRIDGE VELOCITY=      3.36

  EGPRS     EGLWC       H3      QWEIR      QPR      BAREA      ELLC      ELTRD     CLASS

    90.00     80.18      .01     1913.    10080.     4000.     90.00     60.00     11.00
```

2.00	30.00	80.00	57.63	.00	80.18	.18	.00	.00	95.00
12000.	645.	10710.	645.	794.	3001.	794.	0.	0.	95.00
.00	.81	3.57	.81	.080	.030	.080	.000	50.00	77.77
.000104	-0.	-0.	-0.	0	17	7	.00	258.78	422.23

3265 DIVIDED FLOW

3.00	30.00	80.00	.00	.00	80.18	.18	.00	.00	95.00
12000.	645.	10710.	645.	794.	3000.	794.	0.	0.	95.00
.00	.81	3.57	.81	.080	.030	.080	.000	50.00	77.77
.000104	-0.	-0.	-0.	0	0	1	.00	258.76	422.23

```
T1      TEST S COMPUTATIONS USING NORMAL BRIDGE ROUTINE (X2.4-5)
T2      CRITICAL DEPTH ABOVE TOP OF BRIDGE-ROADWAY XSECS 27975 AND 27997-
T3      BIG COTTONWOOD CREEK

J1  ICHECK    INQ      NINV      IDIR      STRT      METRIC    HVINS    Q       WSEL      FQ

      -1.      -0.       -0.       -0.   -.000000     -.00      -.0    4500.  4346.790   -.000

NC        .050      .050      .030      .300      .500     -.000     -.000     -.000     -.000     -.000

X1   27900.000    17.000  1945.000  2020.000     -.000     -.000     -.000     -.000     -.000     -.000
GR    4360.000   600.000  4350.000  1460.000  4348.000  1630.000  4346.000  1690.000  4345.600  1740.000
GR    4345.100  1870.000  4344.000  1945.000  4342.000  1985.000  4341.000  1995.000  4341.000  2012.000
GR    4342.000  2015.000  4344.000  2020.000  4346.000  2070.000  4348.000  2080.000  4350.000  2200.000
GR    4350.800  2260.000  4359.000  2400.000     -.000     -.000     -.000     -.000     -.000     -.000

X1   27975.000    16.000  1988.000  2012.000    75.000    75.000    75.000     -.000     -.000     -.000
X2       -.000     -.000     -.000  4346.000  4349.700     -.000     -.000     -.000     -.000     -.000
GR    4360.000   200.000  4352.000  1380.000  4351.100  1470.000  4350.000  1550.000  4349.300  1630.000
GR    4348.900  1820.000  4348.100  1900.000  4349.700  1988.000  4341.500  1988.000  4341.500  2012.000
GR    4349.700  2012.000  4350.000  2065.000  4352.000  2150.000  4354.000  2200.000  4357.500  2280.000
GR    4360.000  2500.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

X1   27997.001      .000      .000      .000    22.000    22.000    22.000     1.000      .000     -.000
X2       -.000     -.000     -.000  4346.000  4349.700     -.000     -.000     -.000     -.000     -.000

X1   28060.000    22.000   970.000  1013.000    90.000    40.000    63.000     -.000     -.000     -.000
GR    4360.000      .000  4352.000   345.000  4350.100   385.000  4352.000   415.000  4352.600   500.000
GR    4352.000   565.000  4351.500   585.000  4350.000   665.000  4349.700   740.000  4348.600   850.000
GR    4348.000   940.000  4348.000   970.000  4346.000   983.000  4343.000   990.000  4343.000  1008.000
GR    4346.000  1013.000  4347.600  1035.000  4348.000  1065.000  4355.500  1066.000  4356.000  1160.000
GR    4357.500  1300.000  4360.000  1800.000     -.000     -.000     -.000     -.000     -.000     -.000
EJ       -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000     -.000

                                  *** PROFILE COMPUTATIONS ***

CCHV=    .300 CEHV=    .500
  SECNO     DEPTH    CWSEL     CRIWS     WSELK     EG        HV        HL        OLOSS   BANK ELEV
  Q         QLOB     QCH       QROB      ALOB      ACH       AROB      VOL       TWA    LEFT/RIGHT
  TIME      VLOB     VCH       VROB      XNL       XNCH      XNR       WTN       ELMIN      SSTA
  SLOPE     XLOBL    XLCH      XLOBR     ITRIAL    IDC       ICONT     CORAR     TOPWID     ENDST

 27900.00     5.79  4346.79      .00  4346.79  4347.70      .91      .00      .00  4344.00
    4500.    1166.    3067.     267.     414.     338.      91.       0.       0.  4344.00
      .00     2.82     9.08     2.93     .050     .030     .050     .000  4341.00  1666.30
  .004571      -0.      -0.      -0.        0        0        1      .00   407.65  2073.95

3685 20 TRIALS USED WSEL,CWSEL

7185 MIN SPECIFIC ENERGY

3720 ASSUMED CRITICAL DEPTH
```

SECNO Q TIME SLOPE	DEPTH QLOB VLOB XLOBL	CWSEL QCH VCH XLCH	CRIWS QROB VROB XLOBR	WSELK ALOB XNL ITRIAL	EG ACH XNCH IDC	HV AROB XNR ICONT	HL VOL WTN CORAR	OLOSS TWA ELMIN TOPWID	BANK ELEV LEFT/RIGHT SSTA ENDST

NORMAL BRIDGE,NRD= 0 MIN ELTRD= 4349.70 MAX ELLC= 4346.00

27975.00	9.50	4351.00	4351.00	.00	4351.65	.65	.63	.00	4349.70
4500.	2846.	1318.	337.	594.	139.	82.	1.	1.	4349.70
.00	4.79	9.47	4.10	.050	.030	.050	.030	4341.50	1477.28
.019931	75.	75.	75.	30	10	1	-385.21	630.22	2107.50

NORMAL BRIDGE,NRD= 0 MIN ELTRD= 4349.70 MAX ELLC= 4346.00

27997.00	10.29	4351.79	.00	.00	4351.98	.19	.19	.14	4349.70
4500.	3249.	796.	455.	1024.	158.	170.	2.	1.	4349.70
.01	3.17	5.03	2.67	.050	.030	.050	.029	4341.50	1401.46
.004760	22.	22.	22.	5	0	1	-385.21	739.42	2140.88

3265 DIVIDED FLOW

28060.00	8.89	4351.89	.00	.00	4352.16	.27	.14	.04	4348.00
4500.	1995.	1872.	633.	1043.	312.	235.	5.	2.	4346.00
.01	1.91	6.00	2.69	.050	.030	.050	.028	4343.00	347.53
.001099	90.	63.	40.	2	0	1	.00	561.27	1065.52

EXHIBIT 9

OUTPUT DATA DESCRIPTION

A. All variables discussed below apply to the cross section identified by SECNO.

Variable	Description
*SECNO	Identifying cross section number. Equal to the number in first field of card X1.
*DEPTH	Depth of flow.
*CWSEL	Computed water surface elevation.
*CRIWS	Critical water surface elevation.
*WSELK	Known water surface elevation from high water mark.
*EG	Mean energy gradient elevation across the entire cross section which is equal to the computed water surface elevation CWSEL plus the mean velocity head HV.
*HV	Mean velocity head across the entire cross section.
*HL	Energy loss due to friction.
*OLOSS	Energy loss due to minor losses such as transition losses.
*Q	Total flow in the cross section.
*QLOB	Amount of flow in the left overbank.
*QCH	Amount of flow in the channel.
*QROB	Amount of flow in the right overbank.
ALOB	Cross section area of the left overbank.
*ACH	Cross section area of the channel.
AROB	Cross section area of the right overbank.

*Variables that can be printed in the summary.

Variable	Description
*VOL	Cumulative volume of water in the river since the first cross section.
TWA	Cumulative top width of the river since the first cross section.
*TIME	Travel time from the first cross section to the present cross section in hours.
VLOB	Mean velocity in the left overbank.
*VCH	Mean velocity in the channel.
VROB	Mean velocity in the right overbank.
**XNL	Manning's "n" for the left overbank area.
**XNCH	Manning's "n" for the channel area.
**XNR	Manning's "n" for the right overbank area.
**WTN	Weighted value of Manning's "n" for the channel based on the distance between cross sections and channel flow from the first cross section. Used when computing Manning's "n" from high water marks.
*ELMIN	Minimum elevation in the cross section.
*SLOPE	Slope of the energy grade line. (The summary printout value has been multiplied by 10,000.)
XLOBL	Distance in the left overbank between the previous cross section and the current cross section.
*XLCH	Distance in the channel between the previous cross section and the current cross section.
XLOBR	Distance in the right overbank between the previous cross section and the current cross section.
ITRIAL	Number of trials required to balance the assumed and computed water surface elevations.

** The summary printout value has been multiplied by 1,000.

Variable	Description
IDC	Number of trials required to determine critical depth.
ICONT	Number of trials to determine the water surface elevation by the slope area method or the number of trials to balance the energy gradient in the special bridge routine.
CORAR	Area of the bridge deck subtracted from the total cross sectional area in the normal bridge routine.
*TOPWID	Cross section width at the assumed water surface elevation.
EGPRS	The energy grade line elevation computed assuming pressure flow.
EGLWC	The energy grade line elevation computed assuming low flow control.
H3	Drop in water surface elevation from upstream to downstream sides of the bridge computed using Yarnell's equation assuming Class A low flow.
QWEIR	Total weir flow at the bridge.
QPR	Total pressure flow at the bridge.
BAREA	Net area of the bridge opening below the low chord. Equals BAREA entered on Card SB.
*ELLC	Elevation of the bridge low chord. Equals ELLC entered on card X2 if used, otherwise it equals the maximum low chord in the BT table.
*ELTRD	Elevation of the top of roadway. Equals ELTRD entered on card X2 if used, otherwise it equals the maximum low chord in the BT table.
CLASS	The controlling type of flow is identified using the following coded values for this variable: 1. Low Flow - Class A 2. Low Flow - Class B 3. Low Flow - Class C 10. Pressure Flow Alone 11. Weir Flow (Overbank) and Class A Low Flow (Bridge) 12. Weir Flow (Overbank) and Class B Low Flow (Bridge) 13. Weir Flow (Overbank) and Class C Low Flow (Bridge) 30. Weir Pressure Flow (Bridge)

Variable	Description
SSTA	The station on the GR cards where the water surface intersects the ground on the left side.
STEND	The station on the GR cards where the water surface intersects the ground on the right side.
*XLBEL	Left bank elevation.
*RBEL	Right bank elevation.

B. The following variables can be printed out with the summary printout option along with those variables from the previous list that have an asterisk (*):

Variable	Description
*CASE	A variable indicating how the water surface elevation was computed. Values of -1, -2, and 0 indicate assumptions of critical depth, minimum difference or a balance between the computed and assumed water surface elevations.
STCHL	Station of the left bank.
STCHR	Station of the right bank.
STENCL	The station of the left encroachment.
STENCR	The station of the right encroachment.
CLSTA	The centerline station of the trapezoidal excavation.
BW	The bottom width of the trapezoidal excavation.

EXHIBIT 10

INPUT DATA DESCRIPTION

This exhibit is arranged to enable the user to quickly determine the input requirements for his particular job. It is "task-oriented"; once the user is familiar with the input required for basic applications, he need only refer to those portions of the exhibit that are pertinent to his job.

The Table of Contents on the following page contains index blocks that correspond in position to index blocks on the first page of each subsection of the exhibit. The first subsection describes input requirements for basic applications, and the user should be thoroughly familiar with this subsection.

The sequential arrangement of cards is shown in exhibit 11, Summary of Input Cards, which should be used to determine where cards for a particular task should be inserted in the data deck.

Variable locations for each input card are shown by field number. Each card is divided into ten fields of eight columns each except field 1. Variables occuring in field 1 may only occupy card columns 3-8 since card columns 1 and 2 (called field 0 for simplicity) are reserved for 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 the numbers -1, 0, 1. Other variables contain numbers which express the variable magnitude. For these a + sign is 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 is considered positive.

EXHIBIT 10
INPUT DATA DESCRIPTION

TABLE OF CONTENTS

*Numbers in parentheses refer to card fields 1-10.

1. REQUIRED CARDS FOR BASIC APPLICATIONS
CARDS T1, T2, T3, J1(4-9), NC X1(1-9), GR, EJ, ER*

a. CARD T1

Title card for output title. This card is required for each job.

Field	Variable	Value	Description
0	IA	T1	Card identification characters.
1-10	none		Numbers and alphabetical characters for title.

b. CARD T2

Title card for output title. This card is required for each job.

Field	Variable	Value	Description
0	IA	T2	Card identification characters.
1-10	none		Numbers and alphabetical characters for title.

c. CARD T3

Title card for output title. The river name should be entered in card columns 9-32 for output in the title of the cross section and profile plots. This card is required for each job.

Field	Variable	Value	Description
0	IA	T3	Card identification characters.
1		0	Not used.
2,3,4	Title		Title for cross section and profile plots.
5-10	none		Numbers and alphabetical characters for title.

d. CARD J1

Job card specifying starting conditions and program options for this job. This card is required for each job.

*Numbers in parentheses refer to card fields 1-10.

d. CARD J1 (continued)

Field	Variable	Value	Description
0	IA	J1	Card identification characters.
4	IDIR	0	Subcritical flow. Cross sectional data (GR cards) are read starting at the downstream end.
		1	Supercritical flow. Cross sectional data are read starting at the up-stream end.
5	STRT	-1	Start computations at critical depth.
		0	Start with known water surface elevation. Enter WSEL in field 9.
		+	Start by slope-area method. Enter estimated energy slope here.
6	METRIC	0	Input and output in English units.
		1	Input and output in Metric units.
7	HVINS	-1	No interpolated cross sections to be inserted by computer.
		0	Interpolated cross sections will be automatically inserted by computer when the change in velocity head between cross sections exceeds 0.5 feet.
		+	Enter maximum allowable change in velocity head between cross sections. If this value is exceeded, inter-polated cross sections will be inserted by computer.
8	Q	0	Only if INQ (J1.2) is 2 or greater.
		+	Starting river flow.
9	WSEL	+	If STRT (J1.5) is zero enter known starting water surface elevation. If STRT is + enter approximate water surface elevation.

e. CARD NC

Manning's "n" and the expansion and contraction coefficients for transition losses are entered for starting each job, or for changing values previously specified.

Field	Variable	Value	Description
0	IA	NC	Card identification characters.
1	XNL	0	No change in Manning's "n" value for the left overbank.
		+	Manning's "n" value for the left overbank.
2	XNR	0	No change in Manning's "n" value for the right overbank.
		+	Manning's "n" value for the right overbank reach length which is half way between the previous and current and future and current cross sections.
3	XNCH	0	No change in Manning's "n" value for the channel.
		+	Manning's "n" value for the channel.
4	CCHV	0	No change in contraction coefficient.
		+	Contraction coefficient used in computing transition losses.
5	CEHV	0	No change in expansion coefficient.
		+	Expansion coefficient used in computing transition losses.

f. CARD X1

This card is required for each cross section (300 cross sections can be used for each profile) and is used to specify the cross section geometry and program options applicable to that cross section.

Field	Variable	Value	Description
0	IA	X1	Card identification characters.

f. CARD X1 (continued)

Field	Variable	Value	Description
1	SECNO	+	Cross section identification number.
		-	Start new tributary backwater at this cross section.
2	NUMST	0	Previous cross section is used for current section. Next GR cards are omitted.
		+	Total number of stations on the next GR cards.
3	STCHL	0	May be omitted if NUMST(X1.2) is 0.
		+	The station of the left bank of the channel. Must be equal to one of the STA(N) on next GR cards.
4	STCHR	0	May be omitted if NUMST(X1.2) is 0.
		+	The station of the right bank of the channel. Must be equal to one of the STA(N) on GR cards and equal to or greater than STCHL.
5	XLOBL	+	Length of reach between current cross section and next downstream cross section of the left overbank. Zero for first cross section if IDIR=0 (Subcritical flow).
6	XLOBR	+	Length of reach between current cross section and next downstream cross section for the right overbank. Zero for first cross section if IDIR=0.
7	XLCH	+	Length of reach between current cross section and next downstream cross section for the channel. Zero for first cross section if IDIR=0.
8	PXSECR	0	Cross section stations will not be changed by the factor PXSECR.

f. CARD X1 (continued)

Field	Varaible	Value	Description
		1	Cross section stations, either previous (NUMST=0, X1.2) or current (NUMST is +), will be multiplied by 1 (no change) and elevations will be increased or decreased by PXSECE.
		+	Factor by which all cross section stations (either previous or current) except first will be multiplied by to increase or decrease area. A 1.1 would increase area by 10 percent not considering any change by PXSECE.
9	PXSECE	0	Cross section elevations will not be changed.
		+ -	Constant to be added (+) or subtracted (-) from all cross section elevations (either previous or current).

g. CARD GR

This card specifies the elevation and station of each point in a cross section used to describe the ground profile, and is required for each X1 card unless NUMST(X1.2) is zero. The points outside of the channel determine the subdivision of the cross section which corrects for the nonuniform velocity distribution.

Field	Variable	Value	Description
0	IA	GR	Card identification characters.
1	EL(1)	+ -	Elevation of cross section point 1 at station STA(1). May be positive or negative.
2	STA(1)	+	Station of cross section point 1.
3	EL(2)	+ -	Elevation of cross section point 2 at STA(2).
4	STA(2)	+	Station of cross section point 2.

Continue with additional GR cards using up to 100 points to describe the cross section. Stations should be in increasing order.

h. CARD EJ

Required following the last cross section for each job. This card is omitted for all but the first profile for multiple profile jobs because the cross section cards are read for the first profile only. Each group of cards beginning with Card T1 is considered a job.

Field	Variable	Value	Description
0	IA	EJ	Card identification characters.
1-10			Not used.

i. CARD ER

Required at the end of a run consisting of one or more jobs in order to end computation on stop command. Three blank cards after the EJ card of the last job are required followed by the ER card.

Field	Variable	Value	Description
0	IA	ER	Card identification characters.
1-10			Not used.

2. MULTIPLE PROFILES, SUMMARY PRINTOUT
CARDS J2(1), J3

a. CARD J2

Field	Variable	Value	Description
0	IA	J2	Card identification characters.
1	NPROF	0 or 1	Cross section cards (X1 and GR) will be read.
		-1	Calls for summary printout for a single-profile job.
		2-14	Profile number using cross section data from previous job (omit cards NC through EJ). Up to 15 profiles using 300 cross sections on each can be computed without re-entering cards NC through EJ.
		15 or greater	Same as above except this is last profile, and therefore the summary printout will be called.

b. CARD J3

Optional card. Used on first profile of a multiple profile run.

Job card specifying option of selecting from 7 to 9 variables for summary printout (see J2.1) which are different from the seven standard variables. The 6 variables SECNO, XLCH, ELTRD, ELLC, ELMIN, Q will normally be printed. The first seven variables shown below will also be printed if this card is omitted. If one or more of the variables 8-30 are desired, then the seven numbers corresponding to the desired variables should be placed in fields 1-7. Variables of ELTRD and ELLC can be replaced by two other variables (selected by fields 8 and 9) if they do not vary with each profile (generally the variables with *).

Number	Variable	Number	Variable	Number	Varaible	Number	Variable
1	CWSEL	8	DEPTH	15	QROB	23	XLBEL*
2	CRIWS	9	WSELK	16	XNL*	24	RBEL*
3	EG	10	HV	17	XNCH*	25	ACH
4	TOPWID	11	HL	18	XNR*	26	VCH
5	S	12	OLOSS	19	WTN	27	STENCL*
6	TIME	13	QLOB	20	(1) CASE	28	STENCR*
7	VOL	14	QCH	21	STCHL*	29	CLSTA*
				22	STCHR*	30	BW*

(1) Case is a variable indicating how the water surface elevation was computed. Values of -1, -2, and 0 indicate assumptions of critical depth, minimum difference or a balance between the computed and assumed water surface elevations.

b. CARD J3 (continued)

Field	Variable	Value	Description
0	IA	J3	Card identification characters.
1-7	IVAR(I)	+	Seven numbers from above table which correspond to the variables that are desired to be printed in the summary table.
8-9		0	ELLC and ELTRD will be used in summary table.
		+	Numbers corresponding to variables which will replace ELTRD and ELLC in the summary table.

3. OPTIONAL CARDS FOR ROUGHNESS DESCRIPTION
CARDS J2(6), NH, NV

a. J2 CARD

Field	Variable	Value	Description
6	FN	0	A factor of 1.0 will be used.
		+	Factor to multiply all Manning's "n" values by.

b. CARD NH

Used to permanently change the overbank roughness coefficients to values which vary with the horizontal distances from the left side of the cross section. Normally the roughness coefficients should be changed at the next cross section.

Field	Variable	Value	Description
0	IA	NH	Card identification characters.
1	NUMNH	+	Total number of Manning's "n" values entered on NH cards (maximum twenty). If more than one NH card is used, field 1 on the other cards would contain an STN(N) value.
2,4,6.. 20	VALN(N)	+	Manning's "n" coefficient between stations STN(N-1) and STN(N). The channel "n" which was specified on Card NC will be used for the channel regardless of the values in this table.
3,5,7.. 19	STN(N)	+	Station corresponding to VALN(N). Each station must equal one of the stations on the next GR cards. Stations must be in increasing order.

c. CARD NV

Used to change the channel roughness coefficient "n" based on water surface elevations.

Field	Variable	Value	Description
0	IA	NV	Card identification characters.

c. CARD NV (continued)

Field	Variable	Value	Description
1	NUMNV	+	Total number of Manning's "n" values entered on NV cards (maximum twenty). If more than one NV card is used field 1 on the other cards would contain an EL(N) value.
2,4,6.. 20	VALN(N)	+	Manning's "n" coefficient for area below ELN(N). The overbank "n" values specified on Card NC will be used for the overbank roughness regardless of the values in this table.
3,5,7.. 21	ELN(N)	+	Elevation of the water surface corresponding to VALN(N) in increasing order.

4. OPTIONAL CARDS FOR SPECIFYING DISCHARGE
CARDS J1(2,10), X2(1), QT

a. J1 CARD

Field	Variable	Value	Description
2	INQ	0	Card QT is not used.
		2 to 20	Field number of flow on Card QT to be used for job.
10	FQ	0	A factor of 1.0 will be used.
		+	Factor to multiply all flows by.

b. X2 CARD

Field	Variable	Value	Description
1	QNEW	0	No change in flow.
		+	Value of the new flow in the river. This value will be used for all remaining cross sections unless changed by another X2 card or by a QT card.

c. CARD QT

Specifies a table of flows for use in computing a series of water surface profiles. The field of the flow being used for this job is specified by variable INQ(J1.2).

Field	Variable	Value	Description
0	IA	QT	Card identification characters.
1	NUMQ	+	Total number of flows (maximum nineteen) entered on the QT cards. If two QT cards are used, field 1 on the second card would contain a flow value.
2-10	Q(N)	+	Flow values to be used for multiple profiles. Variable INQ(J1.2) indicates which field is used for this job. INQ may range from 2 to 20.

5. BRIDGE LOSSES
CARDS X2(3-9), BT, SB

a. CARD X2

Field	Variable	Value	Description
0	IA	X2	Card identification characters.
3	IBRID	0	Special bridge routine will not be used.
		1	Special bridge routine will be used. Card SB is required just ahead of the X1 card for the current cross section.
4	ELLC	0	Special or normal bridge routines are not being used <u>or</u> a bridge table is read on Card BT and (for the special bridge routine only) the maximum low chord value on the BT cards is within the main bridge span.
		+	Elevation of a constant low chord for the bridge for use by the normal bridge routine <u>or</u> (for the special bridge routine) the maximum low chord elevation within the bridge span which is used to help distinguish between pressure flow and low flow.
5	ELTRD	0	Special or normal bridge routines are not being used <u>or</u> a bridge table is read on Card BT.
		+	Elevation of a constant top of roadway for use by the normal bridge routine <u>or</u> (for the special bridge routine) the minimum roadway elevation on the BT cards which is used to determine if weir flow exists.

a. CARD X2 (continued)

Field	Variable	Value	Description
6	BLOSS	0	Change in water surface elevation will not be entered.
		+	Change in water surface elevation to be used between current and previous cross sections.
7	REPBT	0	Do not repeat bridge table (BT cards) used from previous cross section.
		1	If current cross section is based on previous (field 2 of Card X1=0), use bridge table from previous cross section for the current but add PXSECE(X1.9) to all low chord elevations (top of roadways, remain same). This option used in describing top of fixed diameter culvert for several cross sections. Horizontal stations are not changed when a bridge section is repeated.
8	CMOM	0	Drag coefficient for calculating pier losses with momentum equation is equal to 2.00.
		+	Drag coefficient to be used for calculating pier losses with momentum equations.
9	BSQ	0	No bridge skew is used. Factor of 1.0 will be used.
		+	This factor is multiplied by all horizontal stations (RDST) used to describe the bridge profile (BT cards).

b. CARD BT

The bridge geometry described by this card may be used by either the normal or special bridge routine to compute losses through bridges. It can also be used to backwater through circular sections. Each station on Card BT should correspond to a station on Card GR, and each low chord elevation outside the bridge structure should be the same as the ground points. The GR cards should never reflect the top of roadway profile.

When the normal bridge routine is used exclusively, the points outside of the main bridge span (which are used to describe the weir flow area in the special bridge routine) may be omitted.

Field	Variable	Value	Description
0	IA	BT	Card identification characters.
1	NRD	+	Number of points describing the bridge roadway and low chord to be read on Card BT. Entered only on first BT card. The maximum number of points is 50.
2	RDST(1)	+	Roadway station corresponding to RDEL(1) and XLCEL(1).
3	RDEL(1)	+	Top of roadway elevation at station RDST(1). Should be greater than the estimated energy elevation.
4	XLCEL(1)	+	Low chord elevation at station RDST(1).
5	RDST(2)	+	Roadway station corresponding to RDEL(2) and XLCEL(2).
6	RDEL(2)	+	Top of roadway elevation at station RDST(2).
7	XLCEL(2)	+	Low chord elevation at station RDST(2).
8	RDST(3)	+	Roadway station corresponding to RDEL(3) and XLCEL(3).
9	RDEL(3)	+	Top of roadway elevation at station RDST(3).
10	XLCEL(3)	+	Low chord elevation at station RDST(3).

Continue on in field 1 of additional BT cards up to RDST(NRD), RDEL(NRD), and XLCEL(NRD). The last roadway elevation RDEL(NRD) should be greater than the estimated energy elevation.

c. CARD SB

This special bridge card is used to specify data for use in the special bridge routine and is only required when using the special bridge routine. This card should be entered between cross sections that are upstream and downstream of the bridge.

c. CARD SB (continued)

Field	Variable	Value	Description
0	IA	SB	Card identification characters.
1	XK	+	Pier shape coefficient, "K", for use in Yarnell's energy equation for Class A flow.
2	XKOR	+	Total loss coefficient, "K", between cross sections on either side of bridge, for use in orifice flow equation.
3	COFQ	+	Coefficient of discharge "C" for use in weir flow equation.
4	RDLEN	0	Flow over roadway is not being considered <u>or</u> a table of roadway elevations and corresponding stations will be read in on Card BT for determining "L" in the weir flow equation.
		+	Average length of roadway "L" in feet for use in the weir flow equation. Use a constant value of "L" only if the length of weir does not change with depth of flow. Otherwise use Card BT to read in the top of roadway.
5	BWC	+	Bottom width of bridge opening including any obstruction in feet or meters.
6	BWP	0	No obstruction through the bridge. Normal bridge routine will be used in this case if low flow controls.
		+	Total width of obstruction (piers) in feet or meters.
7	BAREA	+	Net area of bridge opening below the low chord in square feet or square meters.
8	SS	0	Vertical side slopes.
		+	Number of horizontal units per 1 vertical unit for the side slope of the trapezoidal channel under the bridge.

c. CARD SB (continued)

9	ELCHU	0	Horizontal channel invert beneath bridge.
		+	Elevation of the channel invert at the upstream side of the bridge.
10	ELCHD	0	Horizontal bridge invert.
		+	Elevation of the channel invert at the downstream side of the bridge.

6. SPECIFICATION OF INEFFECTIVE FLOW AREAS
CARDS X3, ET

a. CARD X3

Field	Variable	Value	Description
0	IA	X3	Card identification characters.
1	IEARA	0	Total area of cross section described on GR cards below the water surface elevation is used in the computations.
		10	Only the cross sectional area confined by levees below the water surface elevation is used in the computations, unless the water surface elevation is above the top of levee (elevations corresponding to STCHL(X1.3) and STCHR(X1.4)), in which case flow areas outside the levee will be included.
2	ELSED	0	A sediment elevation is not specified.
		+	Elevation of sediment desposition. This elevation is extended horizontally until it intersects the cross section and the area below this elevation is not considered to carry flow.
3	ENCFP	0	Width between encroachments is not changed or is not specified.
		+	Width between encroachments is centered in the channel, midway between the left and right overbanks. Flow areas outside this width are not included in the computations. This width will be used for all cross sections unless changed by a positive ENCFP on Card X3 of another cross section or Card ET or unless overridden by the use of STENCL (X3.4).
4	STENCL	0	Encroachments by specifying station and/or elevation will not be used on the left overbank.

a. CARD X3 (continued)

Field	Variable	Value	Description
		+	Station of the left encroachment. Flow areas to the left of (less than) this station and below ELENCL are not included in the computations. This option will override the option using ENCFP when both are used.
5	ELENCL	0	An encroachment elevation on the left side is not applicable and is therefore assumed very high.
		+	Elevation of the left encroachment. Flow areas below this elevation and less than STENCL are not included in the computations.
6	STENCR	0	An encroachment station on the right is not used.
		+	Station of the right encroachment. Flow areas to the right of (greater than) this station and below ELENCR are not included in the computations.
7	ELENCR	0	An encroachment elevation on the right side is not applicable and is therefore assumed very high.
		+	Elevation of the right encroachment. Flow areas below this elevation and greater than STENCR are not included in the computations.
8	ELLEA	0	The elevation (XLBEL) on the GR cards corresponding to STCHL (card X1) is used to decide if the left flow area is effective or not when using the effective area option (IEARA=10).
		+	This elevation is used instead of XLBEL. When this value is used, artificial levees are not required.

a. CARD X3 (continued)

Field	Variable	Value	Description
9	ELREA	0	Same as ELLEA except for right bank flows.
		+	Same as ELLEA except for right bank flows.
10			Not used.

b. CARD ET

An additional input card ET may be inserted with other change cards (NC, QT, NH, or NV) to allow different encroachment widths (ENCFP) to be used for different profiles on the same cross sections.

Field	Variable	Value	Description
0	IA	ET	Card identification characters.
1	None	None	Blank field.
2,3,4.. 10	ENCFP(N)	+	Encroachment widths corresponding to value of INQ(J1.2). First card field is normally blank since INQ is normally 2 or greater. Up to 9 values. See X3.3.

7. DIRECT SOLUTION FOR MANNING'S n
CARDS J1(3), X2(2)

a. J1 CARD

Field	Variable	Value	Description
3	NINV	0	Option to compute Manning's "n" from known high water marks will not be used.
		1	Manning's "n" will be computed from known high water marks. Enter known water surface elevation as variable WSELK on second field of Card X2(X2.2) for each cross section.

b. X2 CARD

Field	Variable	Value	Description
2	WSELK	0	High water mark elevations are not being used.
		+	Elevation of known high water mark at this cross section. Required if NINV (J1.3) equals one.

8. ADDITIONAL GROUND POINTS
CARD X4

a. CARD X4

An additional input card X4 may be inserted following cards X1, X2, or X3 in order to add additional points to describe the ground profile of the cross section. This option is useful when modifying data cards for a proposed levee as it allows points to be added anywhere in the cross section. The X4 card may not be used to describe the artificial levees required for bridges since the values of STCHL and STCHR must be on the GR cards.

Field	Variable	Value	Description
0	IA	X4	Card identification characters.
1	NELT	+	Number of additional points to supplement the next set of GR cards read in describing the ground profile of the cross section.
2	ELT(1)	+	Elevation of first additional ground point.
3	STAT(1)	+	Station of first additional ground point. All stations must be less than the maximum station on the GR cards. The pairs of elevations and stations do not have to be in any particular order.
4,5 etc.			Additional pairs of elevation and station values. Maximum of 20 pairs.

9. PLOTS OF CROSS SECTIONS AND PROFILES
CARDS J2(2-5), X1(10)

a. CARD J2

Field	Variable	Value	Description
2	IPLOT	0	No cross sections will be plotted for this job unless individual plots are specified by using IPLOT on Card X1(X1.10).
		1	Plot all points of all job cross sections.
		10	Plot cross section points up to water surface elevation for all cross sections.
3	PRFVS	0	Computer selects vertical scale of profile plot for current profile based on an elevation spread not exceeding 12 inches.
		+	User selects vertical scale to be used for current profile. Enter number of elevation units per inch.
		-	No profile will be plotted.
4	XSECV	0	Computer selects vertical scale of cross section plot for each cross section individually.
		+	User selects vertical scale to be used for all cross sections. Enter number of elevation units per inch.
5	XSECH	0	Computer selects horizontal scale of cross section plot for each cross section individually.
		+	User selects horizontal scale to be used for all cross sections. Enter number of horizontal units (feet or meters) per line of output. If the vertical scale of the profile (PRFVS) is given, then the value of XSECH will be used for the horizontal scale of both the cross sections and profiles.

b. X1 CARD

Field	Variable	Value	Description
10	IPLOT	0	Current cross section will not be plotted, unless all cross sections were requested by Card J2.
		1	Plot current cross section using all points.
		10	Plot current cross section using only those points up to the water surface elevation.

10. TRACES AND DATA PRINTOUT
CARDS J1(1), X2(10), J2(10)

a. CARD J1

Field	Variable	Value	Description
1	ELRAN	-1	Print data cards NC-EJ before execution.
		0	If ELRAN not specified, an allowable elevation range of 150 ft. is assumed for the maximum elevation minus minimum elevation range for BT and GR cards.
		+	Specified allowable maximum elevation minus minimum elevation range for BT and GR cards.

b. X2 CARD

Field	Variable	Value	Description
10	ITRACE	0	No trace for this cross section unless ITRACE on Card J2(J2.10) is specified.
		1	Major trace for current cross section.
		10	Major and minor trace for current cross sections.

c. CARD J2

Field	Variable	Value	Description
10	ITRACE	0	No trace for this job unless specified by individual cross sections using ITRACE on Card X2(X2.10)
		1	Major trace for all cross sections.
		10	Major and minor trace for all cross sections. (Large amount of output.)

11. DATA COMMENT CARDS
CARDS C_

Title cards (for labeling cross sections) which appear immediately ahead of the T1 card will be printed just ahead of the cross section whose number appears in field 1 of cards 3-100. At least 3 comment cards are required since the first two are not printed.

Card Number	Field	Variable	Value	Description
1	0	IA	C_	Card identification characters (C, blank).
1	1-10	--	--	Blank.
2	0	IA	C_	Card identification characters.
2	1	NUMCT	+	Number of data comment cards to be printed (up to 98).
2	2-10	--	--	Blank.
3-100	0	IA	C_	Card identification characters.
	1	CNOS		Cross section number (field 1 of X1 card) where title is to be printed.
3-100	2-10	COCD		Title to be printed ahead of cross section number CNOS.

12. CRITICAL DEPTH OPTION
CARD J2(7)

J2 CARD

Field	Variable	Value	Description
7	ALLDC	-1	Critical depth will be computed for all cross sections using an allowable error of 2.5 percent of the depth.
		+	Critical depth will be computed using an allowable error of ALLDC percent.
		0	Critical depth will not be computed unless the actual depth is close to critical (except when low flow occurs for the special bridge routine and when super critical flow profiles are computed).

13. CHANNEL MODIFICATION DUE TO EXCAVATION
CARDS J2(8,9), CI

Through the use of subroutine CHIMP the existing cross section (as described by GR cards) may be modified by a trapazoidal channel excavation as specified by the use of the optional card CI and the 8th and 9th fields of the J2 card. The CI card should be located after the X1 card of the cross sections where the improvement applies. The trapazoidal modification will start on the first cross section that has a CI card and will continue on each cross section until a CI card is read that has .01 for the channel bottom. Any changes in the variables on the CI card must be made by another CI card. Only those variables that change need to be shown on the CI card.

a. CARD J2

Field	Variable	Value	Description
8	IBW	0	If a CI card is read, the 6th field of the CI card will be used to describe the bottom width of the improvement.
		6-10	Field number of channel bottom width on CI card to be used for this profile.
9	CHNIM	0	Overbank N values are unchanged.
		+	NH card (horizontal n value variation) is simulated by computer so that the channel n value is used for a distance of CHNIM on each side of the left or right bank stations (which may be modified by the channel excavation described by the CI card).

b. CARD CI

Field	Variable	Value	Description
0	IA	CI	First 2 columns of card for card identification.
1	CLSTA	0	Value on previous CI card is used.
		+	Station of the centerline of the trapezoidal channel excavation which is expressed in terms of the stations used in the natural cross section description (GR cards).

b. CARD CI (continued)

Field	Variable	Value	Description
		-1	CLSTA is determined by computer as half way between bank stations.
2	CELCH	0	Value on previous CI card is used.
		+	Elevation of channel invert.
		-1	Elevation of channel invert is equal to minimum elevation in cross section.
3	CNCH	0	Value of previous CI card is used.
		+	New channel "n" value.
4	XLSS	0	Value on previous CI card is used.
		+	Left side slope of channel expressed as horizontal divided by vertical (2.0 for 2 horizontal to 1 vertical).
5	RSS	0	Value of previous CI card is used.
		+	Right side slope of channel expressed as horizontal divided by vertical.
6-10	BW	0	Value on previous CI card is used.
		.01	No channel improvement until another CI card is read.
		>.01	Bottom width of trapezoidal channel in feet. Field used (6-10) for this profile corresponds to field specified on 8th field of J2 card.

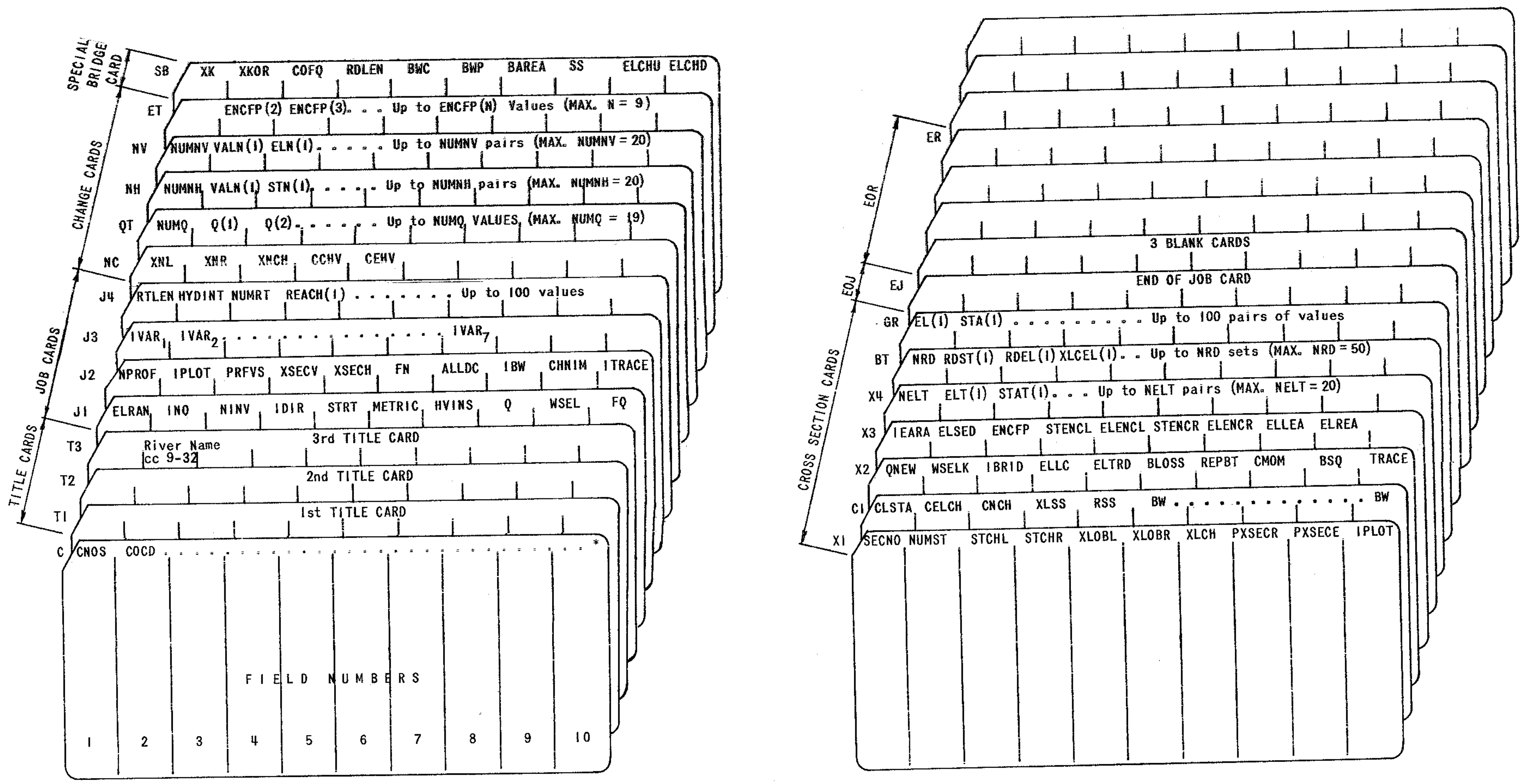
14. STORAGE-DISCHARGE OUTPUT
CARD J4

This optional card provides punched cards for routing by Modified Puls using program HEC-1. The cards punched are U,2 and 3 cards (see program description for HEC-1). This option can be used only if multiple profiles are computed and if the summary printout is requested. Routing reach cross section numbers (REACH(I)) must be on X1 cards.

If a J3 card is used to change variables used in the summary printout, then variables 6 (TIME) and 7(VOL) must be shown on that card. This card requests punched routing cards. It is used only on the first profile of a series.

Field	Variable	Value	Description
0	IA	J4	Card identification characters.
1	RTLEN	+	Ratio (usually=1) used to determine the number of sub-reaches for each routing reach. Equal to the ratio of the travel time (K) to the product of the time interval (ΔT) and the number of routing sub-reach steps (NSTPS). Use +1 when K=ΔT for NSTPS=1, K=2ΔT for NSTPS=2, etc. A value of 2 would provide one step when K=2ΔT.
2	HYDINT	+	Computation and tabulation interval in minutes for HEC-1.
3	NUMRT	+	Number of values of REACH(I) to be read on remainder of this card.
4-10	REACH(I)	+	Reach or section numbers where outflow values are needed. Each reach number is equal to the section number (X1.1) of the cross section at the downstream end of a routing reach except the last number which is the beginning of the upstream reach. Up to 100 values may be used.

SUMMARY OF INPUT CARDS
EXHIBIT 11



* Optional cards which may be used to label cross sections. At least three are required since the first two are not printed.

Exhibit 11

```
C         723-X6-L202A HEC-2 10FEB71 CDC6600 READ,PRINT WRITE
C         CHANGES 1-22 EXCEPT 13,16,19,21 FEB 71
C           PROGRAM NO 22-J2-L232  WATER SURFACE PROFILES
C           FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C           BACKWATER MAIN RENUMBERED  1NOV1968
C           HYDROLOGIC ENGINEERING CENTER, ARMY CORPS OF ENGINEERS
C           TAPE 6 IS USED TO STORE INPUT DATA
C           TAPE 7 IS USED TO STORE PLOTTED CROSS SECTIONS
C           TAPE 8 IS USED TO STORE DATA USED IN PLOTTING PROFILE
C      TAPE 9 IS USED TO PRINT COMMENT CARDS
C           CALL SUBROUTINES BLFLO (1360.08),BWEIR(2980),DC(3100)
C      SCALF(1090,3605), XSEC(3630), PROF(1110), CHIMP(2127)
C           CALL SUBROUTINE SLARA(2930.01,3105.01,3125)
C           SUBROUTINES   STATEMENT NUMBERS
C                              FROM  TO
C              MAIN             1000-3895
C              CHIMP            1000-4020
C              ADDPTS           1010-1950
C               DC              4000-4570
C              BLFLO            5000-5590
C              BWEIR            6000-6880
C              YCRIT            7000-7040
C              SLARA            7100-7220
C              SCALE            7750-7950
C              XSEC             8000-8980
C              PROF             9000-9510
C           LIBRARY SUB. NONE
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION ELT(20),STAT(20),STAO(102),ELO(102),ELOR(200),STAOR(200)
C           QVAR(8,300,15) IS 15 PROFILES, 300 CROSS SECTIONS, AND 8
C              ITEMS TO BE SUMMARIZED.
C           MEMORY CAN BE REDUCED BY CHANGING DIMENSION AS SHOWN BELOW
C           AND BY ADDING CARD(GO TO 1116) AFTER STAT 3870
C     DIMENSION SECVR(5,1),QVAR(8,1,1)
      DIMENSION SECVR(5,300),QVAR(8,300,14)
      DIMENSION IDCRD(20),ELN(20),RDSTR(20),IT(121),CNOS(100),COCD(21)
      DIMENSION VAR(7),VART(30),IVAR(7),ICICN(10),NAMVAR(19),IVA(7)
      DIMENSION REACH (100),FLOW(15),CVOL(15),XQ(15),PCVOL(15),DVOL(15)
C     CHANGE 15 FOR PUNCHING HEC-1 ROUTING CARDS
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
```

```
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
 1000 FORMAT (A2,10F13.5)
 1001 FORMAT(1X,A2,10F12.5)
      DATA NPUNCH/ 4HEND /
      DATA BLANK,IDCRD(1),IDCRD(2),IDCRD(3),IDCRD(4),
     1IDCRD(5),IDCRD(6),IDCRD(7),IDCRD(8),IDCRD(9),
     2IDCRD(10),IDCRD(11),IDCRD(12),IDCRD(13),IDCRD(14),
     3IDCRD(15),IDCRD(16),IDCRD(17),IBLANK/4H    ,2HJ1,
     42HJ2,2HNC,2HQT,2HNH,2HNV,2HX1,2HX2,2HX3,
     52HCI,2HSB,2HBT,2HGR,2HEJ,2HER,2HET,2HX4,
     62H  /
      DATA IDCRD(18)/2HC /
      DATA IDCRD(19)/2HJ3/
      DATA IDCRD(20)/2HJ4/
      DATA NAMVAR/
     16H CWSEL,6H CRIWS,6H    EG,6HTOPWID,
     26H 10K*S,6H  TIME,6HVOL   ,6H DEPTH,
     36H WSELK,6H    HV,6H    HL,
     46H OLOSS,6H  QL08,6H   QCH,
     56H  QROB,6H K*XNL,6HK*XNCH,6H K*XNR,6H K*WTN/
 1002 FORMAT(2X,10F13.5)
 1005 FORMAT(1X,10F9.2)
 1010 FORMAT(1X,4F9.2,4F9.3,2F9.2)
 1015 FORMAT(1X,9F9.0,F10.2)
 1020 FORMAT(1X,F9.6,3F9.0,3I9,2F9.2)
 1025 FORMAT(12F10.2)
 1026 FORMAT(2X,12F10.3)
 1030 FORMAT(A2,F6.0,9F8.0)
 1035 FORMAT(1H )
 1040 FORMAT(1X,10F13.5)
C
 1045 FORMAT (1H1)
 1050 FORMAT (1H0)
 1055 FORMAT(10F12.2)
C          USE VARIABLES TO CUT DOWN FLOATING POINT CONSTANTS
      REWIND 7
      REWIND 8
      ZERO=0.0
      ONE=1.0
      TWO=2.0
      TEN=10.0
      ITEN=10
      RTLEN=0.0
      NUMCT=0
      IZERO=0
      JQCON=1
      NPRFP=0
      NPROF=0
      GO TO 1115
C          PLOT PROFILE    *    *    *    *    *    *    *    *    *
C
 1065 XWT=ISECN*10
      IF(ISECN-5) 1070,1075,1075
 1070 REWIND 8
      GO TO 1115
 1075 END FILE 7
      WRITE(8,1055) ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ZERO,ZERO
      YWT=111.
```

```
      IF(IDIR)1080,1080,1085
 1080 ELMX1=TELMX
      IF(WSEL-TELMX) 1090,1090,1081
 1081 ELMX1=WSEL
      GO TO 1090
 1085 ELM1=ELMIN
 1090 X=ZERO
      Y=ZERO
      Z=ZERO
      XMIN=ZERO
      TRACE=1090.
      IF(ISWT3) 1092,1092,1091
 1091 PRINT 1025,TRACE,XMIN,ELM1,CUMDS,ELMX1,XWT,YWT,X,Y,Z,TEM
 1092 CALL SCALE(XMIN, ELM1,CUMDS,ELMX1,XWT,YWT,X,Y,Z,TEM)
      TRACE=1093.
      IF(ISWT3) 1094,1094,1093
 1093 PRINT 1025,TRACE,XMIN,ELM1,CUMDS,ELMX1,XWT,YWT,X,Y,Z,TEM
 1094 IF(PRFVS)1110,1110,1095
 1095 N=PRFVS
      Y=PRFVS
      IF(IDIR) 1105,1105,1100
 1100 I=ELMX1/Y+1.
      X=I*N-11*N
      GO TO 1110
 1105 I=ELM1/Y
      X=I*N
C
 1110 IF(ISWT3) 1112,1112,1111
 1111 TRACE=1111.
      PRINT 1025,TRACE,X,Y,Z
 1112 CALL PROF(X,Y,Z,TITLE,IDIR)
      IF(ISWT3) 1115,1115,1113
 1113 TRACE=1113.
      PRINT 1025,TRACE,X,Y,Z
C
C         *    *    *    *    *    *    *    *    *    *    *    *    *
C                   READ IN 3 TITLE CARDS
C
 1115 IF(NPRFP-15)1117,3865,3865
 1117 IF(NPROF)3865,1116,1116
C
 1116 PRINT 1045
      READ 1118,IA,(EL(N),N=1,20)
 1118 FORMAT(A2,A2,19A4)
      PRINT 1118,IA,(EL(N),N=1,20)
      IF(NUMCT-1)1126,1126,1125
 1125 REWIND 9
      NUMCD=1
      GO TO 1122
 1126 CNOS(1)=1000000.
      NUMCD=1
      NUMCT=1
      IF(IA-IDCRD(18))1122,1119,1122
C     READ AND STORE DATA COMMENT CARD ON TAPE 9
 1119 READ 1120,IA,X
      NUMCT=X
      REWIND 9
 1120 FORMAT(A2,F6.0,18A4)
      DO 1121 I=1,NUMCT
      READ 1120,IA,CNOS(I),(COCD(N),N=1,18)
```

```
 1121 WRITE(9,1120) IA,CNOS(I),(COCD(N),N=1,18)
C
      READ 1118,(EL(N),N=1,21)
      PRINT 1118,(EL(N),N=1,21)
C
      REWIND 9
C
 1122 DO 1123 I=1,2
      READ 1118,(EL(N),N=1,21)
 1123 PRINT 1118,(EL(N),N=1,21)
      PRINT 1035
      DO 1130 N=3,8
 1130 TITLE(N-2)=EL(N)
      REWIND 6
C          INITIALIZE JOB CARDS IN CASE THEY ARE NOT READ IN
      IPRNT=0
      CLSTA=0.0
      FN=1.0
      IDIR=0
      INQ=0
      NINV=0
      STRT=0.0
      HVINS=.5
      ITRACE=0
      ICHECK=0
      NPROF=1
      METRIC=0
      BASIN=0
      BLOSS=0.0
      IPLOT=0
      PRFVS=0.0
      XSECV=0.0
      XSECH=0.0
      ALLDC=2.5
       IECCD=0
      IBW=6
      CHNIM=0.0
      J3=0
C        INITIALIZE CHANGE CARD
      XNL=.00001
      XNR=.00001
      XNCH=.00001
      CCHV=0.0
      CEHV=0.0
      NUMQ=0
      NUMNH=0
      NUMNV=0
      ICHIMP=0
      NRD=0
      NSTRD=1
      PXSECR=0.0
      PXLOBL=0.0
      PXLOBR=0.0
      PXLCH =0.0
      IFNCR=0
      IRDX1=0
      CMOM=2.
      DATPR=0.0
C
C          READ ALL CARDS BUT HEADERS AND WRITE ALL BUT HEADERS,J1,J2,
```

```
C          ON TAPE 6
C
 1135 READ 1030,IA,(RDINP(I),I=1,10)
      IF(DATPR)1139,1139,1136
 1136 IF(IA-IDCRD(7))1134,1137,1134
 1137 PRINT 1035
 1134 PRINT 1138,IA,(RDINP(I),I=1,10)
 1138 FORMAT(1X,A2,10F12.2)
 1139 IF(IA-IDCRD(15)) 1140,3895,1140
 1140 IF(IA-IDCRD(1))1145,1150,1145
 1145 IF(IA-IDCRD(2))1146,1190,1146
 1146 IF(IA-IDCRD(19))1148,1226,1148
 1148 IF(IA-IDCRD(20)) 1230,1231,1230
C
C        JOB1 CARD
C
 1150 ICHECK= RDINP(1)
      IF(RDINP(1))1151,1152,1152
 1151 DATPR=1.
 1152 ICRDP=1
      INQ= RDINP(2)
      NINV= RDINP(3)
      IDIR= RDINP(4)
      STRT= RDINP(5)
      METRIC= RDINP(6)
      HVINS= RDINP(7)
      Q=RDINP(8)+.001
      WSEL=RDINP(9)
C          COUNTER TO SEE IF STARTING NC CARD IS READ
      INC=0
      FQ=RDINP(10)
C        DETERMINE MANNING'S CONSTANT AND GRAVITATIONAL ACCELERATION
      IF(METRIC) 1155,1155,1160
 1155 CONST=1.486
      TWOG=64.4
      ONEG=32.2
      GO TO 1165
 1160 CONST=1.000
      TWOG=19.64
      ONEG=9.82
 1165 IF(FQ) 1170,1170,1175
 1170 FQ=1.
 1175 PRINT 1180
 1180 FORMAT(5H J1  ,6HICHECK,4X,3HINQ,7X,4HNINV,6X,4HIDIR,6X,4HSTRT,6X,
     16HMETRIC,4X,5HHVINS,5X,1HQ,9X,4HWSEL,6X,2HFQ)
      PRINT 1035
      PRINT 1185,(RDINP(I),I=1,10)
      Q=RDINP(8)*FQ+.001
C
 1185 FORMAT(4F10.0,F10.6,F10.2,F10.1,F10.0,2F10.3)
      PRINT 1035
      GO TO 1135
C
C        JOB2 CARD
C
 1190 ITRACE=RDINP(10)
      IPRNT=IPRNT+4
      ICRDP=2
      IBW=RDINP(8)
      CHNIM=RDINP(9)
```

```
      IF(IBW-6)1191,1192,1192
 1191 IBW=6
      GO TO 1194
 1192 IF(IBW-10)1194,1194,1193
 1193 IBW=10
 1194 CONTINUE
      IPLOT=RDINP(2)
      PRFVS=RDINP(3)
      XSECV=RDINP(4)
      XSECH=RDINP(5)
      IF(RDINP(7))1200,1200,1195
 1195 ALLDC=RDINP(7)
C             FACTOR TO MULT. ALL N VALUES BY
 1200 FN=RDINP(6)
      IF(FN) 1205,1205,1210
 1205 FN=1.
 1210 IF(RDINP(1)-1.)1212,1215,1215
 1212 IF(RDINP(1))1213,1225,1225
 1213 NPROF=-1
      GO TO 1225
 1215 NPROF=RDINP(1)
      IF(NPROF-1) 1214,1214,1211
 1211 JQCON=JQCON+1
 1214 K=JQCON
      DO 1217 J=1,300
      DO1216 I=1,8
      QVAR(I,J,K)=0.0
 1216 CONTINUE
 1217 CONTINUE
 1220 FORMAT(5H J2   ,5HNPROF,5X,5HIPLOT,5X,5HPRFVS,5X,5HXSECV,5X,5HXSECH
     1,5X,2HFN,7X,5HALLDC,5X,3HIBW,7X,5HCHNIM,6X,6HITRACE)
 1225 PRINT 1220
      PRINT 1035
      PRINT 1026,(RDINP(I),I=1,10)
      PRINT 1035
      IF(NPROF-1)1135,1135,1240
C     J3 CARD
 1226 DO 1227 I=1,7
 1227 IVAR(I)=RDINP(I)
      PRINT 1228
 1228 FORMAT(5H J3   ,13HVAR(I),I=1,7))
      PRINT 1035
      PRINT 1015,(RDINP(I),I=1,10)
      J3=1
      GO TO 1135
C
 1230 WRITE(6,1000)IA,(RDINP(I),I=1,10)
      IF(IA-IDCRD(14)) 1135,1240,1135
C                J4 CARD
 1231 PRINT 1232
 1232 FORMAT(5H J4   ,5HRTLEN,5X,6HHYDINT,4X,5HNUMRT,5X,15HROUTING REACHE
     1S)
      PRINT 1035
      PRINT 1026,(RDINP(I),I=1,10)
      RTLEN=RDINP(1)
      HYDINT=RDINP(2)
      NUMRT=RDINP(3)
      PRINT 1035
      N=NUMRT
      IF(NUMRT-7)1235,1235,1233
```

```
 1233 READ 1234,(REACH(I),I=8,N)
      PRINT 1026,(REACH(I),I=8,N)
 1234 FORMAT(2X,F6.0,9F8.0)
 1235 DO 1236 I=1,7
 1236 REACH(I) = RDINP(I+3)
      GO TO 1135
C           WRITE ALL DATA ON TAPE 6
C         READ ANY CARD
C
C           EJ CARD HAS BEEN READ - LAST CARD FOR JOB
C
 1240 REWIND 6
      IPRNT=15
      SECNO=0.0
 1245 ISECN=IZERO
      IEARP=IZERO
      ISWT3=0.0
      ISWT2=0.0
      ISARA=STRT
      IF(ITRACE-1) 1260,1255,1250
 1250 ISWT2=1
 1255 ISWT3=1
 1260 IF(STRT)1261,1270,1265
 1261 PRINT 3720
      GO TO 1270
 1265 SLOPE=STRT
      ISARA=10
 1270 HR23=ZERO
      XWSEL=ZERO
      AROB=ZERO
      Q1ROB=ZERO
      Q1LOB=ZERO
      ICASE=IZERO
      WSELT=ZERO
      TWLEN=ZERO
      TSECN=ZERO
      WTN=ZERO
      WSELK=ZERO
      TIME=0.0
      CINTS=0.0
      XNINS=-2.
      CUMDS=ZERO
      IWSGS=0
C         *    *    *    *    *    *    *    *    *    *    *    *    *
C
      VOL=ZERO
      TWA=0.0
      IF(JQCON-1)1273,1273,1280
 1273 IF(J3)1274,1274,1280
 1274 DO 1275 I=1,7
 1275 IVAR(I)=I
 1280 IF(HVINS)1305,1285,1300
 1285 IF(METRIC) 1290,1290,1295
 1290 HVINS=.5
      GO TO 1300
 1295 HVINS=.152
C
 1300 IWSGS=1
      GO TO 1310
 1305 HVINS=1000.
```

```
 1310 WSELT=WSEL
      QCOMP=0.0
      WSELK=WSEL
      PRINT 1035
      IF (ISARA)1320,1315,1320
C          KNOWN WATER SURFACE EL
 1315 XKWSE  = WSEL
 1320 EGPRS=ZERO
      IBRID=IZERO
      KSEC1 = IZERO
      ENCFP=ZERO
      CLASS=0.0
C
C          *    *    *    *    *    *    *    *    *    *    *    *    *
C
C
 1325 IF(CINTS-XNINS)1610,1610,1330
C
C          READ CARD AND IDENTIFY
C
 1330 IF(IRDX1) 1332,1332,1331
 1331 IRDX1=0
      GO TO 1333
 1332 READ(6,1000)IA,(RDINP(I),I=1,10)
 1333 IF(ISWT3) 1335,1335,1334
 1334 PRINT 1001,IA,(RDINP(I),I=1,10)
 1335 DO 1339 I=1,17
      IF(IA-IDCRD(I))1339,1345,1339
C
 1339 CONTINUE
      PRINT 1340
 1340 FORMAT(25H 1340 CARD NOT RECOGNIZED)
      PRINT 1000,IA,(RDINP(I),I=1,10)
      I=18
C          IS CURRENT CARD AN X1 CARD
 1345 IF(NSTRD) 1347,1347,1355
C            IS CURRENT CARD X2 OR X3 OR BT OR X4 OR CI
 1348 IF(I-9) 1346,1355,1346
 1347 IF(I-8) 1348,1355,1348
 1346 IF(I-12) 1351,1355,1351
 1351 IF(I-17) 1352,1355,1352
 1352 IF(I-10)1349,1355,1349
C          NO GR CARDS, START COMPUTATION
C          STORE    CARD FOR FUTURE XSECTION
 1349 DO 1350 I=1,10
 1350 RDSTR(I)=RDINP(I)
      IRDX1=10
      GO TO 1865
 1355 ICRDP=I
C              J1   J2   NC   QT   NH   NV   X1   X2   X3   CI   SB   BT
C       GR     EJ   ER   ET   X4
C               1    2    3    4    5    6    7    8    9   10   11   12
      GO TO (1150,1190,1370,1405,1485,1450,1540,1715,1780,1795,1360,1800
     1,1865,1065,3895,1536,1791,1065),I
C
C          *    *    *    *    *    *    *    *    *    *    *    *    *
C
C          COMPUTE WSEL FOR BRIDGE ROUTINE FOR LOW FLOW CONTROL
C
C          SB CARD - SPECIAL BRIDGE ROUTINE
```

```
 1360 XK= RDINP(1)
      XKOR= RDINP(2)
      COFQ= RDINP(3)
      RDLEN= RDINP(4)
      BWC= RDINP(5)
      BWP= RDINP(6)
      BAREA= RDINP(7)
      SECNO=-SECNO
      ISB=10
      IF(XKOR) 1361,1361,1363
 1361 XKOR=1.2
      PRINT 1362
 1362 FORMAT(27H 1362 XKOR INCREASED TO 1.2)
 1363 IF(BWC) 1364,1364,1366
 1364 PRINT 1365
 1365 FORMAT(19H 1365 SB CARD,BWC=0)
      GO TO 3785
 1366 IF(BAREA) 1367,1367,1369
 1367 PRINT 1368
 1368 FORMAT(21H 1366 SB CARD,BAREA=0)
      GO TO 3785
 1369 CALL BLFLO
C          *    *    *    *    *    *    *    *    *    *    *    *    *
      IF  (IEND)1330,1330,3785
C
C          READ CARD NC - NEW N VALUES OR SHOCK LOSSES
 1370 INC=10
      NUMNV=0
      NUMNH=0
      DO 1390 I=1,3
      IF(RDINP(I)) 1390,1390,1374
 1374 GO TO (1375,1380,1385),I
 1375 XNL=RDINP(1)*FN
      GO TO 1390
 1380 XNR=RDINP(2)*FN
      GO TO 1390
 1385 XNCH=RDINP(3)*FN
      GO TO 1390
 1390 CONTINUE
      IF(RDINP(4)) 1330,1330,1395
 1395 CCHV=RDINP(4)
      CEHV=RDINP(5)
      IPRNT=IPRNT+1
      PRINT 1400,CCHV,CEHV
 1400 FORMAT(6H CCHV=,F8.3,6H CEHV=,F8.3)
      GO TO 1330
C
C          QT CARD
 1405 NUMQ=RDINP(1)
      IF(NUMQ-INQ+1) 1410,1420,1420
 1410 PRINT 1415
 1415 FORMAT(22H 1415 INQ EXCEEDS NUMQ)
      GO TO 3785
 1420 IF(NUMQ-9)1425,1425,1430
 1425 IF(RDINP(INQ)) 1426,1426,1427
 1426 Q=RDINP(2)
      GO TO 1428
 1427 Q=RDINP(INQ)*FQ
 1428 IF(Q)1530,1530,1330
 1430 READ(6,1002)  (RDINP(I),I=11,20)
```

```
      IF(INQ-20)1435,1435,1440
 1435 Q=RDINP(INQ)*FQ
      IF(Q)1530,1530,1330
 1440 PRINT 1445
 1445 FORMAT(18H 1445 Q EXCEEDS 19)
      GO TO 3785
C
C
C           NV CARD-CHANGE MANNINGS N BY ELEV TABLE
 1450 NUMNV= RDINP(1)
      IF(NUMNV-20) 1453,1453,1451
 1451 PRINT 1452
 1452 FORMAT(23H 1452 NV CARDS EXCEED 4)
      NUMNV=20
 1453 NN=NUMNV*2+1
      PRINT 1455
 1455 FORMAT(18H 1455 NV CARD USED)
      IF(NUMNV-4)1465,1465,1460
 1460 READ(6,1002)   (RDINP(I),I=11,NN)
 1465 ELN(1)=RDINP(3)
      VALN(1)=RDINP(2)*FN
      DO 1470 N=2,NUMNV
      ELN(N)=RDINP(2*N+1)
      IF(ELN(N)-ELN(N-1)) 1480,1470,1470
C
 1470 VALN(N)=RDINP(2*N)*FN
      IF(ISWT3) 1330,1330,1475
 1475 TRACE=1470.
      PRINT 1025,TRACE,(VALN(N),ELN(N),N=1,NUMNV)
      GO TO 1330
 1480 PRINT 1481
 1481 FORMAT(25H 1481 EL(N) DONT INCREASE)
      GO TO 3785
C
C           *    *    *    *    *    *    *    *    *    *    *    *    *
C           NH CARD - TABLE N VALUES
C
 1485 NUMNH= RDINP(1)
      PRINT 1490
 1490 FORMAT(18H 1490 NH CARD USED)
      NN=NUMNH
      NN=NN*2+1
      IF(NUMNH-20) 1495,1495,1520
 1495 IF (NN-10)1510,1510,1505
 1505 READ(6,1002)  (RDINP(I),I=11,NN)
 1510 NN=(NN-1)/2
      VALN(1)=RDINP(2)*FN
      STN(1)=RDINP(3)
      DO 1515 I=2,NN
      VALN(I)=RDINP(2*I)*FN
      STN(I)=RDINP(2*I+1)
      IF(STN(I)-STN(I-1)) 1517,1515,1515
C
 1515 CONTINUE
      VALN(NN+1)=VALN(NN)*FN
      STN(NN+1)=STN(NN)+100000.
      GO TO 1330
 1517 PRINT 1518
 1518 FORMAT(37H 1518 NH CARD STATIONS NOT INCREASING)
      GO TO 3785
```

```
 1520 PRINT 1525
 1525 FORMAT(25H 1525 NH VALUES EXCEED 20)
      GO TO 3785
C
 1530 PRINT 1535
 1535 FORMAT(/9H 1535 Q=0/)
      GO TO 3785
C
C            ENCROACHMENT TABLE READ
 1536 ENCFP=RDINP(INQ)
       IECCD=10
      GO TO 1330
C
C            *    *    *    *    *    *    *    *    *    *    *    *    *
C            X1 CARD - FIRST GENERAL CROSS SECTION CARD
C
C
 1540 SECNP=SECNO
      SECNO=RDINP(1)
      CINTS=0.0
      XNINS=-2.
      CAREA=ZERO
      IF(NPROF-1)1545,1545,1551
 1545 JQCON=1
 1551 IF(INC) 1552,1552,1554
 1552 PRINT 1553
 1553 FORMAT(30H 1553 STARTING NC CARD OMITTED)
 1554 IF(IDIR) 1560,1560,1555
 1555 XLOBL=PXLOBL
      XLOBR=PXLOBR
      XLCH=PXLCH
      PXLOBL=RDINP(5)
      PXLOBR=RDINP(6)
      PXLCH=RDINP(7)
      GO TO 1565
 1560 XLOBL=RDINP(5)
      XLOBR=RDINP(6)
      XLCH= RDINP(7)
 1565 PXSECR=RDINP(8)
      OXLCH=XLCH
      IF(PXSECR)1566,1566,1567
 1566 PXSECR=1.
 1567 IF(ITRACE-1)1570,1575,1575
 1570 ISWT2=0
      ISWT3=0
 1575 PXSECE=RDINP(9)
      IF(ISECN)1585,1585,1580
 1580 WSELK=0.0
C            PLOT ONLY CROSS SECTIONS DESIRED
 1585 IF(RDINP(10)) 1595,1595,1590
 1590 PLOT=RDINP(10)
      GO TO 1605
 1595 PLOT =0.0
      IF(IPLOT) 1605,1605,1600
 1600 PLOT=IPLOT
C            INITIALIZE DATA ON X2,X3 CARDS IN CASE CARDS NOT READ
C
 1605 IBRID=0
      BASIN=0.0
      BLOSS=0.
```

```
      ELLC=9999999.
      ELTRD=9999999.
      IEARA=0
      ELSED=0.0
      ELLEA=0.0
      ELREA=0.0
      ELWAS=9999999.
      BSQ=1.0
      IF(ENCFP)1604,1604,1602
 1602 ELENCL=100000.
      ELENCR=100000.
      IF(RDINP(2)) 1603,1603,1601
 1601 STCHL=RDINP(3)
      STCHR=RDINP(4)
 1603 STENCL=(STCHL+STCHR-ENCFP)*.5
      STENCR=(STCHL+STCHR+ENCFP)*.5
      GO TO 1606
 1604 STENCL=0.0
      ELENCL=0.0
      ELENCR=0.0
      STENCR=0.0
 1606 NSTRD=RDINP(2)
      REPBT=0.0
      NELT=0
C
C           CHECK FOR USING PREVIOUS CROSS SECTION FOR CURRENT
C
      IF(NSTRD) 1611,1611,1705
C     RETURN TO ORIGINAL CROSS SECTION DATA
 1611 IF(STENLP)1614,1614,1612
 1614 IF(STENCR)1619,1619,1618
 1619 IF(ICHIMP)1613,1613,1612
 1618 STENCL=.001
 1612 NUMST=NUMSTO
      NLCH=NLCHO
      NRBEL=NRBELO
      ELMAX=ELMAXO
      TELMX=TELMXO
 1613 DO 1607 I=1,NUMST
      EL(I)=ELO(I)
 1607 STA(I)=STAO(I)
      IF(ISWT3)1655,1655,1616
 1616 TRACE=1616.
      PRINT 1025,TRACE,(EL(I),STA(I),I=1,NUMST)
C              CARDS 1617,1608,1609,1609+1 REMOVED
      GO TO 1655
C           PXSECR  = FACTOR TO INCREASE AREA OF CROSS SECTION
C           CALCULATE INTERPOLATED CROSS SECTION
C
 1610 CINTS=CINTS+1.
      Y=(XNINS-CINTS+1.)/(XNINS+1.)
      IF(AREAT)1615,1615,1620
 1615 AREAT=PAT
 1620 X=1.+((PAT/AREAT)-1.)*Y
      TEM=SECNO
      SECNO=1.+CINTS*.01
      PCARA=CAREA
 1625 CAREA=X
      IF(CINTS-1.)1630,1630,1635
 1630 PXSECR=X
```

```
      X=PELMN-ELMIN
      PXSECE  =X*Y
      ELINS=-X*(1.-Y)
      SECNP=TEM
      NRDP=NRD
      ELLCP=ELLC
      ELTRP=ELTRD
      X=1./(XNINS+1.)
      TELLEA=X*(ELLEA-PELLEA)
      TELREA=X*(ELREA-PELREA)
      ELLEA=PELLEA+TELLEA
      ELREA=PELREA+TELREA
      QINT=(Q-PQ)/(XNINS+1.)
      Q=QINT+PQ
C           DO NOT USE ELTRD,ELLC FOR INTERPOLATED CROSS SECTION
      ELLC=9999999.
      ELTRD=9999999.
      RDINP(5)=0.0
      NRD=0
      GO TO 1640
 1635 PXSECR= CAREA/PCARA
      PXSECE=ELINS
      TEM=SECNO-.01
      Q=QINT+PQ
      ELLEA=PELLEA+TELLEA
      ELREA=PELREA+TELREA
 1640 PRINT 1645,TEM,PXSECE ,PXSECR
 1645 FORMAT (/34H 1645 INT SEC ADDED BY RAISING SECF10.2, 1H, F8.3,21HF
     1T AND MULTIPLYING BY,F8.3/)
      IPRNT=IPRNT+3
      IF(CINTS-XNINS)1655,1655,1650
 1650 SECNO=SECNP
      NRD=NRDP
      ELLC=ELLCP
      ELTRD=ELTRP
 1655 X=STA(1)
C           PXSECE=UNIFORM INCREMENT TO ADD TO ALL ELEVATIONS
      EL(1)=EL(1)+PXSECE
      DO 1660 N=2,NUMST
      EL(N)=EL(N)+PXSECE
      TEM=(STA(N)-X)*PXSECR
      X=STA(N)
 1660 STA(N)=STA(N-1)+TEM
      NRD=0
 1685 STCHL=STA(NLCH)
      STCHR=STA(NRBEL)
      IF(ENCFP) 1688,1688,1686
 1686 STENCL=(STCHL+STCHR-ENCFP)*.5
      STENCR=(STCHL+STCHR+ENCFP)*.5
 1688 RBEL=EL(NRBEL)
      XLBEL=EL(NLCH)
      STMAX=STA(NUMST)
      ELMIN=ELMIN+PXSECE
      ELMAX=ELMAX+PXSECE
      TELMX=TELMX+PXSECE
      IF(ELLC-99999.) 1690,1695,1695
 1690 ELLC=ELLC+PXSECE
 1695 IF (ISWT3)1710,1710,1700
 1700 TRACE=1700.
      PRINT 1701
```

```
 1701 FORMAT (/6H TRACE,9X,8HRDINP(2),2X,8HRDINP(3),2X,
     15HELMAX,5X,5HELMIN,5X,5HTELMX,5X,5HSTMAX,5X,
     25HSTCHL,5X,5HSTCHR/)
      PRINT 1025,TRACE,RDINP(2),RDINP(3),ELMAX,ELMIN,TELMX,STMAX,STCHL,
     1STCHR
      PRINT 1702
 1702 FORMAT (10X,22HEL(N),STA(N),N=1,NUMST)
      PRINT 1025,(EL(N),STA(N),N=1,NUMST)
      PRINT 1703
 1703 FORMAT (10X,14HRDINP(I),I=1,8)
      PRINT 1025,(RDINP(I),I=1,8)
      PRINT 1704
 1704 FORMAT (/6H TRACE,9X,5HCINTS,5X,6HXNINTS,4X,3HPAT,7X,
     15HAREAT,5X,5HELINS,5X,5HPELMN,5X,5HELMIN,5X,3H  X,7X,
     23H  Y,7X,5HCAREA,5X,5HPCARA/)
      PRINT 1025,TRACE,CINTS,XNINS,PAT,AREAT,ELINS,PELMN,ELMIN,X,Y,
     1CAREA,PCARA
      IPRNT=IPRNT+4
      GO TO 1710
C
C           ***********************************************************
C
 1705 STCHL=RDINP(3)
      STCHR=RDINP(4)
      NUMST= RDINP(2)
      NRD=0
      IF(STCHR-STCHL) 1706,1710,1710
 1706 PRINT 1707,STCHL,STCHR
 1707 FORMAT(14H 1707 STCHL OF,F10.2,19H GREATER THAN STCHR,F10.2)
      STCHL=STA(2)
C         CARD DELETED
 1710 IF(CINTS-1.-XNINS) 1865,1865,1330
C
C           X2 CARD
C
 1715 IF(RDINP(1)) 1725,1725,1720
 1720 Q=RDINP(1)*FQ
 1725 IF(RDINP(2))1735,1735,1730
 1730 WSELK=RDINP(2)
 1735 IBRID=RDINP(3)
      BSQ=RDINP(9)
      IF(BSQ)1733,1733,1734
 1733 BSQ=1.
 1734 CMOM=RDINP(8)
      IF(CMOM)1731,1731,1732
 1731 CMOM=2.
 1732 BLOSS=RDINP(6)
      IF(NSTRD) 1736,1736,1740
 1736 REPBT=RDINP(7)
      IF(REPBT) 1740,1740,1737
 1737 IF(NRDP) 1740,1740,1738
 1738 NRD=NRDP
      DO 1739 N=1,NRD
 1739 XLCEL(N)=XLCEL(N)+PXSECE
      ELLC=ELLCP
      ELTRD=ELTRP
      IF(ISWT3)1740,1740,1741
 1741 TRACE=1741.
      X=NRDP
      PRINT 1040, TRACE,ELLC,ELTRD,X
```

```
      PRINT 1040,(RDST(I),I=1,NRD)
      PRINT 1040,(RDEL(I),I=1,NRD)
      PRINT 1040,(XLCEL(I),I=1,NRD)
C
C           TRACE ONLY CROSS SECTIONS DESIRED
 1740 IF(RDINP(10)-1.) 1755,1750,1745
C
 1745 ISWT2=1
C
 1750 ISWT3=1
      GO TO 1760
 1755 IF(ITRACE-1) 1760,1750,1745
 1760 IF(NSTRD) 1765,1765,1770
 1765 IF(RDINP(5)) 1330,1330,1770
 1770 ELTRD = RDINP(5)
      ELLC=RDINP(4)
      IF(REPBT)1773,1773,1774
 1773 NRD=0
 1774 IF(ELTRD)1330,1775,1330
 1775 ELTRD=9999999.
      ELLC=ELTRD
      GO TO 1330
C
C           X3 CARD - EFFECTIVE AREA DESC
 1780 IEARA= RDINP(1)
      ELSED= RDINP(2)
      IF(IECCD)1776,1776,1777
 1776 STENCL=RDINP(4)
      ELENCL= RDINP(5)
      STENCR= RDINP(6)
      ELENCR= RDINP(7)
      ELLEA=RDINP(8)
      ELREA=RDINP(9)
 1777 IF(STENCL)1778,1778,1783
 1778 IF(STENCR)1781,1781,1779
 1779 STENCL=.001
      GO TO 1783
 1781 IF(RDINP(3))1790,1790,1782
 1782 ENCFP=RDINP(3)
      STENCL=(STCHL+STCHR-ENCFP)*.5
      STENCR=(STCHL+STCHR+ENCFP)*.5
 1783 IF(ELENCL)1784,1784,1785
 1784 ELENCL=100000.
 1785 IF(ELENCR)1788,1788,1789
 1788 ELENCR=100000.
 1789 IF(RDINP(3))1790,1790,1786
 1786 ENCFP=RDINP(3)
 1790 ELWAS=RDINP(8)
      GO TO 1330
C           X4 CARD - ADDITIONAL VALUES OF EL, STA TO BE INSERTED IN
C                 GROUND PROFILE DATA (GR CARDS)
 1791 NELT=RDINP(1)
      IF(NELT-5) 1793,1792,1792
 1792 NN=2*NELT+1
      READ (6,1002) (RDINP(I),I=11,NN)
 1793 DO 1794 I=1,NELT
      J=2*I
      ELT(I)=RDINP(J)
 1794 STAT(I)=RDINP(J+1)
      GO TO 1330
```

```
C          CHIMP CARD
 1795 DO 1787 I=1,10
 1787 ICICN(I)=0
      DO 1809 I=1,10
      IF(RDINP(I))1811,1809,1796
 1796 GO TO(1797,1798,1799,1801,1802,1803,1803,1803,1803,1803),I
 1797 CLSTA=RDINP(I)
      GO TO 1809
 1798 CELCH=RDINP(I)
      GO TO 1809
 1799 CNCH=RDINP(I)
      GO TO 1809
 1801 XLSS=RDINP(I)
      GO TO 1809
 1802 RSS=RDINP(I)
      GO TO 1809
 1803 IF(I-IBW)1809,1804,1809
 1804 BW=RDINP(I)
      GO TO 1809
 1811 ICICN(I)=1
 1809 CONTINUE
      IF(BW-.01) 1812,1812,1813
 1812 ICHIMP=0
      GO TO 1330
 1813 ICHIMP=10
      GO TO 1330
C
C          ************************************************************
C          READ BT CARD-TABLES OF BRIDGE LOW CHORD AND TOP OF ROADWAY
C
 1800 DO 1805 I=1,50
      RDST(I)=0.0
      RDEL(I)=0.0
 1805 XLCEL(I)=0.0
      NRD=RDINP(1)
      IF(NRD-52) 1808,1808,1806
 1806 PRINT 1807
 1807 FORMAT(28H 1807 BT CARDS EXCEED 50 PTS)
      GO TO 3785
 1808 NN=3*NRD+1
      IF (NRD-3) 1815,1815,1810
 1810 READ (6,1002)(RDINP(I),I=11,NN)
 1815 DO 1820 I=1,NRD
      J=I*3
      RDST(I+1)= RDINP(J-1)
      RDEL(I+1)= RDINP(J)
 1820 XLCEL(I+1)= RDINP(J+1)
      X=RDST(1)
      J=NRD+1
      DO 1825 N=2,J
      TEM=(RDST(N)-X)*BSQ
      X=RDST(N)
 1825 RDST(N)=RDST(N-1)+TEM
      RDST(1)=RDST(2)
      RDEL(1)=RDEL(2)+10000.
      XLCEL(1)=XLCEL(2)
      NRD=NRD+2
      RDST(NRD)=RDST(NRD-1)
      RDEL(NRD)=RDEL(NRD-1)+10000.
      XLCEL(NRD)=XLCEL(NRD-1)
```

```
C               FIND MAX LOW CHORD AND MIN ROADWAY ELEV
 1835 IF(ELLC-999999.)1855,1855,1836
 1836 ELLC=XLCEL(1)
C         6 CARDS REMODED 1852-1861
      ELTRD=RDEL(1)
      DO 1851 I=1,NRD
      IF(ELLC-XLCEL(I)) 1840,1845,1845
 1840 ELLC=XLCEL(I)
 1845 IF(ELTRD-RDEL(I)) 1851,1851,1850
 1850 ELTRD=RDEL(I)
C
 1851 CONTINUE
C         6 CARDS REMOVED 1852-1861
C           DATA CHECK OF BT CARDS
 1855 DO 1862 I=2,NRD
      IF(RDST(I)-RDST(I-1)) 1856,1858,1858
 1856 PRINT 1857
 1857 FORMAT(31H 1857 BT CARD,STA DONT INCREASE)
      PRINT 1025,(RDINP(J),J=2,NN)
      PRINT 1025,(RDST(J),RDEL(J),XLCEL(J),J=2,NRD)
 1858 IF(RDEL(I)-XLCEL(I)) 1859,1862,1862
 1859 PRINT 1860,XLCEL(I),RDEL(I)
 1860 FORMAT(14H 1860 XLCEL OF,F10.2,16H EXCEEDS RDEL OF,F10.2)
C
 1862 CONTINUE
      GO TO 1330
C
C          ***********************************************************
C          START READING CROSS SECTION CARDS AND
C          ESTABLISHING ELMIN,RBEL,XLBEL,NLCH,RAISE XSECTION
C
C          GR CARD
C
 1865 N = TWO
      EGMAX=0.0
      J=6
      TRIAL=ZERO
      ICONT=ONE
      ITYDC=ZERO
      DPER=0.001
      QC=ZERO
      IFNSA=IZERO
      ITRIL=IZERO
      DIFMN=10000.
      DIFWS=0.0
      IDC=IZERO
      EGCRI=0.0
      IF(IFNCR) 1869,1869,1880
 1869 IF(IDIR)1875,1875,1870
 1870 CRIWS=999999.
      GO TO 1880
 1875 CRIWS=ZERO
 1880 DELMN=ZERO
C
C          READ CARD  CROSS SECTION DATA
C
 1885 IF(CINTS-1.-XNINS) 2105,2105,1890
 1890 IF(NSTRD) 1891,1891,1895
 1891 J=NUMSTO
      K=J
```

```
      X=0.0
      GO TO 1909
 1895 ELMIN=999999.
      NRBEL=1
      NLCH=1
      XLBEL=ZERO
      RBEL=ZERO
      STA(1)=RDINP(2)
      EL(1)=RDINP(1)+50.
      DO 1900 I=2,6
      STA(I)=RDINP(2*I-2)
 1900 EL(I)=RDINP(2*I-3)
      NUMST=NUMST+1
      J=NUMST
      IF(J-6) 1910,1910,1905
 1905 READ (6,1002)    (EL(I),STA(I),I=7,J)
 1910 K=J+1
      STA(K)=STA(K-1)+.01
      EL(K)=EL(K-1)+50.
      DO 1913 I=2,NUMST
      IF(STA(I)-STA(I-1)) 1911,1913,1913
 1911 PRINT 1912
 1912 FORMAT(37H 1912 GR CARDS,STATIONS DONT INCREASE)
      PRINT 1025,(STA(K),K=1,NUMST)
      GO TO 3785
C
 1913 CONTINUE
      X=PXSECE
C           STORE ORIGINAL CROSS SECTION DATA BEFORE ADDING PTS
 1909 DO 1906 I=1,K
      ELO(I)=EL(I)+X
 1906 STAO(I)=STA(I)
      DO 1918 I=1,K
      IF(STCHL-STA(I))1916,1917,1918
 1916 IF(STCHR-STA(I))1919,1919,1918
 1917 NLCHO=I
 1918 CONTINUE
      I=K
 1919 NRBELO=I
      ISECN=ISECN+1
      NUMSTO=K
      TELMXO=EL(K)-50.
      ELMAXO=EL(K)
 1914 IF(STENCL)1908,1908,1907
 1907 IF(STENCR)1927,1926,1927
 1926 STENCR=STA(NUMST)
 1927 CALL ADDPTS(EL,STA,NUMST,STMAX,STCHL,STCHR,ENCFP,
     1 STENCL,ELENCL,ISWT3,STENCR,ELENCR)
      HVINS=1000.
      J=J+4
 1908 IF(ELSED)1922,1924,1922
 1922 DO 1920 I=2,J
      IF(ELSED-EL(I)) 1920,1920,1915
C     CROSS SECTION ELEVATIONS ARE RAISED VERTICALLY TO SEDIMET ELEV
 1915 EL(I)=ELSED
C
 1920 CONTINUE
 1924 IF(ISWT3)1923,1923,1921
 1921 TRACE=1920.
      PRINT 1025,TRACE,ELSED,(EL(I),STA(I),I=2,J)
```

```
      PRINT 1025,TRACE,(ELO(I),STAO(I),I=1,J)
1923  IF(ELENCL) 1960,1960,1925
1925  DO 1955 I=1,J
      IF(STENCL-STA(I)) 1930,1930,1935
1930  IF(STENCR-STA(I))1945,1945,1955
1935  IF(EL(I)-ELENCL) 1940,1940,1955
1940  EL(I)=ELENCL
      GO TO 1955
1945  IF(EL(I)-ELENCR) 1950,1950,1955
1950  EL(I)=ELENCR
1955  CONTINUE
      IF(ISWT3)1960,1960,1957
1957  TRACE=1955.
      PRINT 1026,TRACE,ELENCL,ELENCR,STENCL,STENCR
      PRINT 1026,(EL(I),STA(I),I=1,J)
1960  DO 2025  I=2,J
      IF(EL(I)-ELMIN)1965,1970,1970
1965  ELMIN=EL(I)
1970  IF(STA(I)-STCHR)1980,1975,1980
1975  RBEL=EL(I)
      NRBEL=I
1980  IF(STA(I)-STCHL)1995,1985,1995
1985  IF(DELMN-1.)1990,1995,1995
1990  NLCH=I
      XLBEL=EL(I)
      DELMN=ONE
C
1995  IF(STA(I))2000,2000,2010
2000  IF(I-10)2010,2010,2028
C
2010  IF(I-102)2025,2015,2015
2025  CONTINUE
      I=J
      GO TO 2030
2015  PRINT 2020
2020  FORMAT(35H 2020 NUMBER EL, STA PTS EXCEED 100/)
      X=NUMST
      Y=I
      PRINT 1002,X,Y,(STA(K),K=1,NUMST)
      GO TO 3785
C
C
C          *************************************************************
C          CORRECT FOR SKEW,RAISE OR LOWER ENTIRE SECTION,
C             AND RAISE CROSS SECTION ENDS BY ADDEL FEET
C                PXSECE=INCREMENT TO RAISE OR LOWER ALL ELEVATIONS
C                PXSECR=SKEW COEFFICIENT
2028  I=I-1
2030  IF(NSTRD) 2075,2075,2035
2035  IF(PXSECR-.00001) 2050,2050,2040
2040  X=STA(2)
      DO 2045 IK=3,I
      Y=STA(IK)-X
      X=STA(IK)
2045  STA(IK)=STA(IK-1)+PXSECR*Y
2050  DO 2055 IK=2,I
2055  EL(IK)=EL(IK)+PXSECE
      STCHL=STA(NLCH)
      STCHR=STA(NRBEL)
      RBEL=EL(NRBEL)
```

```
      XLBEL=EL(NLCH)
      ELMIN=ELMIN+PXSECE
      STMAX=STA(I) + .01
      STA(1)=STA(2)
      EL(1)=EL(2)+50.
      I=I+1
      STA(I)=STA(I-1)+ .01
      EL(I)=EL(I-1)+50.
      IF(STENCL)2059,2059,2057
 2057 TELMX=TELMXO
      GO TO 2075
 2059 TELMX=EL(I)-50.
C
 2075 IF(EL(I-1)-EL(2))2080,2085,2085
 2080 ELMAX=EL(I-1)
      YMAX=EL(2)
      GO TO 2090
 2085 ELMAX=EL(2)
      IF(STENCL)2087,2087,2086
 2086 YMAX=TELMX
      GO TO 2090
 2087 YMAX=EL(I-1)
 2090 NUMST = I
      IF(WSEL) 2100,2095,2100
 2095 WSEL=(ELMAX+ELMIN)*.5
      PRINT 2096
 2096 FORMAT(40H 2096 WSEL NOT GIVEN,AVG OF MAX,MIN USED)
 2100 ELMAX=ELMAX+50.
      STMAX=STA(I)
C
 2105 X=NELT
      Y=NUMST
      K=NUMST
      IF(NELT) 2117,2117,2106
 2106 DO 2114 N=1,NELT
      IF(ELT(N)-ELMIN) 2103,2104,2104
 2103 ELMIN=ELT(N)
 2104 DO 2113 I=1,K
      J=NUMST+N-I
      IF(STA(J)-STAT(N))2107,2107,2108
 2107 STA(J+1)=STAT(N)
      EL(J+1)=ELT(N)
      GO TO 2109
 2108 STA(J+1)=STA(J)
      EL(J+1)=EL(J)
      IF(J-NRBEL) 2111,2110,2111
 2110 NRBEL=J+1
 2111 IF(J-NLCH) 2113,2112,2113
 2112 NLCH=J+1
 2113 CONTINUE
      STA(1)=STAT(N)
      EL(1)=ELT(N)
 2109 K=K+1
 2114 CONTINUE
      NUMST=NUMST+NELT
      RBEL=EL(NRBEL)
      XLBEL=EL(NLCH)
      IF(ISWT3) 2116,2116,2115
 2115 TRACE=2115.
      PRINT 1025,TRACE,(STA(I),I=1,NUMST)
```

```
      PRINT 1025,TRACE,(EL(I),I=1,NUMST)
      PRINT 1025,TRACE,(ELT(I),STAT(I),I=1,NELT)
      X=NRBEL
      Y=NLCH
      Z=NELT
      W=NUMST
      PRINT 1002,TRACE,X,Y,Z,W
 2116 NELT=0
      IF(NUMST-100) 2117,2117,2015
 2117 WSELT=WSEL
      IF(STENCL)2121,2121,2119
 2121 DO 2123 K=1,NUMST
      ELO(K)=EL(K)
 2123 STAO(K)=STA(K)
      NLCHO=NLCH
      NRBELO=NRBEL
      ELMAXO=ELMAX
      TELMXO=TELMX
      NUMSTO=NUMST
      IF(ISWT3)2119,2119,2124
 2124 TRACE=2124.
      PRINT 2128,TRACE
 2128 FORMAT(6H TRACE,F8.0)
      PRINT 1025,(EL(N),STA(N),N=1,NUMST)
 2119 IF(ICHIMP)2126,2126,2120
 2120 IF(CINTS-1.-XNINS)2126,2126,2122
 2122 DO 2127 I=1,NUMST
      ELOR(I)=EL(I)
 2127 STAOR(I)=STA(I)
      CLSTA=(CLSTA-STA(1)) *PXSECR+STA(1)
      ELOR(1)=EL(1)-50.
      ELOR(NUMST)=EL(NUMST)-50.
      IF(ICICN(2)) 2139,2139,2138
 2138 CELCH=ELMIN
 2139 IF(ICICN(1)) 2129,2129,2141
 2141 CLSTA=.5*(STCHL+STCHR)
      IF(NSTRD)2143,2143,2129
 2143 CLSTA=.5*(STAO(NLCHO)+STAO(NRBELO))
 2129 CALL CHIMP
      TRIAL=0.0
      PRINT 2137,CLSTA,CELCH,BW,STCHL,STCHR
 2137 FORMAT(1X,5HCHIMP,1X,6HCLSTA=,F10.2,1X,6HCELCH=,F10.2,1X,
     13HBW=,F10.2,1X,6HSTCHL=,F10.2,1X,6HSTCHR=,F10.2)
      IF(CHNIM) 2133,2133,2134
 2134 NUMNH=3
      VALN(1)=XNL
      VALN(2)=XNCH
      VALN(3)=XNR
      STN(1)=STCHL-CHNIM
      STN(2)=STCHR+CHNIM
      STN(3)=STMAX
      PRINT 2136,(VALN(I),STN(I),I=1,3)
 2136 FORMAT(1X,4H2136,10H NH VALUES,6F12.3)
 2133 EL(1)=EL(1)+50.
      EL(NUMST)=EL(NUMST)+50.
 2126 IF(WSEL)2125,2118,2125
 2118 WSEL=ELMIN+TEN
      WSELT=WSEL
C
C
```

```
 2125 N=1
      IF(KSEC1)2150,2150,2130
C             ASSUME 1ST ESTIMATE OF WATER SURFACE EL FOR ALL BUT 1ST
C                SECTION AND BRIDGE
C
 2130 IF(IBRID)2135,2135,2150
 2135 IF(IWSGS)2140,2145,2140
 2140 WSEL=ELMIN+PCWSE-PELMN
      WSELT=WSEL
      ICASE=ONE
      GO TO 2150
 2145 WSEL=WSEL+SAVE*.3333*(XLOBL+XLOBR+XLCH)
      WSELT=WSEL
      ICASE=TWO
C
C          ****************************************************************
C          CHECK AND CORRECT WSEL FOR MAX AND MIN ELEVATIONS
C
 2150 IF(NINV)2160,2160,2155
 2155 WSEL=WSELK
 2160 IF(IFNCR)2162,2162,2163
 2162 N=2
      GO TO 2230
 2163 IF(ELMIN-WSEL)2170,2165,2165
C
 2165 WSEL=ELMIN+DELMN
      ICASE=TWO+ONE
      DELMN = DELMN+ONE
 2170 N=TWO
 2175 IF(WSEL-ELMAX)2195,2180,2180
 2180 X    =ELMAX-.01
      IF(X-XWSEL)2190,3835,2190
C          BRANCH WHEN SECTION IS NOT HIGH ENOUGH
C
 2190 IF(BLOSS)2192,2192,3835
 2192 WSEL=X
      ICASE=TWO+TWO
C
C          ****************************************************************
C          CHECK WSEL FOR RIGHT SIDE OF CRITICAL DEPTH
C
 2195 IF(IDIR)2215,2215,2200
 2200 IF(WSEL-CRIWS)2230,2230,2205
 2205 IF(KSEC1-10)3715,2210,2210
 2210 WSEL=CRIWS-DPER*(CRIWS-ELMIN)
      ICASE=TEN/TWO
      DPER=DPER+.01
      GO TO 2230
 2215 IF(WSEL-CRIWS)2220,2230,2230
 2220 IF(KSEC1-10)3715,2225,2225
 2225 WSEL=CRIWS+DPER*(CRIWS-ELMIN)
      ICASE=TEN/TWO
      DPER=DPER+.01
C
C          ****************************************************************
C          OMIT LEFT O.B. AREA IF NOT EFFECTIVE
C
 2230 IF(ELMAX-WSEL)3835,2235,2235
 2235 IF(IFARA)2260,2260,2237
 2237 IF(ELLEA)2238,2238,2240
```

```
 2238 ELLEA=XLBEL
      ELREA=RBEL
 2240 IF(WSEL-ELLEA)2245,2245,2260
 2245 N=NLCH+1
      ELMIN=EL(N-1)
      DO 2255 J=N,NRBEL
      IF(ELMIN-EL(J))2255,2255,2250
 2250 ELMIN=EL(J)
C
 2255 CONTINUE
C
C
C
 2260 IF(EL(N)-WSEL)2270,2265,2265
 2265 N=N+1
      IF(N-NUMST)2260,2165,2165
C
C          ***************************************************************
C          INITIALIZE DATA
C
 2270 TLENO=ZERO
      TQ=ZERO
      IFNIS=IZERO
      ALOB=ZERO
      Q1LOB=ZERO
      ACH=ZERO
      WPCH=ZERO
      AROB=ZERO
      Q1ROB=ZERO
      TWR=ZERO
      TWL=ZERO
      TWCH=ZERO
      CORRP=ZERO
      CORAR=ZERO
      IDIVF=ZERO
      ESTEN=STMAX
      SSTEN=0.0
      NSTRT=N-1
      IF(Q) 1530,1530,2275
C
C          ***************************************************************
C          COMPUTE STARTING STA FOR X SECTION
C
 2275 X=(EL(N-1)-WSEL)/(EL(N-1)-EL(N))
      Y=X*(STA(N)-STA(N-1))+STA(N-1)
      XST=Y
 2345 XHT=ZERO
      XEL=WSEL
 2350 IF(WSEL-EL(N)) 2825,2830,2352
 2352 ST=STA(N)
      ELEV=EL(N)
C
C          ***************************************************************
C          LOOK UP TABLE VALUE OF ELTRD AND ELLC
      XELLC = ELLC
      XRDEL = ELTRD
 2355 IF(NRD)2385,2385,2360
 2360 IF(RDST(1)-ST)2370,2370,2365
 2365 XELLC=9999999.
      XRDEL=9999999.
```

```
      GO TO 2385
 2370 DO 2375 I=2,NRD
      IF(RDST(I)-ST)2375,2372,2380
 2372 IF(XST-ST)2373,2374,2374
 2373 XRDEL=RDEL(I)
      XELLC=XLCEL(I)
      GO TO 2385
 2374 IF(RDST(I)-RDST(I+1))2373,2376,2373
 2376 XRDEL=RDEL(I+1)
      XELLC=XLCEL(I+1)
      GO TO 2385
C
 2375 CONTINUE
      XRDEL=9999999.
      XELLC=9999999.
      GO TO 2385
 2380 X = (ST-RDST(I-1))/(RDST(I)-RDST(I-1))
      XRDEL = X * (RDEL(I)-RDEL(I-1)) + RDEL(I-1)
      XELLC = X * (XLCEL(I)-XLCEL(I-1)) + XLCEL(I-1)
C
 2385 XLEN=ST-XST
      IF(XLEN+.01)2387,2390,2390
 2387 PRINT 3800
      PRINT 1025,SECNO,XST,ST,STA(N),STA(N+1),STA(N-1),STA(N+2)
      XLEN=0.0
      XST=ST
 2390 HT=WSEL-ELEV
C
C           ****************************************************************
C           CORRECT AREA FOR BRIDGE DECK
C
      CORR=ZERO
C           CORRECT WP FOR LENGTH OF LOW CHORD
      CORLN = ZERO
      IF (IBRID) 2395,2395,2460
 2395 IF(HT)2445,2445,2400
 2400 IF(WSEL-XRDEL)2405,2420,2420
 2405 IF(WSEL-XELLC)2445,2445,2410
 2410 CORR=-(WSEL-XELLC)
      CORLN=ST-XST
      IF(XELLC-ELEV-.01)2415,2415,2445
 2415 CORR = -(WSEL-ELEV)
      CORLN = ZERO
      GO TO 2445
 2420 IF(ELEV-XRDEL)2425,2460,2460
 2425 IF(XELLC-ELEV)2440,2430,2430
 2430 CORR=-(XRDEL-XELLC)
      CORLN = TWO*(ST-XST)
      IF(XEL-XELLC)2445,2445,2435
 2435 CORLN = (ST -XST) * (XELLC - ELEV)/(XEL-ELEV)  +ST-XST
      GO TO 2445
 2440 CORR = -XRDEL+ELEV
 2445 IF(XRDEL-99999.) 2450,2460,2460
 2450 X=XRDEL-XELLC
      IF(CORR-X)2460,2460,2455
 2455 CORR=X
 2460 HT=HT+CORR
      IF(HT)2465,2475,2475
 2465 PRINT 2467
 2467 FORMAT(12H 3810 HT IS-)
```

```
      TRACE=2465.
      PRINT 1055,TRACE,HT,CORR,XELLC,XRDEL,ST,ELEV,WSEL,CORLN
      HT=ZERO
C
C          *************************************************************
C          COMPUTE AREA
C
 2475 AREA=.5*(XHT+HT)*XLEN
      CORAR=XLEN*.5*(CORR+CORRP)+CORAR
      CORRP=CORR
      X=ELEV-XEL
      IF(X)2480,2485,2485
 2480 X=-X
C
C          *************************************************************
C          COMPUTE WETTED PERIMETER
C
 2485 WETPR=((ST -XST)*(ST-XST) + X*X)**.5 + CORLN
C
C          ADJUST WETTED PERIMETER FOR VERTICAL SIDE SLOPES
C
 2495 IF(STCHL-ST)2505,2500,2510
 2500 IF(STA(N)-STA(N-1))2510,2505,2510
C
 2505 IF(STCHR-ST)2510,2615,2615
C     CHECK LEFT SIDE OF ELEMENT FOR VERTICAL (EXCLUDING CHANNEL)
 2510 IF(ST-XST)2595,2595,2515
 2515 IF(N-3)2555,2520,2520
 2520 IF(STA(N-2)-STA(N-1))2555,2525,2525
 2525 IF(WSEL-EL(N-2))2540,2530,2530
 2530 IF(EL(N-1)-EL(N-2))2535,2555,2555
 2535 X     =       EL(N-2)-EL(N-1)
      GO TO 2545
 2540 X     =       WSEL-EL(N-1)
 2545 IF(X) 2555,2555,2550
 2550 WETPR=WETPR+X
 2555 IF(STA(N)-STMAX)2560,2595,3815
 2560 IF(STA(N+1)-STA(N))2565,2565,2595
 2565 IF(WSEL-EL(N+1))2580,2570,2570
 2570 IF(EL(N)-EL(N+1))2575,2595,2595
 2575 X     =       EL(N+1)-EL(N)
      GO TO 2585
 2580 X     =       WSEL-EL(N)
 2585 IF(X) 2595,2595,2590
 2590 WETPR=WETPR+X
C          *************************************************************
C          COMPUTE HYDRAULIC RADIUS
C
 2595 IF(AREA-.1)2600,2600,2605
C
 2600 HR23=.01
      GO TO 2615
 2605 IF(WETPR)2600,2600,2610
 2610 HR23=(AREA/WETPR)**.6667
C
C          *************************************************************
C          FIND CURRENT N VALUE, REACH LENGTH, AND TOP WIDTH
C
C
 2615 NTEST=0
```

```
      IF(STCHL-ST)2635,2625,2630
 2625 IF(XST-STCHL)2630,2635,2630
C
 2630 XNCUR=XNL
      ICH = ONE
      TWL=TWL+ST-XST
      GO TO 2680
C
 2635 IF(STCHR-ST)2650,2640,2640
 2640 XNCUR=XNCH
      ACH=ACH+AREA
      WPCH=WPCH+WETPR
      VEL=ZERO
      Q1=ZERO
      ICH = ZERO
      TWCH=TWCH+ST-XST
      NTEST=1
      GO TO 2680
 2650 IF(IFARA)2660,2660,2651
 2651 IF(ELREA)2652,2652,2655
 2652 ELREA=RBEL
 2655 IF(WSEL-ELREA)2855,2855,2660
C
 2660 XNCUR=XNR
      TWR=TWR+ST-XST
      ICH = ONE
      GO TO 2680
 2665 IF(XNCUR) 2670,2670,2675
 2670 TRACE=2670.
      PRINT 1025,TRACE,XNCUR,XNCH,XNL,XNR,ST,STCHL,STCHR
      XNCUR=.001
 2675 VEL=(CONST/XNCUR)*HR23*.01
      Q1=VEL*AREA
      GO TO 2755
C
C           FIND N VALUE IN TABLE - N VS STATION
C
 2680 IF(NUMNH) 2700,2700,2685
 2685 DO 2690 I=1,NUMNH
      IF(STN(I)-ST)2690,2695,2695
C
 2690 CONTINUE
      XNCUR = VALN(NUMNH)
      GO TO 2750
 2695 XNCUR = VALN(I )
      GO TO 2750
C
C
C     FIND VALUE IN TABLE - N VS ELEVATION
C
 2700 IF(NUMNV) 2750,2750,2705
 2705 IF(NTEST) 2750,2750,2710
C           IS WSEL WITHIN TABLE LIMITS
 2710 IF(WSEL-ELN(1)) 2720,2730,2715
 2715 IF(WSEL-ELN(NUMNV)) 2730,2730,2720
C
 2720 PRINT 2725
 2725 FORMAT(49H 2725 WSEL EXCEEDS LIMITS OF TABLE FOR MANNINGS N)
C           DETERMINE N VALUE
C
```

```
 2730 DO 2735 I=2,NUMNV
      IF(WSEL-ELN(I)) 2740,2745,2735
C
 2735 CONTINUE
      I=NUMNV
 2740 X =  ELN(I)-ELN(I-1)
      Y =  WSEL-ELN(I-1)
      Z=Y/X
      XNCUR=Z     *(VALN(I   )-VALN(I-1))+VALN(I-1)
      IF(ISWT3) 2743,2743,2742
 2742 TRACE=2740.
      PRINT 1025,TRACE,XNCUR,WSEL,ST
 2743 XNCH=XNCUR
      GO TO 2750
 2745 XNCUR=VALN(I)
      XNCH=XNCUR
 2750 IF(ICH)2755,2755,2665
C
C
C
 2755 IF(STCHR-STA(N))2760,2765,2765
 2760 AROB=AROB+AREA
      Q1ROB=Q1ROB+Q1
      GO TO 2775
 2765 IF(STCHL-STA(N))2775,2770,2770
 2770 ALOB=ALOB+AREA
      Q1LOB=Q1LOB+Q1
C
C          ************************************************************
C          PROGRAMMED TRACE
C
C
 2775 IF(ISWT2)2780,2785,2780
 2780 PRINT 2781
 2781 FORMAT (//50H       N       ELEV          ST         AREA      WETPER,
     120H       HR23         VEL)
      X=N
      PRINT 1025, X,ELEV,ST,AREA,WETPR,HR23,VEL
      PRINT 2782
 2782 FORMAT(/50H       Q1         ACH         WPCH      AROB      Q1ROB   ,
     118H     ALOB      Q1LOB)
      PRINT 1025, Q1,ACH,WPCH,AROB,Q1ROB,ALOB,Q1LOB
      PRINT 2783
 2783 FORMAT(/87H      CORR        HT          XHT       WSEL         XST
     1CORLN    XRDEL     XELLC      XNCUR)
      PRINT 1025, CORR,HT,XHT,WSEL,XST,CORLN,XRDEL,XELLC,XNCUR
      IPRNT=IPRNT+ITEN
C
C          ************************************************************
C
 2785 IF(STA(N)-STMAX)2790,2855,3815
 2790 XHT=HT
      XST=ST
      XEL=ELEV
      N=N+1
C          IS THIS POSSIBLY THE LAST INC. AREA IN X SECTION
      IF(IFNIS)2815,2815,2835
C          NOT LAST INCREMENTAL AREA
 2815 IF(WSEL-EL(N))2825,2830,2820
 2820 ST=STA(N)
```

```
      ELEV=EL(N)
      GO TO 2355
C
C           NEXT AREA PROBABLY WILL BE LAST INC. AREA
C
C           CALCULATE ENDING STATION
C
 2825 X=(WSEL-EL(N-1))/(EL(N)-EL(N-1))
      Y=X*(STA(N)-STA(N-1))+STA(N-1)
      ST=Y
      NLST=N
      ELEV=WSEL
      IFNIS=ITEN
      GO TO 2355
C
 2830 IFNIS=ITEN
      ST=STA(N)
      ELEV=WSEL
      GO TO 2355
C
C           ************************************************************
C           MAKE SURE THAT WAS LAST INC. AREA IN X SECTION
C
 2835 N=N-1
 2840 N=N+1
      IF(EL(N)-WSEL)2850,2845,2845
 2845 IF(STMAX-STA(N))3815,2855,2840
 2850 IFNIS=IZERO
C           IT WAS NOT LAST INC. AREA
      IDIVF=TEN
      GO TO 2275
C
C           ************************************************************
C           CALCULATE SLOPE OF E.G. EL
C
 2855 IF(ACH)2865,2860,2865
 2860 V1CH=ZERO
      R23CH=ZERO
      GO TO 2880
 2865 R23CH=(ACH/WPCH)**.6667
      IF(XNCH) 2870,2870,2875
 2870 V1CH=.01
      GO TO 2880
 2875 V1CH=(CONST/XNCH)*R23CH*.01
C
 2880 Q1CH=V1CH*ACH
      IF(TRIAL-0.)2885,2885,2895
 2885 IF(CINTS)2890,2890,2895
 2890 AREAT=ACH
C
 2895 TQ=Q1CH+Q1ROB+Q1LOB
      TLENQ=Q1CH*XLCH+Q1ROB*XLOBR+Q1LOB*XLOBL
      TQ=TQ+.0001
      AVGLN=TLENQ/TQ
      S=((.01*Q)/TQ)**2
      IF(ISWT3) 2899,2899,2896
 2896 TRACE=2896.
      Y=KSEC1
      X=ICASE
      PRINT 1025,TRACE,S,Q,TQ,TLENQ,Q1CH,Q1ROB,Q1LOB,AVGLN,V1CH,V1ROB
```

```
      PRINT 1025,TRACE,V1LOB,SLOPE,WSEL,X,CRIWS,Y
C
C          ***************************************************************
C          CALCULATE FRICTION LOSS
C
 2899 IF(KSEC1) 2900,2900,2910
 2900 IF(ISARA)2905,2905,2925
 2905 SLOPE=S
 2910 SAVE=(SLOPE+S)*.5
      WLEN=TLENQ/TQ
      HL=WLEN*SAVE
      VCH=V1CH*Q/TQ
C
C          ***************************************************************
C          CALCULATE VELOCITY HEAD
C
 2915 IF(AROB)3825,2935,2920
 2920 V1ROB=Q1ROB/AROB
      GO TO 2940
C
C
 2925 IF(IFNSA)2930,2930,2905
 2930 IEND=4080
      CALL SLARA
      IF(IEND-2980)2150,2905,3715
 2935 V1ROB=ZERO
C
C
 2940 IF(ALOB)3825,2950,2945
 2945 V1LOB=Q1LOB/ALOB
      GO TO 2955
 2950 V1LOB=ZERO
 2955 VROB=V1ROB*Q/TQ
      VLOB=V1LOB*Q/TQ
      QCH=VCH*ACH
      QLOB=VLOB*ALOB
      QROB=VROB*AROB
      X=QCH*VCH*VCH+QLOB*VLOB*VLOB+QROB*VROB*VROB
      VAVE =(QCH*VCH+QLOB*VLOB+QROB*VROB)/Q
      HV=X/(TWOG*Q)
C
C          ***************************************************************
C          CHECK FOR SPECIAL BRIDGE ROUTINE
C
      IF(IBRID)2960,2985,2960
C          *    *    *    *    *    *    *    *    *    *    *    *    *
 2960 IF(EGPRS)2980,2980,2965
 2965 IF(IBRID)2980,2980,2970
 2970 IF(KSEC1)2985,2985,2975
 2975 IF(IFNCR)3100,3100,2980
C          ***************************************************************
 2980 CALL BWEIR
C          *    *    *    *    *    *    *    *    *    *    *    *    *
C
      IF(IEND-3140)2150,3140,2982
 2982 IF(IEND-3155) 3155,3155,3785
C
C          CALCULATE SHOCK LOSS
C
C
```

```
 2985 IF(KSEC1)2990,2990,2995
 2990 XHV=HV
      XEG = HV+WSEL
 2995 IF(HV-XHV)3005,3000,3000
 3000 IF(IDIR)3010,3010,3015
 3005 IF(IDIR)3010,3015,3010
C
 3010 CHV=CEHV
      GO TO 3020
C
 3015 CHV=CCHV
 3020 X=HV-XHV
      IF(X)3025,3030,3030
 3025 X=-X
 3030 XLOSS=HL+CHV*X
      IF(IDIR)3040,3035,3040
 3035 EG=XEG+XLOSS
      GO TO 3045
 3040 EG=XEG-XLOSS
 3045 IF(NINV)3090,3090,3050
C
C          MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
C          COMPUTE MANNINGS N VALUE IF NINV IS +
C
 3050 CWSEL=WSELK
      DEPTH=CWSEL-ELMIN
      IF(KSEC1) 3052,3052,3055
 3052 Y=ZERO
      TOPWID= TWCH + TWL + TWR
      GO TO 3305
 3055 EG=CWSEL+HV
      XLOSS=EG-XEG
      HL=XLOSS-CHV*X
      TEM=S
      IF(WLEN)3060,3060,3065
 3060 SAVE=S
      GO TO 3070
 3065 SAVE=HL/WLEN
 3070 S=-SLOPE+SAVE*2.
      IF(S) 3071,3071,3080
 3071 S = SAVE
      IF(S) 3072,3072,3074
 3072 PRINT 3073,WSEL,EG,PCWSE,XEG,WLEN,SECNO,SECNP
 3073 FORMAT(29H 3073 NEGATIVE SLOPE , WSEL =,F10.3, 4H EG=,F10.3,7H PCW
     1SE=,F10.3,5H XEG=,F10.3, 6H WLEN=,F10.3,/
     231H RESTART COMPUTATIONS AT SECNO=,F10.2,35H USING N-VALUES COMPUT
     3ED FOR SECNP=,F10.2)
      KSEC1=IZERO
      GO TO 2125
 3074 PRINT 3075
 3075 FORMAT(18H 3075 SET S = SAVE)
      TRACE=3076.
      PRINT 3076
C
C
 3076 FORMAT (/6H TRACE,9X,4HWSEL,6X,3H  X,7X,3H  S,7X,
     14HSAVE,6X,3H HL,7X,5HXLOSS,5X,2HEG,8X,5HCWSEL,5X,3HTEM)
      PRINT 3077,TRACE,WSEL,X,S,SAVE,HL,XLOSS,EG,CWSEL,TEM
 3077 FORMAT(3F10.3,4F10.5,4F10.3)
 3080 X=CONST*R23CH*S**.5/VCH
```

```
      XNL=(X/XNCH)*XNL
      XNR=(X/XNCH)*XNR
      XNCH=X
      IF(ISWT3)3155,3155,3085
 3085 TRACE=3085.
      PRINT 3076
      X=ISECN
      PRINT 3077,TRACE,WSEL,X,S,SAVE,HL,XLOSS,EG,CWSEL,TEM
C
      GO TO 3155
 3090 CWSEL=EG-HV
      IF(ISWT3)3091,3095,3091
 3091 TRACE=3091.
      PRINT 1040,S,SLOPE,SAVE,HL,XEG,XLOSS,WLEN
 3095 IF(IFNCR)3100,3100,3130
 3100 CRIWS=0.0
      IF(IDIR) 3102,3102,3101
 3101 CRIWS=999999.
C
C          **************************************************************
C          COMPUTE CRITICAL DEPTH
C          **************************************************************
C
 3102 CALL DC
C          **************************************************************
      IF(IEND-1240)3110,3105,3110
 3105 IEND=4090
      CALL SLARA
      IF(IEND-2980)2150,2905,3715
 3110 IF(IEND-3670)2150,3115,3835
 3115 TWR = TWR + .001
      TWL = TWL + .001
      TWCH = TWCH + .001
      Q1=Q1CH+Q1LOB+Q1ROB
      ITYDC=IZERO
      QC=Q
      IEND=4180
      IF(ISWT3) 3125,3125,3120
 3120 Y=KSEC1
      X=ISARA
      TRACE=3120.
      PRINT 1025,TRACE,EG,HV,WSEL,X,Y,XEG,XLOSS,HL,WLEN,SAVE,SLOPE
 3125 CALL SLARA
      IF(IEND-2980)2150,2905,3715
C
C          **************************************************************
C          IS SECTION 1ST X SECTION
 3130 IF(KSEC1)3135,3135,3140
C          1ST SECTION
 3135 EG=WSEL+HV
      CWSEL=WSEL
      Y=ZERO
      DEPTH=CWSEL-ELMIN
      TOPWID=TWCH+TWL+TWR
      IF(ISECN-1)3255,3255,3220
C
 3140 ERROR=CWSEL-WSEL
      IF(NINV)3142,3142,3155
 3142 IF(ERROR)3145,3150,3150
 3145 ERROR=-ERROR
```

```
 3150 IF(.01-ERROR)3675,3155,3155
C
C          ************************************************************
C          SECTION BALANCES, COMPUTE VOLUME WATER
C
 3155 Y=HV-XHV
      IF(Y)3160,3165,3165
 3160 Y=-Y
 3165 IF(IBRID)3170,3170,3220
 3170 IF(XLCH-50.) 3220,3175,3175
 3175 IF(NINV) 3180,3180,3220
 3180 IF(ELTRD-99999.) 3185,3185,3190
 3185 IF(ELTRP-99999.) 3220,3220,3190
C
 3190 IF(Y-HVINS)3220,3220,3195
 3195 IF(CINTS)3200,3200,3220
 3200 N=Y/HVINS
      IF(N-3)3210,3205,3205
 3205 N=3
 3210 XNINS=N
      OXLCH=XLCH
      X=1./(XNINS+1.)
      XLOBL =  X*XLOBL
      XLOBR =  X*XLOBR
      XLCH =   X*XLCH
      IFNCR=0
      PXSECE  =(PELMN -ELMIN)/(XNINS+1.)
      GO TO 1610
 3220 X=.5*(ACH+PACH)*XLCH+.5*(AROB+PAROB)*XLOBR
      TOPWID=TWCH+TWL+TWR
      X=X+.5*(ALOB+PALOB)*XLOBL
      VOL=VOL+X/43560.
      X=.5*(TWCH+PTWCH)*XLCH+.5*(TWR+PTWR)*XLOBR
      X=X+.5*(TWL+PTWL)*XLOBL
      TWA=TWA+X/43560.
      TWLEN=TWLEN+WLEN+1.
      TSECN=TSECN+XNCH*XLCH
      WTN=TSECN/TWLEN
      DEPTH=CWSEL-ELMIN
      X=.1
      IF(IDIR)3225,3225,3223
 3223 X=.4
 3225 IF(S-X) 3240,3240,3230
 3230 PRINT 3235,X
 3235 FORMAT(/29H 3235 SLOPE TOO STEEP,EXCEEDS,F10.2/)
 3240 IF(VAVE) 3245,3245,3250
 3245 VAVE=.01
      GO TO 3255
 3250 TIME=TIME+AVGLN/(VAVE*3600.)
C
 3255 IF(IDIVF)3270,3270,3260
 3260 PRINT 3265
 3265 FORMAT(/18H 3265 DIVIDED FLOW/)
      IPRNT=IPRNT+2
 3270 X=WSEL-TELMX
      IF(X)3285,3285,3275
 3275 PRINT 3280,SECNO,X
 3280 FORMAT (19H 3280 CROSS SECTION,F10.2,9H EXTENDED,F10.2,5H FEET/)
      PRINT 1035
      IPRNT=IPRNT+2
```

```
 3285 X=HVINS
      IF(X-1000.)3295,3290,3290
 3290 X=.5
 3295 IF(Y-X)3305,3305,3300
 3300 PRINT 3301
 3301 FORMAT(/32H 3301 HV CHANGED MORE THAN HVINS/)
C           INTERPOLATED CROSS SECTIONS WERE USED
      IPRNT=IPRNT+3
C
C
C           *************************************************************
C           PRINT HEADING
C
 3305 IF(KSEC1)3320,3320,3310
 3310 IF(IPRNT-52)3345,3315,3315
 3315 IPRNT=5
      PRINT 1045
 3320 PRINT 3325
 3325 FORMAT(4X,5HSECNO,4X,5HDEPTH,4X,5HCWSEL,4X,5HCRIWS,4X,5HWSELK,4X,
     12HEG,7X,2HHV,7X,2HHL,7X,5HOLOSS,3X,9HBANK ELEV)
      PRINT 3330
 3330 FORMAT(4X,1HQ,8X,4HQLOB,5X,3HQCH,6X,4HQROB,5X,4HALOB,5X,3HACH,6X,4
     1HAROB,5X,3HVOL,6X,3HTWA,3X,10HLEFT/RIGHT)
      PRINT 3335
 3335 FORMAT(4X,4HTIME,5X,4HVLOB,5X,3HVCH,6X,4HVROB,5X,3HXNL,6X,4HXNCH,5
     1X,3HXNR,6X,3HWTN,6X,5HELMIN)
      PRINT 3340
 3340 FORMAT(4X,5HSLOPE,4X,5HXLOBL,4X,4HXLCH,5X,5HXLOBR,4X,6HITRIAL,3X,3
     1HIDC,6X,5HICONT,5X,5HCORAR,3X,6HTOPWID/)
      PRINT 1035
 3345 IF(IBRID) 3350,3350,3375
C
C           *************************************************************
C           PRINT OUT FOR BRIDGE
C
 3350 IF(ELTRD-99999.) 3355,3460,3460
 3355 I=NRD-2
      IF(I) 3360,3365,3365
 3360 I=0
 3365 PRINT 3370,I,ELTRD,ELLC
      IPRNT=IPRNT+3
 3370 FORMAT(/19H NORMAL BRIDGE,NRD=,I2,11H MIN ELTRD=, F8.2,10H MAX ELL
     1C=, F8.2/)
      GO TO 3460
 3375 I=CLASS
      IF(BLOSS) 3378,3378,3376
 3376 PRINT 3377,BLOSS
 3377 FORMAT(21H 3377 BLOSS READ IN =,F10.2)
      GO TO 3460
 3378 IF(I-2) 3380,3390,3400
 3380 PRINT 3385
 3385 FORMAT(17H CLASS A LOW FLOW/)
      GO TO 3415
 3390 PRINT 3395
 3395 FORMAT(17H CLASS B LOW FLOW/)
      GO TO 3415
 3400 IF(I-10) 3405,3425,3435
 3405 PRINT 3410
 3410 FORMAT(17H CLASS C LOW FLOW/)
 3415 PRINT 3420,WSBR,VBR
```

```
 3420 FORMAT(13H BRIDGE W.S.=,F10.2,18H  BRIDGE VELOCITY=,F10.2)
      GO TO 3446
 3425 PRINT 3430
 3430 FORMAT(14H PRESSURE FLOW/)
      GO TO 3446
 3435 IF(I-30) 3415,3440,3440
 3440 PRINT 3445
 3445 FORMAT(23H PRESSURE AND WEIR FLOW/)
C
 3446 PRINT 3455
      PRINT 3450, EGPRS,EGLWC,H3,QWEIR,QPR,BAREA,ELLC,ELTRD,CLASS
      PRINT 1035
 3450 FORMAT(3F10.2,3F10.0,3F10.2/)
 3455 FORMAT(/88H    EGPRS      EGLWC        H3        QWEIR       QPR
     1BAREA       ELLC       ELTRD     CLASS/)
      IPRNT=IPRNT+4
 3460 TEM = ZERO
      IF(STENCL) 3475,3475,3461
 3461 PRINT 3470,STENCL,STENCR,ELENCL,ELENCR
 3470 FORMAT(/28H 3470 ENCROACHMENT STATIONS=,2F10.1,2X,11HELEVATIONS=,
     12F12.2)
C
 3475 OLOSS=XLOSS-HL
      IF(IEARA) 3500,3500,3480
 3480 IF(WSEL-ELLEA)3490,3490,3485
 3485 IF(WSEL-ELREA)3490,3490,3500
 3490 PRINT 3495,ELLEA,ELREA
 3495 FORMAT(/43H OVERBANK AREA ASSUMED NON-EFFECTIVE,ELLEA=,F12.2,7H EL
     1REA=,F12.2/)
      IPRNT=IPRNT+3
 3500 IF(IFNCR)3510,3510,3505
 3505 TEM = CRIWS
C
C          **************************************************************
C          NORMAL PRINT OUT
C
 3510 IF(SFCNO-CNOS(NUMCD))3514,3511,3514
 3511 PRINT 1035
      READ(9,1120) I,X,(COCD(N),N=1,18)
      PRINT 3513,I,(COCD(N),N=1,18)
 3513 FORMAT(A2,6X,18A4)
      PRINT 1035
      IF(NUMCD-NUMCT)3512,3514,3514
 3512 NUMCD=NUMCD+1
      GO TO 3510
 3514 PRINT 1005,SECNO,DEPTH,CWSEL,TEM,WSELK,EG,HV,HL,OLOSS,XLBEL
      PRINT 1015,Q,QLOB,QCH,QROB,ALOB,ACH,AROB,VOL,TWA,RBEL
      PRINT 1010,TIME,VLOB,VCH,VROB,XNL,XNCH,XNR,WTN,ELMIN
      PRINT 1020,S,XLOBL,XLCH,XLOBR,ITRIL,IDC,ICONT,CORAR,TOPWID
      PRINT 1050
      IPRNT=IPRNT+6
 3515 CUMDS=CUMDS+XLCH
      IF(ISECN-1)3520,3520,3540
 3520 CUMDS=ZERO
      IF(IDIR)3530,3530,3525
 3525 ELMX1=TELMX
      IF(PRFVS)3540,3540,3526
 3526 ELMX1=EG
      GO TO 3540
 3530 ELM1=ELMIN
```

```
C
C
 3540 ITRIL=ITRIL+1
      WRITE(8,1055)TELMX,RBEL,XLBEL,CRIWS,ELMIN,WSEL,EG,SECNO,CUMDS
C           SELECT WT BASED ON DISTANCE PER POINT FOR CHANNEL OR XSECTION
      IF(PLOT-1.0001) 3545,3545,3550
 3545 NLST=NUMST-1
      NSTRT=2
 3550 Y=NLST-NSTRT
      Z=STA(NLST)-STA(NSTRT)
      Y=Z/Y
      X=NRBEL-NLCH
      IF(X)3565,3565,3555
 3555 X=(STCHR-STCHL)/X
      IF(X)3565,3565,3560
 3560 IF(X-Y)3570,3570,3565
 3565 X=Y
 3570 XWT=5.*Z/X
      IF(PLOT-.0001) 3635,3635,3575
C
 3575 IF(XWT-180.) 3585,3585,3580
 3580 XWT=180.
 3585 IF(XWT-60.)3590,3595,3595
 3590 XWT=60.
 3595 XMIN=STA(NSTRT)
      XMAX=STA(NLST)
      YMAX=EL(NSTRT)
      DO 3605 I=NSTRT,NLST
      IF(YMAX- EL(I)) 3600,3605,3605
 3600 YMAX=EL(I)
C
 3605 CONTINUE
      IF(STENCL)3611,3611,3606
 3606 YMAX=TELMX
 3611 YWT= 121.
      X=ZERO
      Y=ZERO
      Z=ZERO
      TEM=ZERO
      IF(ISWT3)3608,3608,3607
 3607 TRACE=3607.
      PRINT 1025,TRACE,XMIN,ELMIN,XMAX,YMAX,XWT,YWT,X,Y,Z,TEM
 3608 TRACE=3608.
      CALL SCALE(XMIN,ELMIN,XMAX,YMAX,XWT,YWT,X,Y,Z,TEM)
      IF(ISWT3)3610,3610,3609
 3609 TRACE=3609.
      PRINT 1025,TRACE,XMIN,ELMIN,XMAX,YMAX,XWT,YWT,X,Y,Z,TEM
C     CHECK FOR READING IN HORIZONTAL AND VERTICAL SCALES
 3610 IF(XSECV-.0001) 3620,3620,3615
 3615 Y=XSECV
 3620 IF(XSECH-.0001) 3630,3630,3625
 3625 Z=XSECH
 3630 CALL XSEC (X,Y,Z,TEM,WSEL,EL,STA,SECNO,NUMST,RDST,RDEL,XLCEL,ELLC,
     1ELTRD,NRD,TITLE,EG,CRIWS,Q,STCHL,STCHR,NSTRT,NLST)
      IF(ISWT3)3635,3635,3631
 3631 TRACE=3631.
      Y=0.0
      PRINT 1025,TRACE,X,Y,Z,TEM,WSEL,SECNO,EG,CRIWS,STCHL,STCHR
C
C           SET PREVIOUS CONDITIONS
```

```
C
 3635 XEG=EG
      IEARP=IEARA
      IF(CINTS)3645,3645,3640
 3640 IF(CINTS-XNINS) 3667,3667,3645
C
 3645 PAT=ACH
C         CARD DELETED 3650
C           USED TO STORE DATA USED FOR SUMMARY PRINTOUT WHERE 2 OR MORE
C              PROFILES USE SAME DATA
      VART( 1)=CWSEL
      VART( 2)=CRIWS
      VART( 3)=EG
      VART( 4)=TOPWID
      VART( 5)=S*10000.
      VART( 6)=TIME
      VART( 7)=VOL
      VART( 8)=DEPTH
      VART( 9)=WSELK
      VART(10)=HV
      VART(11)=HL
      VART(12)=OLOSS
      VART(13)=QLOB
      VART(14)=QCH
      VART(15)=QROB
      VART(16)=XNL*1000.
      VART(17)=XNCH*1000.
      VART(18)=XNR*1000.
      VART(19)=WTN*1000.
      DO 3652 I=1,7
      N=IVAR(I)
 3652 VAR(I)=VART(N)
      SECVR(1,ISECN)=SECNO
      SECVR(2,ISECN)=OXLCH
      IF(ELTRD-999999.) 3660,3655,3655
 3655 SECVR(3,ISECN)=0.0
      SECVR(4,ISECN)=0.0
      GO TO 3665
 3660 SECVR(3,ISECN)=ELTRD
      SECVR(4,ISECN)=ELLC
 3665 SECVR(5,ISECN)=ELMIN
      QVAR(1,ISECN,JQCON)=Q
      QVAR(2,ISECN,JQCON)=VAR(1)
      QVAR(3,ISECN,JQCON)=VAR(2)
      QVAR(4,ISECN,JQCON)=VAR(3)
      QVAR(5,ISECN,JQCON)=VAR(4)
      QVAR(6,ISECN,JQCON)=VAR(5)
      QVAR(7,ISECN,JQCON)=VAR(6)
      QVAR(8,ISECN,JQCON)=VAR(7)
C          END OF STORING SUMMARY DATA
 3667 CLASS=0.0
      PQ=Q
      PELLEA=ELLEA
      PELREA=ELREA
      PHVIN =HVINS
      PXSECR=0.0
      ELTRP=ELTRD
      ELLCP=ELLC
      NRDP=NRD
      XHV=HV
```

```
      PACH=ACH
      PAROB=AROB
      PALOB=ALOB
      PELMN=ELMIN
      IBRID=IZERO
      PHV=HV
      PCWSE=CWSEL
      KSEC1=ITEN
      PVCH=VCH
      SLOPE=S
      PTWL=TWL
      PTWR=TWR
      PTWCH=TWCH
      PCRWS=CRIWS
      ADD50=0.0
      IFNCR=0
      NPRFP=NPROF
C     CARD REMOVED(ICHIMP=0)
      STENLP=STENCL
      IECCD=0
      IF(NSTRD) 3670,3670,1325
 3670 DO 3671 I=1,10
 3671 RDINP(I)=RDSTR(I)
      NSTRD=1
      GO TO 1325
C
C           ************************************************************
C           WHEN TRIAL EXCEEDS 20, CHECK FOR DC OR MAX. ELEV
C
 3675 IF(TRIAL-20.)3730,3680,3690
 3680 PRINT 3685
 3685 FORMAT(31H 3685 20 TRIALS USED WSEL,CWSEL)
      GO TO 3730
 3690 IF(TRIAL-30.) 3730,3691,3695
 3691 IF(EGMAX-EGCRI) 3692,3692,3695
 3692 PRINT 3693
 3693 FORMAT(/38H 3693 PROBABLE MINIMUM SPECIFIC ENERGY/)
      IF(ITRACE)3694,3694,3715
 3694 ISWT3=0
      GO TO 3715
C
 3695 ISWT3=0
      X=ELMAX-.02
      IF(WSEL-X) 3705,3705,3835
 3705 WSEL=DIFWS
      TRACE=3710.
      PRINT 3710,TRACE
 3710 FORMAT(F10.0,31H WSEL ASSUMED BASED ON MIN DIFF)
      GO TO 3725
C           ASSUME CRITICAL DEPTH
C
 3715 PRINT 3720
 3720 FORMAT (/28H 3720 ASSUMED CRITICAL DEPTH/)
      WSEL=CRIWS
 3725 IPRNT=IPRNT+ITEN
      ICASE=6
      KSEC1=IZERO
      IFNSA=ITEN
      GO TO 2150
C
```

```
C          ************************************************************
C          TRACE OF COMPUTING CWSEL
 3730 TRIAL=TRIAL+ONE
      IF(ERROR-DIFMN)3733,3734,3734
 3733 DIFMN=ERROR
      DIFWS=WSEL
 3734 IF(EG-EGMAX) 3732,3732,3731
 3731 EGMAX=EG
 3732 ITRIL=ITRIL+1
      IF(ISWT3)3735,3740,3735
 3735 PRINT 3736
      X=WSEL-CWSEL
 3736 FORMAT(//48H TRIAL   WSEL    CWSEL    DIFF     ELMIN   ELMAX,
     162H   LBEL    RBEL   CRITWS   ELMAX ICASE   EG      HV     XLOSS ,
     215H     HL       ACH)
      PRINT 3737,TRIAL,WSEL,CWSEL,X,ELMIN,ELMAX,XLBEL,RBEL,CRIWS,
     1TELMX,ICASE,EG,HV,XLOSS,HL,ACH,DIFMN,DIFWS
 3737 FORMAT(11H TRACE=3737/F6.2,3F9.3,6F8.2,I6,4F8.3,F8.1/)
      IPRNT=IPRNT+5
C          ************************************************************
C          MAKE NEW ASSUMPTION OF WSEL
C
 3740 IF(TRIAL-TWO)3745,3750,3750
C          2ND ASSUMPTION OF WSEL
 3745 XWSEL=WSEL
      XCWSE=CWSEL
      WSEL=(WSEL+CWSEL)*.5
      ICASE=7
      GO TO 3770
C
C          NORMAL ASSUMPTION OF WSEL
C
 3750 TEM=XCWSE-XWSEL
      Y = XWSEL-WSEL
      X = TEM-CWSEL+WSEL
      TEMP=WSEL
      IF(X)3760,3755,3760
 3755 Y=-Y
      X=CWSEL-XCWSE
      ICASE=9
      WSEL=(X*XWSEL-Y*XCWSE)/(X-Y)
      GO TO 3765
 3760 WSEL=XWSEL-TEM*Y/X
      ICASE=8
 3765 XCWSE=CWSEL
      XWSEL=TEMP
 3770 X=(XWSEL-ELMIN)*.5+ELMIN
      IF( WSEL-XWSEL)3775,3775,2150
 3775 IF(X-WSEL)2150,2150,3780
 3780 TRACE=3782.
      IF(ISWT3) 3784,3784,3781
 3781 PRINT 3782,TRACE,WSEL,X,ICASE
 3782 FORMAT(7H TRACE=,F10.2,31HWSEL CHANGE EXCEEDED 50 PERCENT,2F12.2,I
     18)
 3784 WSEL=X
      ICASE=ITEN
      GO TO 2150
C
C
C          ************************************************************
```

```
C          ERROR IN DATA, READ ALL REMAINING CARDS,START NEXT RUN
 3785 PRINT 3790
 3790 FORMAT(27H 3790,DATA ERROR,JOB DUMPED)
      GO TO 1065
C
C
C          ************************************************************
C          ERROR MESSAGES
C
C         CARD REMOVED 3795
 3800 FORMAT(38H 3800 PREVIOUS ST GREATER THAN CURRENT)
C         2 CARDS REMOVED 3800+1,3800+2
C
 3815 PRINT 3820
 3820 FORMAT(26H 3820 STA(N) GREATER STMAX)
      PRINT 1025,STMAX,(STA(I),I=1,NUMST)
      GO TO 3785
C
 3825 PRINT 3830
 3830 FORMAT(22H 3830 AROB OR ALOB IS-)
      GO TO 2135
C
C          ************************************************************
C          INCREASE SECTION 50 FEET
C
 3835 PRINT 3840,WSEL,ELMAX,ELMIN,EL(1),XWSEL,ICASE
 3840 FORMAT(29H 3840 SECTION NOT HIGH ENOUGH,5F10.3,I10)
      EL(1)=EL(1)+50.
      EL(NUMST)=EL(NUMST-1)+50.
      TELMX=ELMAX
      ELMAX=ELMAX+50.
      ADD50=ADD50+1.
      IF(ADD50-5.)2150,2150,3785
C                    CARD DELETED 3845
 3845 IF(ITYDC) 2150,2135,2150
 3865 PRINT 1035
C          SUMMARY PRINTOUT FOR MULTIPLE PROFILES
      NUMCT=0
      DO 3866 I=1,7
      ITP=IVAR(I)
 3866 IVA (I)=NAMVAR(ITP)
C        2 CARDS DELETED
 3870 PRINT 1045
 3871 PRINT 3872
      ITEM=58/(JQCON+1)
      ICONT=1
 3872 FORMAT(39H SUMMARY PRINTOUT FOR MULTIPLE PROFILES/)
      PRINT 1035
      PRINT 3875,(IVA (I),I=1,7)
 3875 FORMAT(3X,7HSECTION,3X,7HCHANNEL,1X,9HMIN EL OF,2X,9HMAX EL OF,2X,
     16HMIN EL,2X,9HDISCHARGE,7(4X,A6))
      PRINT 3876
 3876 FORMAT(3X,7HNUMBER ,3X,7HLENGTH ,1X,9HROADWAY  ,2X,9HLOW CHORD,2X,
     16HGROUND,4X,5H(CFS))
      PRINT 1035
      DO 3890 J=1,ISECN
      IF(ICONT-ITEM) 3879,3877,3877
 3877 PRINT 1045
      PRINT 3875,(IVA(I),I=1,7)
      PRINT 3876
```

```
      ICONT=1
 3879 DO 3885 M=1,JQCON
      PRINT 3880,(SECVR(I,J),I=1,5),(QVAR(K,J,M),K=1,8)
 3880 FORMAT(10F10.2,F10.2,2F10.2)
 3885 CONTINUE
      PRINT 1035
      ICONT=ICONT+1
 3890 CONTINUE
      IF(RTLEN)3993,3993,3891
C     PUNCH HEC-1 CARDS
 3891 DO 3955 I=1,7
      IF(IVAR(I)-7)3955,3957,3955
 3955 CONTINUE
      PRINT 3956
      I=7
 3956 FORMAT(2X,4H3956,18HVOL NOT ON J3 CARD)
 3957 IVOL=I
      DO 3958 I=1,7
      IF(IVAR(I)-6)3958,3960,3958
 3958 CONTINUE
      I=7
      PRINT 3959
 3959 FORMAT(2X,4H3959,19HTIME NOT ON J3 CARD)
 3960 ITIM=I
      DO 3992 I=1,NUMRT
      X=REACH(I)*1000.+.5
      N=X
      J=X/10000000.
      J=J*10000000.
      ISTAQ=N-J
 3962 DO 3963 N=1,ISECN
      IF(SECVR(1,N)-REACH(I))3963,3966,3964
 3963 CONTINUE
 3964 PRINT 3965,REACH(I),SECVR(1,N)
 3965 FORMAT(2X,4H3965,2X,8HREACH OF,F12.3,2X,21HNOT EQUAL TO SECNO OF,
     1F12.3)
 3966 DO 3967 J=1,JQCON
      FLOW(J)=QVAR(1,N,J)
 3967 CVOL(J)=QVAR(IVOL+1,N,J)
      X=0.0
      IRH=N
      JJ=ITIM+1
      DO 3968 J=1,JQCON
 3968 X=X+QVAR(JJ,N,J)
      Y=JQCON
      XTIME=X/Y
      IF(I-1)3990,3990,3969
 3969 RXLCH=0.0
      JJ=IPRH+1
      DO 3980 J=JJ,N
 3980 RXLCH=RXLCH+SECVR(2,J)
      DTIME=XTIME-PTIME
      LAG=0
      NSTPS=DTIME*60./(HYDINT*RTLEN)
      IF(NSTPS)3981,3981,3983
 3981 NSTPS=1
 3983 DO 3977 J=1,JQCON
      DO 3970 JJ=2,JQCON
      IF(FLOW(J)-XQ(JJ))3971,3971,3970
 3970 CONTINUE
```

```
 3971 X=FLOW(J)-XQ(JJ-1)
      Y=XQ(JJ)-XQ(JJ-1)
      X=X/Y
      XVOL=PCVOL(JJ-1)+X*(PCVOL(JJ)-PCVOL(JJ-1))
      IF(XVOL)3972,3972,3973
 3972 XVOL=0.0
 3973 Y=NSTPS
      DVOL(J)=(CVOL(J)-XVOL)/Y
 3977 CONTINUE
      PRINT 3978,ISTAQP,NSTPS,LAG
      PUNCH 3978,ISTAQP,NSTPS,LAG
 3978 FORMAT(1HU,I7,2I8,7X,1H1,6X,2H-1,32X,6X,2H-1/1HU)
      PRINT 3979,(DVOL(J),J=1,JQCON)
      PUNCH 3979,(DVOL(J),J=1,JQCON)
 3979 FORMAT(1H2,F7.0,9F8.0)
      PRINT 3982,(FLOW(J),J=1,JQCON)
      PUNCH 3982,(FLOW(J),J=1,JQCON)
 3982 FORMAT(1H3,F7.0,9F8.0)
 3985 FORMAT (2X,10F12.2)
C     SET PREVIOUS CONDITIONS
 3990 DO 3991 J=1,JQCON
      XQ(J)=FLOW(J)
 3991 PCVOL(J)=CVOL(J)
      IPRH=IRH
      PTIME=XTIME
      ISTAQP=ISTAQ
 3992 CONTINUE
 3993 JQCON=1
      RTLEN=0.0
C           END OF SUMMARY PRINTOUT
      GO TO 1116
C
 3895 CONTINUE
 3950 STOP
      END
```

```
      SUBROUTINE ADDPTS(EL,STA,NUMST,STMAX,STCHL,STCHR,ENCFP,STENCL,
     1 ELENCL,ISWT3,STENCR,ELENCR)
C     CALL SUBROUTINE 1907
C     INSERT 4 POINT IN GROUND PROFILE TABLE
      DIMENSION EL(100),STA(100)
 1010 FORMAT(2X,F6.0,9F8.0)
 1025 FORMAT(10F10.3)
      EL(1)=EL(2)+50.
      TRACE=1025.
      IF(ISWT3)1035,1035,1030
 1030 PRINT 1025,TRACE,ENCFP,STENCL,ELENCL,STENCR
      PRINT 1025,TRACE,(STA(I),I=1,NUMST)
      PRINT 1025,TRACE,(EL(I),I=1,NUMST)
 1035 SSTEN=STENCL
      ESTEN=STENCR
C           NLOC=CODE (0,1,2) FOR LEFT, WITHIN AND RIGHT ENCR.
C           N=NUMBER OF POINTS BEING ADDED
      N=4
      NPTS=4
      NLOC=2
      DO 1925 I=1,NUMST
 1918 J=NUMST-I+1
      JN=J+N
      IF(NLOC-1) 1923,1919,1921
 1919 IF(STA(J)-SSTEN)1920,1923,1923
 1920 IF(STA(J+1)-STA(J))1915,1916,1915
 1916 X=.5
      GO TO 1917
 1915 X=(SSTEN-STA(J))/(STA(J+1)-STA(J))
 1917 EL(JN)=EL(J)+X*(EL(J+1)-EL(J))
      XEL=EL(JN)
      STA(JN)=SSTEN
      N=0
      JN=J
      NLOC=0
      EL(JN+1)=XEL
      STA(JN+1)=SSTEN-.001
      GO TO 1923
 1921 IF(STA(J)-ESTEN)1922,1923,1923
 1922 IF(STA(J+1)-STA(J))1927,1926,1927
 1926 X=0.5
      GO TO 1928
 1927 X=(ESTEN-STA(J))/(STA(J+1)-STA(J))
 1928 EL(JN)=EL(J)+X*(EL(J+1)-EL(J))
      STA(JN)=ESTEN
      N=1
      NLOC=1
      EL(JN-1)=EL(JN)
      STA(JN-1)=ESTEN-.001
      N=2
 1929 JN=J+N
      IF(STA(J)-SSTEN) 1918,1918,1923
 1923 EL(JN)=EL(J)
      STA(JN)=STA(J)
 1924 TRACE=1924.
 1925 CONTINUE
      NUMST=NUMST+NPTS
 1940 TRACE=1940.
      IF(ISWT3) 1950,1950,1945
 1945 PRINT 1025,TRACE,SSTEN,ESTEN,ENCFP,STENCL,ELENCL,STENCR
```

```
      PRINT 1025,TRACE,(STA(I),I=1,NUMST)
      PRINT 1025,TRACE,(EL(I),I=1,NUMST)
 1950 RETURN
      END
```

```
      SUBROUTINE CHIMP
C     DATE OF LAST CHANGE  20NOV68
C     CHANNEL IMPROVEMENT SECTIONS FOR BACKWATER PROGRAM 23-J2-J212
C       FROM HYDROLOGIC ENGINEERING CENTER PROGRAM NO 23-J2-J234
C     BY BILL EICHERT 15 FEB, 1966
C     FROM TULSA DISTRICT PROGRAM NO 23-G1-G540 BY BILL EICHERT
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION ELT(20),STAT(20),STAO(102),ELO(102),ELOR(200),STAOR(200)
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
 1000 FORMAT(1X,F7.0,9F8.0)
 1010 FORMAT(/8F10.2/)
 1020 FORMAT(20A4)
 1030 FORMAT(/ F10.0,2F10.2,I10/)
      ELCH=CELCH
      IF(CNCH)1045,1045,1040
 1040 XNCH=CNCH
 1045 IND=0
      IWS = 0
      INC = 0
      IRT =0
      NOIMP = 0
      EL(1)=0.0
      STA(1)=0.0
      CON=0.0
      XAEL=0.0
      XCEL=0.0
      NOINP=0
      TRIAL=1.
      NEL=0
      N=1
      TSTCHL=STCHL
      TSTCHR=STCHR
      PEL=ELCH+1.
      INDLBW=0
      INDRTB=0
      SPEC=0.0
      ST1=-1.
```

```
      SPEC2=0.0
      IBWT=0
 1440 IF(SPEC2)1450,1460,1450
 1450 SPEC2=0.0
      ELV=TEL
      ST=TST
      GO TO 1530
 1460 NEL=NEL+1
      ELV=ELOR(NEL)
      ST=STAOR(NEL)
      IF(ELV-ELCH)1465,1462,1465
 1462 ELV=ELV+.01
 1465 CONTINUE
      IF(ST)1790,1790,1470
 1470 IF(ST-CLSTA)1530,1530,1480
 1480 TEM=CLSTA+.5*BW
      IF(ST-TEM)1530,1530,1490
 1490 IF(ELV-ELCH)1530,1500,1500
 1500 Z=(ST-(CLSTA+.5*BW))/RSS
      TCEL=Z+ELCH
      IF(ELV-TCEL)1510,1530,1530
 1510 TCST=(CLSTA-.5*BW) -((PEL-ELCH)*XLSS)
C     POINT IS ON OUTSIDE OF RIGHT SLOPE OF CHANNEL
C     TCST= LEFT INTERSECTION STATION OF NAT. XSECTION + LEFTSIDE
      IF(PST-TCST)1520,1530,1530
 1520 XTEMP=ELV+((PEL-ELV)*(ST-CLSTA))/(ST-PST)
C     PREV. POINT IS TO LEFT OF LEFT SIDE, CURR. TO RIGHT OF RIGHT SIDE
C     NO POINTS IN XSECTION WITHIN TRAPAZOIDAL CHANNEL
      TEL=ELV
      TST=ST
      SPEC2=10.
C     ARTIFICIAL POINT IN NATURAL SECTION DATA AT CENTERLINE STATION OF
C     CHANNEL
      ST=CLSTA
      ELV=XTEMP
 1530 IF(ELV-ELCH)2150,2150,1540
 1540 IF(PEL-ELCH)2160,1550,1550
 1550 IF(N-1)1560,1560,1570
 1560 TEM=1.
      GO TO 1580
 1570 TEM=EL(N-1)-ELCH
 1580 IF(TEM)1680,1590,1680
 1590 IF(ST-CLSTA)1600,1640,1600
 1600 X=CLSTA+.5*BW
      IF(ST-X)1620,1610,1610
 1610 IF(PXOVER)1640,1760,1640
 1620 X=CLSTA-.5*BW
      IF(ST-X)1630,1650,1650
 1630 X=BW*.5+XLSS*(ELV-ELCH)
      CST=CLSTA-X
      IF(ST-CST)2060,2060,1800
C
C
 1640 X=BW*.5+RSS*(ELV-ELCH)
      CST=CLSTA+X
      IF(ST-CST)1650,1660,1660
C
 1650 PXOVER=10.
      GO TO 1680
 1660 EL(N)=ELCH
```

```
      STA(N)=CLSTA+.5*BW
      N=N+1
      INDRTB=10
      IF(ISWT3) 1680,1680,1670
C                                                               TRACE = 1
 1670 TRACE=1.0
      PRINT 1030,TRACE,EL(N-1),STA(N-1),N
 1680 IF(ST-CLSTA)1690,1690,1760
 1690 X=BW*.5+XLSS*(ELV-ELCH)
      CST=CLSTA-X
      IF(CST-ST)1700,2090,1790
C
 1700 IF(N-1)1720,1710,1720
 1710 EL(N)=ELV
      STA(N)=CST
      N=N+1
      PXOVER=10.
      GO TO 2560
 1720 XOVER=10.
      IF(PXOVER-XOVER)1810,1730,1810
 1730 IF(ST-STMAX)1750,1740,1750
 1740 EL(N)=ELV
      STA(N)=CST
      GO TO 2560
 1750 PXOVER=10.
      GO TO 2560
C
C
 1760 X=BW*.5+RSS*(ELV-ELCH)
      CST=CLSTA+X
      IF(CST-ST)1770,2090,1700
 1770 IF(INDLBW)1790,1780,1790
 1780 STCHL=STA(N-1)
      EL(N)=ELCH
      STA(N)=CLSTA-BW*.5
      N=N+1
      EL(N)=ELCH
      STA(N)=CLSTA+BW*.5
      N=N+1
      INDLBW=10
      INDRTB=10
 1790 XOVER=0.0
      IF(N-1)1800,2080,1800
C
 1800 IF(XOVER-PXOVER)1810,2060,1810
 1810 AEL=ELV+.2*(PEL-ELV)
C
 1820 IF(PEL-ELV)1870,1830,1870
 1830 X=CLSTA-BW*.5 -(PEL-ELCH)*XLSS
      IF(PST-X)1840,1850,1850
 1840 ST1=X
      GO TO 1860
 1850 ST1=CST
 1860 CEL=ELV
      GO TO 1990
 1870 ST1=ST-(AEL-ELV)*(ST-PST)/(PEL-ELV)
      X=CLSTA-BW*.5
      IF(PST-X)1880,1880,1920
 1880 XLCS=CLSTA-(BW*.5+XLSS*(PEL-ELCH))
      IF(XLCS-PST)1900,1890,1890
```

```
 1890 CEL=(XLSS*ELCH-ST1+CLSTA-.5*BW)/XLSS
      GO TO 1930
 1900 X=(CLSTA-BW*.5)+(ELCH-ELV)*XLSS
      IF(ST-X)1910,1910,1920
 1910 CEL=(XLSS*ELCH-ST1+CLSTA-.5*BW)/XLSS
      GO TO 1930
C
 1920 CEL=(RSS*ELCH+ST1-CLSTA-.5*BW)/RSS
C
 1930 IF(ISWT3) 1950,1950,1940                              TRACE = 2
C
 1940 TRACE=2.
      PRINT 1010,TRACE,ELV,ST,PEL,PST,AEL,ST1,CEL
      PRINT 1010,TRACE,CON,XAEL,XCEL
 1950 X=CEL-AEL
      IF(X) 1955,1956,1956
 1955 X=-X
 1956 IF(X-.1)1990,1960,1960
 1960 TRIAL=TRIAL+1.
      IF(TRIAL-2.)1970,1980,1970
 1970 CON=(AEL-CEL)/(XAEL-XCEL)
      TEMP=AEL
      AEL=(CON *XAEL-AEL)/(CON-1.)
      XCEL=CEL
      XAEL=TEMP
      GO TO 1820
 1980 XAEL=AEL
      XCEL=CEL
      AEL=ELV+.8*(PEL-ELV)
      GO TO 1820
C
 1990 IF(INDRTB-10)2010,2000,2010
 2000 STCHR=ST1
      INDRTB=15
      GO TO 2010
C
 2010 EL(N)=CEL
      STA(N)=ST1
      N=N+1
      TRIAL=1.
      IF(SPEC-10.)2030,2020,2030
 2020 EL(N)=ELCH
      STA(N)=CLSTA-BW*.5
      N=N+1
      STCHL=ST1
      EL(N)=ELCH
      STA(N)=CST
      N=N+1
      SPEC=0.0
      GO TO 2060
 2030 IF(XOVER-10.)2060,2040,2060
 2040 PXOVER=10.
      IF(ST-STMAX)2560,2050,2560
 2050 STMAX=CST
      ST=STMAX
      EL(N)=ELV
      STA(N)=CST
      N=N+1
      GO TO 2560
 2060 IF(ISWT3) 2080,2080,2070
```

TRACE = 3

```
C
 2070 TRACE=3.0
      PRINT 1030,TRACE,EL(N-1),STA(N-1),N
C
 2080 EL(N)=ELV
      STA(N)=ST
      N=N+1
      PXOVER=0.0
      GO TO 2560
C
 2090 EL(N)=ELV
      STA(N)=ST
      N=N+1
 2100 IF(PXOVER-10.)2120,2110,2120
 2110 ST1=ST
      PXOVER=0.0
      XOVER=0.0
      GO TO 2130
 2120 PXOVER=10.
      XOVER=10.
 2130 IF(INDRTB-10)2560,2140,2560
 2140 STCHR=ST
      INDRTB=15
      GO TO 2560
 2150 XOVER=0.0
 2160 IF(PEL-ELCH)2170,2170,2180
 2170 IF(ELV-ELCH)2320,2320,2180
C
 2180 CST=ST-(ELCH-ELV)*(ST-PST)/(PEL-ELV)
      IF(CST-CLSTA)2310,2310,2190
 2190 X=CLSTA-BW*.5
      IF(CST-X)2230,2200,2200
 2200 IF(INDLBW)2230,2210,2230
 2210 INDLBW=10
      STCHL=STA(N-1)
      IF(PEL-ELV)2220,2450,2450
 2220 STCHL=CST
      GO TO 2500
C
 2230 X=CLSTA+BW*.5
      IF(CST-X)2260,2240,2240
 2240 IF(INDRTB)1680,2250,1680
 2250 INDRTB=10
      GO TO 1680
 2260 EL(N)=ELCH
      STA(N)=CST
      N=N+1
      XOVER=0.0
      XXCST=CLSTA+BW*.5+RSS*(ELV-ELCH)
      IF(ST-XXCST)2290,2270,2270
 2270 IF(ELV-PEL)2060,2060,2280
 2280 EL(N)=ELCH
      STA(N)=CLSTA+.5*BW
      N=N+1
      INDRTB=10
      PXOVER=10.
      XOVER=0.0
      GO TO 1810
 2290 IF(PEL-ELCH)2300,2300,2320
 2300 XOVER=10.0
```

```
      GO TO 2980
 2310 X=CLSTA-BW*.5
      IF(CST-X)2320,2420,2420
 2320 XCST=CLSTA-BW*.5-XLSS*(ELV-ELCH)
      IF(PEL-ELCH)2330,2380,2380
 2330 IF(XCST-ST)2340,2340,2400
 2340 IF(ELV-ELCH)2360,2350,2350
 2350 XOVER=10.
      GO TO 1680
 2360 IF(INDLBW-10)2370,2400,2370
 2370 STCHL=ST1
      INDLBW=10
      GO TO 2400
 2380 IF(XCST-ST)2390,2390,1680
 2390 IF(INDLBW-10)2410,2400,2410
 2400 EL(N)=ELV
      STA(N)=ST
      N=N+1
      XOVER=0.0
      GO TO 2980
 2410 STCHL = ST1
      GO TO 2400
 2420 IF(INDLBW)2500,2430,2500
 2430 INDLBW=10
      IF(PEL-ELV)2440,2450,2450
 2440 STCHL=CST
      GO TO 2500
C
C
 2450 IF(STA(N-1)-ST1)2480,2460,2480
C
 2460 STCHL=STA(N-1)
      EL(N)=ELCH
      STA(N)=CLSTA-BW*.5
      N=N+1
      INDLBW=10
      IF(ISWT3) 2500,2500,2470
C                                                          TRACE = 4
 2470 TRACE=4.
      PRINT 1030,TRACE,EL(N-1),STA(N-1),N
      PRINT 1010,TRACE,PEL,PST,ELV,ST,XOVER,PXOVER
      GO TO 2500
 2480 IF(PXOVER-10.)2490,2460,2490
 2490 SPEC=10.
      XOVER=0.0
      GO TO 1810
 2500 IF(ELV-ELCH)2530,2510,2510
 2510 XOVER=10.
      EL(N)=ELCH
      STA(N)=CST
      N=N+1
      IF(ISWT3) 2980,2980,2520
C                                                          TRACE = 5
 2520 TRACE=5.
      PRINT 1030,TRACE,EL(N-1),STA(N-1),N
      GO TO 2980
 2530 EL(N)=ELCH
      STA(N)=CST
      IF(ISWT3) 2550,2550,2540
C                                                          TRACE = 6
```

```
 2540 TRACE=6.
      PRINT 1030,TRACE,EL(N),STA(N),N
 2550 N=N+1
      XOVER=0.
      GO TO 2320
 2560 PEL=ELV
      PST=ST
      IF(N-100)2570,2570,2990
 2570 IF(ISWT3) 2590,2590,2580
C                                                              TRACE = 7
 2580 TRACE=7.
      PRINT 1030,TRACE,EL(N-1),STA(N-1),N
      PRINT 1010,TRACE,PEL,PST,ELV,ST,XOVER,PXOVER
 2590 IF(ST-STMAX)1440,2600,2600
 2600 IF(NOIMP) 2630,2630,2610
 2610 MAXN = NUMST
      PRINT 2620
 2620 FORMAT(/41H 2620 NO IMPROVEMENT MADE TO THIS SECTION)
      GO TO 2640
 2630 MAXN=N-1
      DO 2635 I=1,MAXN
      IF(STA(I)-STMAX)2635,2640,2635
 2635 CONTINUE
      MAXN=N
      EL(N)=ELCH+ (ST-CLSTA-BW*.5)/RSS
      STA(N)=STMAX-.01
      N=N+1
      MAXN=N
      EL(N)=ELV
      STA(N)=STMAX
 2640 IF(TSTCHL-STCHL)2631,2637,2637
 2631 IF(TSTCHR-STCHL)2637,2652,2636
 2636 DO 2651 J=1,MAXN
      IF(TSTCHL-STA(J))2656,2652,2651
 2651 CONTINUE
      GO TO 2637
 2656 STCHL=STA(J-1)
      GO TO 2637
 2652 STCHL=TSTCHL
 2637 IF(TSTCHR-STCHR)2641,2641,2633
 2633 IF(TSTCHL-STCHR)2638,2654,2641
 2638 DO 2653 J=1,MAXN
      IF(TSTCHR-STA(J))2655,2654,2653
 2653 CONTINUE
      GO TO 2641
 2655 STCHR=STA(J)
      GO TO 2641
 2654 STCHR=TSTCHR
 2641 IF(ISWT3)2735,2735,2645
 2645 PRINT 2650
 2650 FORMAT(// 5X,65HSECNO      STMAX      STCHL      STCHR      XLOBL
     1XLOBR      XLCH)
      PRINT 2660, SECNO,STMAX,STCHL,STCHR,XLOBL,XLOBR,XLCH
 2660 FORMAT(4F10.2,3F10.0)
      PRINT 2670
 2670 FORMAT(/4X,26H           ELTRD       ELLC)
      PRINT 2680,ELTRD,ELLC
 2680 FORMAT(F12.2,F10.2/)
      PRINT 2690
 2690 FORMAT (/80H         BW      CLSTA       XLSS        RSS        ELCH
```

```
     1 NUMST       XNCH      ISWT3)
       PRINT 2700,BW,CLSTA,XLSS,RSS,ELCH,NUMST,CNCH,ISWT3
 2700  FORMAT(/5F10.2,I9,1X,F10.3,I9/)
       PRINT 2710
 2710  FORMAT (31H 2710 COUNT  ELEVATION  STATION/)
       DO 2730 N=1,MAXN
       PRINT 2720,N,EL(N),STA(N)
 2720  FORMAT(I10,2F10.2)
 2730  CONTINUE
 2735  IF(MAXN-100)2800,2800,2740
 2740  PRINT 2750
 2750  FORMAT(/42H 2750 NUMBER OF COMPUTED POINTS EXCEED 100/)
 2800  NOIMP=0
       GO TO 3001
 2980  PXOVER=XOVER
       GO TO 2560
 2990  PRINT 2750
 3001  NUMST=MAXN
       NLCH=1
       DO 3010 I=1,NUMST
       IF(STA(I)-STCHL) 3010,3005,3010
 3005  NLCH=I
       GO TO 3015
C
 3010  CONTINUE
 3015  NRBEL=1
       XLBEL=EL(I)
       DO 3025 I=1,NUMST
       IF(STA(I)-STCHR) 3025,3020,3025
 3020  NRBEL=I
       RBEL=EL(I)
       GO TO 3030
C
 3025  CONTINUE
 3030  ELMIN=EL(1)
       DO 3040 I=1,NUMST
       IF(ELMIN-EL(I)) 3040,3035,3035
 3035  ELMIN=EL(I)
C
 3040  CONTINUE
       X=NLCH
       Y=NRBEL
       Z=NRBEL
       TRACE=3060.
       IF(ISWT3) 3070,3070,3050
 3050  PRINT 3060,TRACE,X,Y,XLBEL,Z,RBEL,ELMIN
 3060  FORMAT(10F12.2)
 3070  IF(IBWT)4020,4020,3080
 3080  PRINT 3090,SECNO
 3090  FORMAT(1X,21H*** IMPROVED SECTION ,F10.2,19H  EL,STA TABLE ***   )
       PRINT 4000,CLSTA,ELCH,XLSS,RSS,XNCH,BW,STCHL,STCHR
 4000  FORMAT(1X,64H   CLSTA     ELCH     XLSS      RSS      XNCH       BW    ST
      1CHL    STCHR   , / (1X,2F8.1,4F8.3,2F9.2, /))
       PRINT 4010,(EL(N),STA(N),N=1,MAXN)
 4010  FORMAT(1X,10F10.2)
 4020  RETURN
       END
```

```
      SUBROUTINE DC
C           METHOD BY MINIMUM SPECIFIC ENERGY-PARABOLIC METHOD
C           LAST CHANGE  4 NOV 1968
C           FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C           FORTRAN SOURCE DECK RENUMBERED ON  4 NOV 1968
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION IDCRD (20),ELOR(200),STAOR(200)
C           ALL VARIABLES IN COMMON     AUG 15, 1967
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
C           DC CALLED FROM 3100 IN MAINLINE
      IDC=IDC+1
      TRACE=4000.
 4000 ITYDC=ITYDC+1
      IF(IDC-80) 4040,4010,4010
 4010 PRINT 4020,TRACE,WSEL1,ELLC,ELTRD,ELMAX,EG1,EGLC
 4020 FORMAT(/F10.0,40H 80 TRIALS NOT ENOUGH FOR CRITICAL DEPTH,10F10.2)
      WSEL=0.0
      IF(IDIR) 4530,4530,4030
 4030 WSEL=999999.
      GO TO 4530
 4040 D1=ZERO
      D2=ZERO
      PWSEL=WSEL
      EGC=WSEL+HV
      IF(ISWT3)4046,4046,4044
 4044 TRACE=4045.
      X=IBRID
      Y=IDC
      Z=ITYDC
      PRINT 4045,TRACE,WSEL1,WSEL,EGC,EG1,EGLC,X,Y,Z
 4045 FORMAT(2X,10F12.3)
 4046 TRACE=4046.
      IF(ITYDC-4)4050,4310,4430
 4050 GO TO (4060,4150,4300,4310),ITYDC
C           FIRST TRY
 4060 HTINC=.05*(WSEL-ELMIN)
      WSEL=WSELT
```

```
      DCASE=1.
      WSEL1=WSEL
      IF(IBRID) 4070,4070,4100
 4070 IF(IDC-1) 4080,4080,4100
 4080 IF(ELTRD-99999.) 4090,4090,4100
 4090 WSEL=ELLC
      DCASE=2.
      WSEL1=WSEL
      PWSEL=0.0
      GO TO 4120
 4100 IF(ISECN-1) 4120,4120,4110
 4110 WSEL1=PCRWS-PELMN+ELMIN
      WSEL=WSEL1
      DCASE=3.
      PWSEL=0.0
 4120 X=2.*HTINC+.01
      IF(WSEL-ELMAX+X)4140,4140,4130
 4130 WSEL=ELMAX -X
      DCASE=4.
      WSEL1=WSEL
      GO TO 4380
 4140 IF(PWSEL-WSELT)4380,4000,4380
C           SECOND TRY
C
 4150 EG1=EGC
      IF(IDC-2) 4160,4160,4170
 4160 EGLC=999999.
 4170 IF(IBRID) 4180,4180,4290
 4180 IF(IDC-2) 4190,4190,4290
 4190 IF(ELTRD-99999.) 4200,4290,4290
 4200 X=ACH+ALOB+AROB
      IF(X-1.) 4210,4220,4220
 4210 X=0.0
      EGLC=999999.
      GO TO 4250
C           CONSTANT=(2G/K)**.5   5.67 ENGLISH   3.11  METRIC (K=2.04)
 4220 IF(CONST-1.001) 4230,4230,4240
 4230 X=3.11*(ACH+ALOB+AROB)**1.5/((TWL+TWR+TWCH)**.5)
      GO TO 4250
 4240 X=5.67*(ACH+ALOB+AROB)**1.5/((TWL+TWR+TWCH)**.5)
C
 4250 QCRIT=X
      EGLC=EGC
      TRACE=4250.
      IF(ISWT3) 4265,4265,4255
 4255 PRINT 4260,TRACE,X,ACH,ALOB,AROB,TWL,TWR,TWCH,DCASE
C
 4260 FORMAT(/F10.0,7H QCRIT=,10F10.2)
 4265 IF(Q-X) 4280,4270,4270
 4270 X=ELTRD
      IF (ELTRD-ELLC)4272,4278,4278
 4272 X=100000.
      DO 4274 I=NLCH,NRBEL
      IF(XLCEL(I)-X)4273,4274,4274
 4273 X=XLCEL(I)
 4274 CONTINUE
      IF(X-ELLC)4275,4275,4278
 4275 X=ELLC
 4278 WSEL=X+1.
      DCASE=5.
```

```
      WSEL1=WSEL
      ITYDC=1
      GO TO 4120
 4280 WSEL=ELLC-2.*HTINC
      DCASE=6.
      WSEL1=WSEL
      ITYDC=1
      GO TO 4120
 4290 HTINC=.05*(WSEL1-ELMIN)
      WSEL=WSEL1+HTINC
      DCASE=7.
      GO TO 4380
C          THIRD TRY
 4300 EG2=EGC
      WSEL=WSEL +HTINC
      DCASE=8.
      GO TO 4380
C          FOURTH TRY FROM PARABOLA ASSUMPTION
C
 4310 X=(WSEL1-ELMIN)*1.5+ELMIN
      Y=(WSEL1-ELMIN)*.5+ELMIN
      D1=EG2-EG1
      D2=EGC-EG2
      IF(D2-D1)4320,4330,4340
 4320 IF(D1)4350,4350,4370
 4330 IF(D1)4350,4550,4370
 4340 WSEL=WSEL1+HTINC*.5-HTINC*D1/(D2-D1)
      DCASE=9.
      HTINC=.05*(PWSEL-ELMIN)
C          CHECK WSEL FOR EXTREME VALUES
      IF(X-WSEL)4350,4360,4360
C          RESTRICT TO 50 PERCENT GREATER THAN PREV. DEPTH
 4350 WSEL=X
      DCASE=10.
      GO TO 4380
 4360 IF(Y-WSEL)4380,4380,4370
 4370 WSEL=Y
      DCASE=11.
      GO TO 4380
C          TRACE OF CRITICAL DEPTH
 4380 IF(ISWT3)4420,4420,4390
C
 4390 TRACE=4390.
      X=ITYDC
      Y=IDC
      D3=D2-D1
      PRINT 4400
C
 4400 FORMAT (/6H TRACE,3X,5H  IDC,7X,6H ITYDC,6X,5HPWSEL,
     17X,6H   EGC,9X,4HWSEL,7X,4HHINC,7X,2HHV,9X,2HD1,9X,
     22HD2,9X,2HD3,5X,5HDCASE)
      PRINT 4410,TRACE,Y,X,PWSEL,EGC,WSEL,HTINC,HV,D1,D2,D3,DCASE
C
 4410 FORMAT (/3F8.0,2F15.5,7F10.2/)
      TRACE=4410.
      PRINT 4260,TRACE,X,ACH,ALOB,AROB,TWL,TWR,TWCH
 4420 X=.01
      IF(WSEL-ELMAX+X)4540,4540,4590
C          ITRYDC GREATER THAN 5
 4430 X=WSEL-WSEL1
```

```
      Y=ALLDC*.01*(PWSEL-ELMIN)
      Y=ALLDC*.01*(PWSEL-ELMIN)
      IF(X)4440,4450,4450
 4440 X=-X
 4450 IF(Y-.5)4470,4470,4460
 4460 Y=.5
 4470 IF(X-Y)4510,4510,4480
C           CHECK PARABOLIC ASSUMPTION FOR MIN ENERGY
 4480 IF(EGC-EG1)4500,4500,4490
C           WRONG DIRECTION
C
 4490 WSEL=.7*WSEL1+.3*WSEL
      DCASE=12.
C           ACCEPT MIN CHANGE OF (.3)**5 OR .002*CHANGE
      IF(ITYDC-15)4380,4500,4500
C
 4500 ITYDC=TWO
      WSEL1=WSEL
      GO TO 4150
 4510 IF(EGC-EG1-.01)4520,4520,4490
 4520 IF(ISWT3)4550,4550,4530
 4530 X=ITYDC
      Y=IDC
      D3=D2-D1
      TRACE=4510.
      PRINT 4400
      PRINT 4410,TRACE,Y,X,PWSEL,EGC,WSEL,HTINC,HV,D1,D2,D3,DCASE
      GO TO 4550
 4540 IEND=1990
      RETURN
 4550 IEND=3670
      IF(IDC-80)4560,4560,4580
 4560 IF(EGLC-EGC)4570,4580,4580
 4570 PRINT 4575,ELLC,EGLC,EGC,WSEL
 4575 FORMAT(/42H 4575 CRITICAL DEPTH ASSUMED BELOW ELLC OF,F10.3,6H EGL
     1C=,F10.3,5H EGC=,F10.3,6H WSEL=,F10.3)
      WSEL=ELLC
      DCASE=13.
      IPRNT=IPRNT+2
      GO TO 4380
C           RETURN WITH CORRECT CRITICAL WATER SURFACE ELEVATION
C
 4580 RETURN
 4590 IEND=4250
      RETURN
      END
```

```
      SUBROUTINE BLFLO
C           LAST CHANGE OCTOBER 1968
C           ROUTINE FOR ANY PRISMATIC CROSS SECTION
C           FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C           FORTRAN SOURCE DECK RENUMBERED ON  1 NOV 1968
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION IDCRD(20),ELOR(200),STAOR(200)
C           ALL VARIABLES IN COMMON     AUG 15, 1967
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
C           BLFLO CALLED FROM STATEMENT 1360.08 IN MAINLINE
 5000 FORMAT(1X,F7.0,9F8.0)
C
 5005 FORMAT(10F13.2)
 5010 IEND=IZERO
      PRINT 5020
 5020 FORMAT(/15H SPECIAL BRIDGE/)
      ELCH=PELMN
      UPPER=2.*(PCWSE-PELMN+PHV)
      SS=0.0
      ELCHU=PELMN
      ELCHD=PELMN
      IPRNT=IPRNT+3
      XK=RDINP(1)
      XKOR=RDINP(2)
      COFQ=RDINP(3)
      RDLEN=RDINP(4)
      BWC=RDINP(5)
      BWP=RDINP(6)
      BAREA=RDINP(7)
      SS=RDINP(8)
      IF(RDINP(9)) 5040,5040,5030
 5030 ELCHU=RDINP(9)
      ELCHD=RDINP(10)
 5040 IBRID=ONE
      IF(ELCHU-.0001) 5060,5060,5050
 5050 IF(ELCHD-.0001) 5060,5060,5080
C
```

```
 5060 PRINT 5070
 5070 FORMAT(54H 5070,VARIABLE ELCHU OR ELCHD ON CARD SB NOT SPECIFIED)
C      CARD  5070+1 REMOVED
 5080 ELCH=(ELCHU+ELCHD)/2.
 5090 QWEIR=ZERO
      QPR=Q
      H3=ZERO
      EGPRS=ZERO
      ZMDS=0.
      D3=PCWSE-ELCHD
      BWN=BWC
      CALL YCRIT(BWN,SS,Q,DCBWC,EC,NTRYC,TWOG,UPPER)
      IFNCR=10
      CRIWS=DCBWC+ELMIN
C      CHECK FOR BRIDGE LOSS BEING READ IN
      IF(BLOSS-.0001) 5110,5110,5100
 5100 WSEL=PCWSE+BLOSS
      RETURN
 5110 IF(BWP) 5120,5120,5140
 5120 WSEL=PCWSE-PELMN+ELMIN
      CRATIO=0.0
      WSBR=PCWSE
      GO TO 5560
C       * * DEPTH, AREA AND Y BAR AT U.S. AND D.S SECTIONS  * * * * * * *
 5140 IF(IDIR) 5150,5150,5160
 5150 X=PCWSE-ELCHD
      CRIWS=DCBWC+ELCHD
      GO TO 5170
 5160 X=PCWSE-ELCHU
      CRIWS=DCBWC+ELCHU
C            AREA FOR UPSTREAM AND DOWNSTREAM CROSS SECTIONS
 5170 TEM=X*BWC+SS*X*X
C            Y BAR OF U.S. AND D.S.
      Y=.3333*X*(3.*BWC+2.*SS*X)/(2.*BWC+2.*SS*X)
C       * * COMPUTE MINIMUM MOMENTUM AT BRIDGE SECTION  * * * * * * * * *
C            COMPUTE CRITICAL DEPTH
      BWN=BWC-BWP
      UPPER=2.*(PCWSE-PELMN+PHV)
      CALL YCRIT(BWN,SS,Q,BDC,EC,NTRYC,TWOG,UPPER)
C            COMPUTE M FOR BRIDGE FOR CRITICAL DEPTH
C            AREA OF BRIDGE OPENING
      Z=BDC*(BWC-BWP)+SS*BDC*BDC
      AREA=Z
C            Y BAR AT BRIDGE
      TEMP=.3333*BDC*(3.*(BWC-BWP)+2.*SS*BDC)/(2.*(BWC-BWP)+2.*SS*BDC)
      TRACE=5170.
C            MOMENTUM WITHIN CONSTRICTION FOR CRITICAL DEPTH
      ZMB=Z*TEMP+Q*Q/(ONEG*Z)
      IF(ISWT3) 5200,5200,5180
 5180 PRINT 5005,TRACE,PCWSE,ELCH,TEM,BWC,Y,BDC,Z,TEMP,BWN,UPPER,DCBWC
C            CHECK FOR SUPERCRITICAL OR BACKWATER
 5200 IF(IDIR) 5210,5210,5240
C       * * COMPUTE MOMENTUM WITHIN CONSTRICTION BASED ON D.S. DEPTH* * *
 5210 ZMDS=TEM*Y-X*BWP*.5*X+Q*Q/(ONEG*TEM)
      D3=X
      X=BWP*D3/TEM
      CRATIO=X
      ZMA=ZMDS
C            TEST FOR CLASS A OR B FLOW
      IF(ZMDS-ZMB) 5225,5225,5220
```

```
C           CLASS A FLOW
C           USE YARNELL EQUATION FOR CLASS A FLOW
 5220 H3=2.*XK*PHV*(XK+10.*(PHV/D3)-.6)*(X+15.*(X**4.))
      WSEL=H3+PCWSE
C           COMPUTE DEPTH AT BRIDGE SECTION
      ICASE=2
      CLASS=1.
      ADEP=D3-.5*H3
      ABWP=0.
      ABWC=BWC-BWP
      ZBWP=0.
      GO TO 5300
C           CLASS B FLOW
C     * * * DOWNSTREAM FLOW IS SUPERCRITICAL * * *
 5225 WSBR=BDC+ELCH
      VCH=Q/AREA
      ZMA=ZMB
      ICASE=6
      CLASS=2.
      ADEP=0.8*DCBWC
      ABWP=BWP
      ABWC=BWC
      ZBWP=0.
      GO TO 5300
 5226 X=ADEP+ELCHD
      D3=ADEP
      PRINT 5227,X,PCWSE
 5227 FORMAT (24H 5227 DOWNSTREAM ELEV IS,F10.2,5H ,NOT,F10.2,56H HYDRAU
     1LIC JUMP OCCURS DOWNSTREAM (IF LOW FLOW CONTROLS)/)
C
C             NOW CALCULATE ICASE=1 (UPSTREAM DEPTH BASED ON MIN. M)
      ICASE=1
      ABWP=BWP
      ABWC=BWC
      ZBWP=BWP
      ADEP=1.2*DCBWC
      GO TO 5300
C           SUPERCRITICAL FLOW
C           MOMENTUM WITHIN CONSTRICTION BASED ON UPSTREAM DEPTH
 5240 ZMUS=TEM*Y-X*BWP*.5*X+Q*Q*(TEM-.5*CMOM*X*BWP)/(ONEG*TEM*TEM)
      D1=PCWSE-ELCHU
C           TEST FOR SUPER - CLASS C OR B
      IF(ZMUS-ZMB) 5270,5250,5250
C           CLASS C
C           CALC ICASE=2 AND 3, CASE2(DEPTH AT BRIDGE BASED ON M)FIRST
 5250 ICASE=4
      CLASS=3.
      ZMA=ZMUS
      ABWP=0.
      ABWC=BWC-BWP
      ZBWP=0.
      ADEP=D1+1.
      GO TO 5300
C           NEXT CALC CASE 3 (DEPTH D.S. BASED ON M)
 5260 WSBR=ELCH+ADEP
      VCH=Q/AREA
      ADEP=D1
      ICASE=3
      ABWP=BWP
      ABWC=BWC
```

```
      ZBWP=0.
      GO TO 5300
C           SUPERCRITICAL FLOW - CLASS B
 5270 WSBR=BDC+ELCH
      CLASS=2.
      VCH=Q/AREA
      ICASE=5
C           CALCULATE ICASE=1, THEN 3 (DEPTH U.S. BASED ON MIN. M)
      ZMA=ZMB
      ADEP=DCBWC+1.
      ABWP=BWP
      ABWC=BWC
      ZBWP=BWP
      GO TO 5300
C           DEPTH U.S. RECOMPUTED FROM CONTROL - NEW BACKWATER REQUIRED
 5280 X=ADEP+ELCHU
      D1=ADEP
      PRINT 5290,X,PCWSE
 5290 FORMAT(22H 5290 UPSTREAM ELEV IS,F10.2,5H ,NOT,F10.2,23H NEW BACKW
     1ATER REQUIRED/)
C           THEN CALCULATE ICASE=3 (D.S. DEPTH BASED ON MIN. M)
      ICASE=3
      ABWP=BWP
      ABWC=BWC
      ZBWP=0.
      ADEP=DCBWC-2.
C           TRIAL AND ERROR FOR DEPTH BY MOMENTUM
C        CASE =              1    2    3     4       5       6
C       SOLVE FOR DEPTHS    US   BR   DS   BR+DS   US+DS   DS+US
 5300 TRACE=5300.
      TRY=0.0
      IF(ISWT3) 5350,5350,5310
 5310 PRINT 5320
 5320 FORMAT(16X,4HZMDS,6X,2HD3,8X,1HX,9X,3HZMA,6X,3HZMB,6X,2HH3)
      PRINT 5330,TRACE,ZMDS,D3,X,ZMA,ZMB,H3,CMOM
 5330 FORMAT(6H TRACE,F7.0,10F10.2)
      PRINT 5340,ICASE,TRY,ADEP,X,Y,Z
 5340 FORMAT( 9H MOMENTUM,I8,6F12.2)
C           AREA FOR U.S. OR D.S.  PRISMATIC CROSS SECTION
 5350 X=ADEP*(ABWC)+SS*ADEP*ADEP
      AREA=X
C           Y BAR FOR U.S. OR D.S.
      Y=.3333*ADEP*(3.*ABWC+2.*SS*ADEP)/(2.*ABWC+2.*SS*ADEP)
      Y=X*Y
C           OBSTRUCTION MOMENTUM - AREA * YBAR
      Z=ADEP*ABWP*.5*ADEP
C           COMPUTED MOMENTUM WITHIN CONSTRICTION
      ZMC=Y-Z+Q*Q*(X-0.5*CMOM*ADEP*ZBWP)/(ONEG*X*X)
      TRY=TRY+1.
      TRACE=5360.
      TEM=ICASE
      IF(ISWT3) 5380,5380,5360
 5360 PRINT 5005,TRACE,TEM,TRY,ADEP,ZMA,ZMC,X,Y,Z
 5380 X=.001*ZMA
      Y=ZMA-ZMC
      IF(Y) 5390,5400,5400
 5390 Y=-Y
C           DOES COMPUTED MOMENTUM WITH CONSTRICTION EQUAL KNOWN MOMENTUM
 5400 IF(Y-X) 5410,5410,5490
C           CORRECT ANSWER FOR DEPTH
```

```
 5410 GO TO (5420,5480,5430,5260,5280,5226),ICASE
 5420 WSEL=ELCHU+ADEP
      GO TO 5560
 5430 WSEL=ELCHD+ADEP
      IF(IDIR) 5440,5440,5450
 5440 IF(DCBWC-ADEP) 5560,5560,5460
 5450 IF(DCBWC-ADEP) 5460,5560,5560
C
 5460 PRINT 5470,DCBWC,ADEP,IDIR,ICASE
 5470 FORMAT(/40H 5470 ERROR DS DEPTH WRONG SIDE CRITICAL,2F10.2,2I8)
 5480 WSBR=ELCH+ADEP
      VCH=Q/AREA
      GO TO 5560
C           MAKE NEW GUESS FOR DEPTH
 5490 IF(TRY-1.) 5500,5500,5510
 5500 XADEP=ADEP
      XMC=ZMC
      ADEP=1.1*ADEP
      GO TO 5350
C           ESTIMATE DEPTH USING TWO PREVIOUS DEPTHS
 5510 TEM=ADEP
      ADEP=ADEP-(ZMA-ZMC)*(XADEP-ADEP)/(ZMC-XMC)
      Z=.1*TEM
      X=TEM+Z
      Y=TEM-Z
C        CHECK ASSUMED DEPTH FOR INCREASING ESTIMATE MORE THAN 10 PERCENT
      IF(ADEP-X) 5530,5530,5520
 5520 ADEP=TEM+Z
      GO TO 5550
C        CHECK ASSUMED DEPTH FOR DECREASING ESTIMATE MORE THAN 10 PERCENT
 5530 IF(ADEP-Y) 5540,5550,5550
 5540 ADEP=TEM-Z
C
 5550 XADEP=TEM
      XMC=ZMC
      GO TO 5350
 5560 PRINT 5570
 5570 FORMAT(5H SB   ,2HXK,8X,4HXKOR,6X,4HCOFQ,6X,5HRDLEN,5X,3HBWC,7X,
     13HBWP,7X,5HBAREA,5X,2HSS,8X,5HELCHU,5X,5HELCHD)
      PRINT 5580,XK,XKOR,COFQ,RDLEN,BWC,BWP,BAREA,SS,ELCHU,ELCHD
 5580 FORMAT(10F10.2)
      PRINT 5590
 5590 FORMAT(1H )
      VBR=VCH
      RETURN
      END
```

```
      SUBROUTINE BWEIR
C           FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C           LAST CHANGE   OCT 1968
C           FORTRAN SOURCE DECK RENUMBERED ON  4 NOV 1968
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION IDCRD(20) ,ELOR(200),STAOR(200)
C           ALL VARIABLES IN COMMON     AUG 15, 1967
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
C           BWEIR CALLED FROM 2980 IN MAINLINE
C           TABLES OF SUBMERGENCE OF WEIR
 6000 FORMAT(1H )
      HDHE(1)= ZERO
      HDHE(2)=  .052
      HDHE(3)=  .086
      HDHE(4)=  .23
      HDHE(5)=  .34
      HDHE(6)=  .495
      HDHE(7)=  .705
      HDHE(8)=  .850
      PERED(1)=100.
      PERED(2)= 60.
      PERED(3)= 40.
      PERED(4)= 10.
      PERED(5)=  6.
      PERED(6)=  3.
      PERED(7)=  ONE
      PERED(8)= ZERO
      TWEL=PCWSE
      ORIF=0.
 6010 FORMAT(12F10.2)
      IF(EGPRS)6030,6030,6020
C           E G HAS BEEN FOUND, SOLVE FOR WSEL BY TRIAL/ERROR
 6020 CWSEL=EG    -HV
      XLOSS=EG    -XEG
      HL= XLOSS
      GO TO 6880
C
```

```
 C          LOW FLOW CONTROL DATA HAS BEEN COMPUTED
 C
  6030 EGLWC=WSEL+HV
 C          CHECK FOR POSSIBLE ORIFICE FLOW
       IF(EGLWC-ELLC)6040,6040,6160
 C          FLOW IS BY LOW FLOW CONTROL
  6040 IF(EGLWC-ELTRD)6050,6050,6230
  6050 IF(BWP) 6060,6060,6080
  6060 PRINT 6070
  6070 FORMAT(/31H 6070,LOW FLOW BY NORMAL BRIDGE/)
       PRINT 6075,EGPRS,EGLWC,ELLC,PCWSE,ELTRD
  6075 FORMAT(1X, 6HEGPRS=,F10.3,2X,6HEGLWC=,F10.3,2X,5HELLC=,F10.3,2X,
      16HPCWSE=,F10.3,2X,6HELTRD=,F10.3)
       IBRID=0
       GO TO 6900
  6080 CWSEL=WSEL
       EG=EGLWC
       IF(IDIR) 6090,6090,6130
  6090 IF(EG-XEG+.01) 6100,6120,6120
  6100 PRINT 6110,EG,XEG
  6110 FORMAT(14H 6110 EGLWC OF,F8.2,17H LESS THAN XEG OF,F8.2)
       EG=XEG
  6120 XLOSS=EG-XEG
       HL= XLOSS
       GO TO 6890
  6130 IF(EG-XEG) 6140,6140,6150
  6140 XLOSS=XEG-EG
       HL=XLOSS
       GO TO 6890
  6150 PRINT 6110,EG,XEG
       EG=XEG
       XLOSS=0.0
       HL=0.0
       GO TO 6890
 C
 C          ORIFICE FLOW IS POSSIBLE
  6160 X=((Q/BAREA)**2)/TWOG
       IF(PCWSE-ELLC)6050,6170,6170
 C
 C
  6170 EGPRS = X*XKOR+TWEL
 C
 C          CHECK FOR PRESSURE FLOW
       IF(EGPRS -EGLWC )6050,6050,6180
 C
 C          FLOW IS BY PRESSURE
 C          CHECK FOR WEIR FLOW
  6180 IF(IDIR)6190,6190,6183
  6183 PRINT 6185
  6185 FORMAT(38H 6180 SUPERCRITICAL FLOW,PRESSURE FLOW)
  6190 IF(EGPRS-ELTRD) 6210,6210,6200
  6200 CLASS=30.
       GO TO 6240
  6210 WSEL=WSEL+TWO
       CLASS=10.
       EG=EGPRS
       IF(EG-XEG) 6220,6900,6900
  6220 PRINT 6110,EG,XEG
       EG=XEG
       GO TO 6900
```

```
C          FLOW IS BY WEIR AND LOW FLOW
 6230 ORIF=10.
      EGPRS=ELLC
      CLASS=CLASS+10.
      NTYCQ=1
C
C
C          FLOW IS BOTH WEIR AND ORIFICE OR WEIR AND LOW FLOW
 6240 X=ELTRD
      IFNCR=0
      IF(ELTRD - TWEL)6250,6260,6260
 6250 X=TWEL
 6260 EG=(EGPRS + X)*.5
      ICONT=IZERO
      IF(ISWT3)6268,6268,6262
 6262 TRACE=6262.
      PRINT 6010,TRACE,ELTRD,ELLC,EGPRS,PCWSE,EGLWC,ORIF,CLASS
 6268 IF(EG-ELMAX) 6280,6280,6270
 6270 EG=ELMAX+50.
C
C
 6280 H=EG-TWEL
      IF(H)6290,6290,6300
 6290 H=0.001
 6300 IF(ORIF) 6410,6410,6310
C          FLOW BY YARNELL CLASS A FOR BRIDGE SECTION
 6310 DSQ=PVCH*PACH
      ITRY=0
      NTYCQ=NTYCQ+1
 6320 X =  DSQ/PACH
C          DOWNSTREAM HV=CVHD
      CVHD=(X**2 )/TWOG
      H3=2.*XK*CVHD*(XK+10.*(CVHD/D3)-.6)*(CRATIO+15.*(CRATIO**4 ))
      USWEL=PCWSE+H3
      USD=(H3+PCWSE)-ELCH
      USVH=EG-USWEL
      IF(USVH) 6330,6330,6340
 6330 USVH=0.1
      EG=USWEL+0.1
 6340 USV=(TWOG*USVH)**.5
      USCHA=USD*BWC+SS*USD*USD
      QPR=USCHA*USV
      IF(QPR)6338,6341,6341
 6338 QPR=0.0
 6341 X=.01*DSQ
      DIFQ=DSQ-QPR
      IF(ISWT3) 6342,6346,6342
 6342 TRACE=6344.
      PRINT 6344,TRACE,ITRY,DSQ,QPR,USCHA,USV,USVH,USD,USWEL,EG,CVHD
 6344 FORMAT(F10.2,I8,10F10.2)
 6346 IF(DIFQ) 6350,6420,6360
 6350 DIFQ=-DIFQ
 6360 DSQ=(QPR+DSQ)*.5
 6370 IF(X-DIFQ) 6380,6380,6420
 6380 ITRY=ITRY+1
      IF(50-ITRY) 6390,6390,6320
 6390 PRINT 6400
 6400 FORMAT(42H 6400 TRIAL AND ERROR FOR CHANNEL Q FAILED)
      IF(NTYCQ-5) 6402,6402,6910
 6402 X=NTYCQ
```

```
      EG=ELTRD+X
      GO TO 6420
C
C           FLOW FROM ORIFICE
C
 6410 QPR=(TWOG**.5)*((H/XKOR)**.5)*BAREA
C
 6420 QWEIR=ZERO
      IF(NRD) 6460,6460,6430
 6430 DO 6440 I=2,NRD
      IF(RDEL(I)-EG)6450,6440,6440
C
 6440 CONTINUE
      EG=ELTRD+ONE
      GO TO 6280
C
C           HEAD, LENGHT FOR 1ST INC AREA-WEIR
 6450 H= (RDEL(I)+EG)*.5-RDEL(I)
      XLEN=(RDST(I)-RDST(I-1))*2.*H /(RDEL(I -1)-RDEL(I))
      IEND=IZERO
      GO TO 6480
 6460 H=EG-ELTRD
      NRD=IZERO
      I=ONE
      XLEN=RDLEN
      IF(H)6470,6470,6480
 6470 EG=ELTRD+.01
      GO TO 6280
C
C           FLOW OVER WEIR
C
C           SUBMERGENCE COEF. FROM WES HDC 111-4
C
 6480 XHDHE = (EG-TWEL)/H
      IF(XHDHE)6490,6500,6500
 6490 XHDHE=.0001
 6500 DO 6510 N=1,8
      IF(XHDHE-HDHE(N))6520,6510,6510
C
 6510 CONTINUE
      N=8
      XHDHE=.85
 6520 X=(XHDHE-HDHE(N-1))/(HDHE(N)-HDHE(N-1))
      Y=PERED(N-1)-X*(PERED(N-1)-PERED(N))
      X=COFQ*.01*(100.-Y)
      IF(H) 6530,6530,6540
 6530 H=.001
 6540 QWEIR=X*XLEN*(H**1.5)+QWEIR
C
C           TRACE FLOW OVER WEIR COMPUTATION
C
C
C
      IF(ISWT3)6550,6580,6550
 6550 TEM=I
      QT=QWEIR+QPR
      Z=QT-Q
      TRACE=6550.
      PRINT 6560
C
```

```
 6560 FORMAT(1H )
      PRINT 6570
 6570 FORMAT(/6H TRACE,8X,5HICONT,5X,2HEG,8X,2HQT,8X,4HQT-Q,6X,1HI,9X,1H
     1H,9X,4HXLEN,6X,4HRDST,6X,          3X,7HRDEL(I),1X,4HSUBC,3X,1HX/9
     2X,5HQWEIR,5X,3HQPR)
      TEMP=ICONT
      PRINT 6010, TRACE,TEMP ,EG,QT,Z,TEM,H,XLEN,RDST (I),RDEL(I),Y,X
      PRINT 6010,TRACE,QWEIR,QPR
      PRINT 6560
      IPRNT=IPRNT+5
 6580 I=I+1
      IF(I-NRD)6590,6650,6680
 6590 IF(EG-RDEL(I))6620,6620,6600
C
C          HEAD, LENGTH FOR MIDDLE VALUES INC. AREAS-WEIR
 6600 IF(IEND)6610,6610,6450
 6610 XLEN=RDST(I)-RDST(I-1)
      H=EG-.5*(RDEL(I)+RDEL(I-1))
      GO TO 6480
C          HEAD, LENGHT FOR LAST INC. AREA-WEIR
C
C          CHECK FOR SECOND ROADWAY DIP
 6620 IF(IEND)6650,6650,6630
 6630 DO 6640 N=I,NRD
      I=N
      IF(EG-RDEL(N))6640,6640,6450
C
 6640 CONTINUE
      GO TO 6680
 6650 IF(RDEL(I)-RDEL(I-1)) 6670,6660,6670
 6660 I=I+1
      GO TO 6650
 6670 H=(RDEL(I-1)+EG)*.5-RDEL(I-1)
      XLEN=(RDST(I)-RDST(I-1))*2.*H/(RDEL(I)-RDEL(I-1))
      IEND=ITEN
      GO TO 6480
C
C          END WEIR FLOW COMPUTATION
C
C
 6680 QT=QWEIR+QPR
      X=QT-Q
      IF(X)6690,6700,6700
 6690 X=-X
 6700 IF(X-.01*Q)6820,6820,6710
 6710 IF(ICONT-1)6720,6760,6740
 6720 XXEG=EG
      EG=EG+ONE
      ICONT=ICONT+1
      XQT=QT
      GO TO 6280
 6730 EG=PCWSE+.001
      GO TO 6810
C          3 OR GREATER GUESS FOR EG
 6740 IF(X-DIFF)6760,6750,6750
 6750 Y=XXEG
      ICONT=ICONT+1
      EG=.7*EG+.3*XXEG
      QT=XQT
      GO TO 6770
```

```
C
 6760 DIFF=X
      X=(Q-QT)/(XQT-QT)
      ICONT=ICONT+1
      Y=EG
      EG=X*(XXEG-EG)+EG
 6770 IF(ICONT-20)6800,6780,6780
 6780 PRINT 6790
 6790 FORMAT(32H 6790 20 TRIALS OF EG NOT ENOUGH)
      GO TO 6820
 6800 IF(EG-PCWSE)6730,6810,6810
C
 6810 XXEG=Y
      XQT=QT
      GO TO 6280
C
C           E.G. IS CORRECT, SLOVE FOR WSEL
C
C
 6820 WSEL=PCWSE
      IF(ORIF) 6850,6850,6830
 6830 PRINT 6840
 6840 FORMAT(34H 6840,FLOW IS BY WEIR AND LOW FLOW)
      WSBR=USWEL
      VBR=USV
 6850 ICASE=15
      IF(EG-XEG)6860,6900,6900
 6860 PRINT 6870,XEG,EG
 6870 FORMAT(20H 6870 D.S. ENERGY OF,F8.2,31H HIGHER THAN COMPUTED ENERG
     1Y OF,F8.2)
      EG=XEG
      GO TO 6900
C
C           END OF BRIDGE ROUTINE FOR PRESSURE FLOW AND WEIR FLOW
 6880 IEND=3140
      RETURN
 6890 IEND=3155
      RETURN
 6900 IEND=2150
      RETURN
C           RETURN WITH JOB DUMP
 6910 IEND=3785
      RETURN
      END
```

```
      SUBROUTINE YCRIT(B,SS,Q,YC,EC,NTRYC,TWOG,UPPER)
C           GOLDEN SECTION SEARCH
C           BY BILL JOHNSON
 7000 XLOWER=0.2
      NTRYC=1
      ERROR=.01
 7005 DIFUL=UPPER-XLOWER
      Y1=.382*DIFUL+XLOWER
      VAR=(Q**2)/TWOG
      EY1=Y1+VAR/((Y1**2)*(B+SS*Y1)**2)
      Y2=.618*DIFUL+XLOWER
      EY2=Y2+VAR/((Y2**2)*(B+SS*Y2)**2)
C
 7010 DIFE=EY1-EY2
      NTRYC=NTRYC+1
      IF(DIFUL) 7015,7040,7015
 7015 IF(DIFUL-ERROR) 7035,7035,7020
 7020 IF(DIFE) 7025,7025,7030
 7025 UPPER=Y2
      Y2=Y1
      EY2=EY1
      DIFUL=UPPER-XLOWER
      Y1=.382*DIFUL+XLOWER
      EY1=Y1+VAR/((Y1**2)*(B+SS*Y1)**2)
      GO TO 7010
 7030 XLOWER=Y1
      Y1=Y2
      EY1=EY2
      DIFUL=UPPER-XLOWER
      Y2=.618*DIFUL+XLOWER
      EY2=Y2+VAR/((Y2**2)*(B+SS*Y2)**2)
      GO TO 7010
 7035 YC=(Y1+Y2)*.5
      EC=(EY1+EY2)*.5
 7040 YC=Y1
      EC=EY1
 7045 RETURN
      END
```

```
      SUBROUTINE SLARA
C           FORTRAN SOURCE DECK RENUMBERED ON 4 NOV 1968
C           FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C           SLOPE AREA LOOP
      DIMENSION STA(102),EL(102),HDHE(8),PERED(8),RDST(57),RDEL(57)
      DIMENSION XLCEL(57), VALN(20), STN(20),RDINP(151),TITLE(6)
      DIMENSION IDCRD (20),ELOR(200),STAOR(200)
C           ALL VARIABLES IN COMMON     AUG 15, 1967
      COMMON  ACH,ADDEL,ALERR,ALOB,ALPHA,AREA,AREAT,AROB,AVGLN,BWC,
     1BAREA,CALPH,CAREA,CCHV,CEHV,CHV,CINTS,COFQ,CORLN,CORR,CRATIO,CVHD,
     2CRIWS,CWSEL,D1,D2,D3,DCRIT,DELMN,DIFF,DPER,BLOSS,
     3EG,EG1,EG2,EGC,EGLWC,EGPRS,EL,ELEV,ELINS,ELLC,ELCH,ELCHU,ELCHD
      COMMON  ELMAX,ELMIN,ELTRD,ERROR,H,H3,HDHE
     1,HL,HR23,HT,HTINC,HV,HVINS,I,IBRID,ICASE,ICE,ICH,ICONT,ICRI,
     2ICRIS,IDC,IDCP,IDIR,IEND,IEARA,IEARP,IFNCR,IFNIS,IFNSA,IPRNT,ISARA
     3,ISWT2,ISWT3,ITEN,IWSGS,IZERO,INQ,ISECN,ITRIL,ITRY,ITYDC,J,KSEC1,
     4N,NINV,NLCH,NN,NRD,NSEC,NUMST,ONE,PACH,PALOB,PAROB,PVCH
      COMMON  PAT,PCALP,PCARA,PCRWS,PCWSE,PELMN,PERED,
     1PHV,PTWCH,PTWL,PTWR,PWSEL,PXLAM,Q,Q1,Q1CH,Q1LOB,Q1ROB,
     2QC,QCH,QCOMP,QLOB,QPR,QROB,QT,QWEIR,R23CH,RBEL,RDEL,RDINP,
     3RDLEN,RDST,S,SAVE,SECNO,SECNP,SLOPE,ST,STA,SS
      COMMON  STCHL,STCHR,STMAX,STN,SWSEL,TELMX,TEM,
     1TEMP,TEN,TIME,TLENQ,TQ,TRACE,TRIAL,TSECN,TWA,TWCH,TWL,TWEL,
     2TWLEN,TWO,TWR,V1CH,V1LOB,V1ROB,VALN,VAVE,VCH,VEL,VLOB,VOL,VROB,
     3WETPR,WLEN,WPCH,WSEL,WSEL1,WSELK,WSELT,WTN,X,XCWSE
      COMMON  XEG,XEL,XELLC,XHDHE,XHT,XHV,XK,XKOR,XKWSE,XLAM,
     1XLAM1,XLBEL,XLCEL,XLCH,XLEN,XLOBL,XLOBR,XLOSS,XNCH,XNCUR,
     2XNINS,XNL,XNR,XQCOM,XQT,XRDEL,XST,XWSEL,XXEG,Y,ZERO,Z
      COMMON USD,USCHA,USV,USVH,BWP,ALLDC,WSBR,VBR
      COMMON CONST,TWOG,ONEG,CLASS,EGWOS,EGCRI,CMOM,ELOR,STAOR
      COMMON BW,CLSTA,XLSS,RSS,CELCH,CNCH,ICHIMP,NRBEL
C           SLARA CALLED FROM STATEMENTS 2930,3105,3125 IN MAINLINE
 7100 IF(IEND-4090)7105,7110,7160
 7105 QCOMP = TQ*100.*(SLOPE)**.5
 7110 ERROR = QCOMP-Q
      IF(ERROR)7115,7120,7120
 7115 ERROR = - ERROR
C
C           SLOPE/AREA TRACE
C
 7120 TEM=Q*0.01
      IF(ISWT3)7140,7140,7125
 7125 PRINT 7130
 7130 FORMAT(//62H   TRACE    ICOUNT     QCOMP        TQ          WSEL      XW
     1SEL    QC,8H    ICASE)
      TRACE=7130.
      X=ICONT
      Y=ICASE
      PRINT 7135,TRACE, X     ,QCOMP,TQ,WSEL,XWSEL,QC,Y
 7135 FORMAT(12F10.2)
      IPRNT=IPRNT+4
 7140 IF(TEM-ERROR)7145,7160,7160
 7145 IF(ICONT-1)7220,7150,7220
 7150 ICONT=ICONT+1
      XWSEL = WSEL
      XQCOM = QCOMP
      IF(QCOMP-Q)7155,7155,7215
 7155 WSEL = WSEL+TWO
      ICASE=ITEN
      IEND=1960
```

```
      RETURN
7160  IF(ISARA)7165,7170,7200
7165  XKWSE =WSEL
7170  CRIWS = WSEL
      IFNCR=ITEN
      X=CRIWS+HV
      EGCRI=X
      EGMAX=EG
      TRACE=7170.
      IF(ISWT3) 7173,7173,7171
7171  PRINT 7172,TRACE,CRIWS,HV,EGCRI,EG
7172  FORMAT(10F10.2)
7173  IF (KSEC1)7195,7195,7175
7175  IF(EG-X)7185,7185,7180
7180  WSEL=WSELT
      ICASE=16
      IEND=1960
      RETURN
7185  IF(IDIR) 7186,7186,7180
7186  PRINT 7190
7190  FORMAT(/25H 7185 MIN SPECIFIC ENERGY/)
      IEND=3740
      RETURN
7195  WSEL = XKWSE
      ICASE=12
      IEND=1960
      RETURN
7200  IF(QC)7205,7210,7205
7205  IFNCR=ITEN
      CRIWS = WSEL
      WSEL = SWSEL
      EGCRI=CRIWS+HV
      EGMAX=EG
      ICASE=13
      IEND=1960
      RETURN
7210  IFNSA=ITEN
      SWSEL = WSEL
      IEND=2980
      RETURN
7215  WSEL = WSEL-TWO
      ICASE=11
      IEND=1960
      RETURN
7220  X = (Q-QCOMP)/(XQCOM-QCOMP)
      ICONT=ICONT+1
      IF(ICONT-100)7225,7225,7230
7225  TEM = WSEL
      WSEL = X * (XWSEL-WSEL)+WSEL
      ICASE=14
      XWSEL = TEM
      XQCOM = QCOMP
      IEND=1960
      RETURN
7230  PRINT 7235
7235  FORMAT(34H 7230 SLOPE-AREA TRIALS EXCEED 100)
      GO TO 7210
      END
```

```
      SUBROUTINE SCALE(XMIN,YMIN,XMAX,YMAX,XWT,YWT,X,Y,Z,TEM)
C          FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
      DIMENSION STN(3)
      DIMENSION IDCRD (20)
C          SCALE CALLED FROM 1090,3605 IN MAINLINE
C          X = FIRST VALUE OF VERTICAL SCALE-ROUNDED OFF (END PRODUCT)
C          Y = SPACING OF 10 UNITS OF Y-ROUNDED (END PRODUCT)
C          Z = SPACING OF 1 LINE OF PRINT-ROUNDED (END PRODUCT)
C          TEM= FIRST VALUE OF HORIZONTAL SCALE-ROUNDED OFF(END PRODUCT)
C          FIRST VALUE OF VERTICAL SCALE NOT ROUNDED DOWN
 7750 X=YMIN
      Y=(YMAX-YMIN)*10./(YWT-1.)
C          Y = SPACING OF 10 UNITS OF Y (DISTANCE BETWEEN SEL(I) AND
C              SEL(I+1) NOT ROUNDED UP)
C          FIND A VERTICAL SCALE (Y) WHICH IS A MULTIPLE OF 1,2 OR 5   *
C
 7760 DO 7780 IN=1,10
      N=(10**IN)/10
      STN(1)=1*N/100
      STN(2)=2*N/100
      STN(3)=5*N/100
      DO 7770 M=1,3
      IF(STN(M)-Y)7770,7790,7790
C
 7770 CONTINUE
      M=3
 7780 CONTINUE
      IN=10
C
 7790 Y=STN(M)
C          FIND THE SCALE (FY) JUST LARGER THAN (Y)   *    *    *    *    *
      IF(M-3) 7800,7810,7810
 7800 FY=STN(M+1)
      GO TO 7820
 7810 IN=IN+1
      FY=(10**IN)/1000
C          CALCULATE FIRST VERTICAL SCALE VALUE (X)   *    *    *    *    *
C
 7820 N=Y
C
      I=X/Y
      IF(I)7830,7840,7840
 7830 I=I-1
 7840 X=I*N
C          CHECK MAXIMUM VERTICAL SCALE VALUE WITH YMAX    *    *    *    *
      TEM=X
C          NUMBER OF VERTICAL SCALE ORDINATES
      N=((YWT-1.)/10.)
C
      DO 7850 I=1,N
 7850 TEM=TEM+Y
      IF(TEM-YMAX)7860,7870,7870
C          CHANGE VERTICAL SCALE TO NEXT HIGHER SCALE
 7860 Y=FY
      GO TO 7820
C
C
C
C          FIND A HORIZONTAL SCALE (MULT. OF 1,2,5)   *    *    *    *    *
 7870 Z=XMAX-XMIN
```

```
      IF(Z)7880,7890,7890
 7880 Z=-Z
C           Z = HORIZONTAL SCALE PER LINE OF PRINT
 7890 Z=Z/XWT
C
      DO 7910 IN=1,10
      A=(10**IN)/10
      STN(1)=1.*A/100.
      STN(2)=2.*A/100.
      STN(3)=5.*A/100.
C
      DO 7900 M=1,3
      IF(STN(M)-Z)7900,7920,7920
C
 7900 CONTINUE
      M=3
 7910 CONTINUE
      IN=10
C
 7920 Z=STN(M)
C          CALCULATE FIRST HORIZONTAL SCALE VALUE (TEM)    *    *    *    *
      I=XMIN/Z
      IF(I)7930,7940,7940
 7930 I=I-1
 7940 TEM=I
      TEM=TEM*Z
      RETURN
      END
```

```
      SUBROUTINE XSEC(X,Y,Z,TEM,WSEL,EL,STA,SECNO,NUMST,RDST,RDEL,XLCEL,
     1ELLC,ELTRD,NRD,TITLE,EG,CRIWS,Q,STCHL,STCHR,NSTRT,NLST)
C     PLOT ROUTINE FOR BACKWATER CROSS SECTIONS
C     BY BILL EICHERT   18 NOV. 1967
C          FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
C          XSEC CALLED FROM  3630  IN MAINLINE
      DIMENSION IT(121),VAR(5),  IS(121),SEL(13),EL(102),STA(102),RDST(5
     17),RDEL(57),XLCEL(57),IVAR(5),TITLE(6),ISUB(3),PVAR(5)
      DATA IE,ITC,IA,IN,IK,IW,IX,IPER,IBL,ITT,IB,BLANK/
     11HE,1HC,1HA,1HN,1HK,1HW,1HX,1H.,1H ,1HT,1HB,
     24H    /
      ZH=.5*Z
      RDEL(NRD+1)=99999999.
      XLCEL(NRD+1)=99999999.
      RDST(NRD+1)=999999.
      STA(NUMST+1)=999999.
      PVAR(4)=0.0
      PVAR(5)=0.0
      VAR(4)=0.0
      IF (NRD) 8004,8004,8003
 8003 RDST(1) = RDST(2) -.01
 8004 VAR(5) = 0.0
C
C          INITIALIZE STANDARD AND TEMPORARY TABLE (IS) AND (IT)   *   *
      DO 8005 I=1,121
      IS(I)= IBL
 8005 IT(I)= IBL
C
C          STORE PERIODS IN STD. TABLE
      DO 8010 I=1,121,10
      IS(I)=IPER
C          COMPUTE VERTICAL SCALE LABELS   *   *   *   *   *   *   *   *
 8010 IT(I)=IPER
C
 8020 SEL(1)=X
      DO 8030 I=2,13
 8030 SEL(I)=SEL(I-1)+Y
      VAR(1)=CRIWS
      VAR(2)=EG
      VAR(3)=WSEL
      IVAR(1)=ITC
      IVAR(2)=IE
      IVAR(3)=IW
C
      C=10./(SEL(2)-SEL(1))
      ST=TEM - Z
C          CALCULATE SUBSCRIPT OF IT TABLE FOR WSEL,EG,CRIWS
C          LIMIT SUBSCRIPT TO I=2-121
C          STORE IN BOTH TABLES IT AND IS
      DO 8080 N=1,3
      I=C*(VAR(N)-SEL(1))+1.5
      IF(I)8040,8040,8050
 8040 I=2
      GO TO 8070
 8050 IF(I-121)8070,8070,8060
 8060 I=121
C
 8070 IT(I)=IVAR(N)
      ISUB(N)=I
      IS(I)=IVAR(N)
```

```
 8080 CONTINUE
C          ADJUST FOR FIXED BRIDGE ELS. OR NO BRIDGE   *   *   *   *   *
C
      IF(NRD)8090,8090,8140
 8090 RDST(1)=0.0
      RDST(2)=STA(NUMST)
      IF(ELLC-999999.)8120,8120,8100
C     NO BRIDGE
 8100 DO 8110 I=1,2
      RDEL(I)=999999999.
 8110 XLCEL(I)=999999999.
      GO TO 8140
C     BRIDGE IS CONSTANT
 8120 DO 8130 I=1,2
      RDEL(I)= ELTRD
 8130 XLCEL(I)=ELLC
C          SLEW,LABEL ELEV. SCALE, PRINT HORIZONTAL LINES (.)   *   *
C
C
 8140 WRITE(7,8150)
 8150 FORMAT(1H1)
      WRITE(7,8160) SECNO
 8160 FORMAT(1X,13HCROSS SECTION,F10.2)
      WRITE(7,8170)(TITLE(I),I=1,6)
 8170 FORMAT(1X,5HRIVER,2X,6A4)
      WRITE (7,8180) Q
 8180 FORMAT (11H DISCHARGE=,F10.0//)
      WRITE(7,8190)
 8190 FORMAT (46H PLOTTED POINTS (BY PRIORITY)-B=BOTTOM BRIDGE,,
     152HT=TOP BRIDGE,X=GROUND,W=WATER SUR,E=ENERGY GRADIENT,,
     215HC=CRITICAL WSEL)
      WRITE(7,8200)(SEL(I),I=1,12)
 8200 FORMAT(/5H ELEV,F6.0,11F10.0/)
      WRITE (7,8210)
 8210 FORMAT(/5X,8HSTA-FEET/)
 8220 FORMAT (F8.0,1X,1H.,9X,1H.,9X,1H.,9X,1H.,9X,1H.,9X,1H.,9X,
     11H.,9X,1H.,9X,1H.,9X,1H.,9X,1H.,9X,1H.,9X,1H.)
C          STORE VALUES OF RDEL(N) AND XLCEL(N)
C          JUST PREVIOUS TO STARTING STATION
C                                                            *   *   *
      DO 8240 NTD=1,NRD
      IF(RDST(NTD)-STA(NSTRT)) 8230,8250,8250
 8230 PVAR(4)=RDEL(NTD)
      PVAR(5)=XLCEL(NTD)
 8240 CONTINUE
 8250 PST=-Z
      J=1
      I=1
C          PLOT NUMST POINTS OF CROSS SECTION   *   *   *   *   *   *
C
C
C
C          SUBSCRIPT OF ELEV                    *   *   *   *   *   *
      DO 8940 N=NSTRT,NLST
C
C
 8260 SPACE=0.0
 8270 ST=ST+Z
      SPACE=SPACE+1.
C          DO I PLOT GIVEN EL PT NOW
```

```
      IF(ST-STA(N)+ZH)8280,8470,8470
C           DO I PLOT GIVEN BRIDGE PT NOW
 8280 IF(ST-RDST(NTD)+ZH)8290,8700,8700
C           CALCULATE SUBSCRIPTS FOR INTERPOLATED POINTS    *    *    *    *
 8290 IF(STA(N)-PST) 8310,8300,8310
 8300 X=PEL
      GO TO 8320
C           X=INTERPOLATED GROUND POINT
 8310 X=PEL+(EL(N)-PEL)*SPACE*Z/(STA(N)-PST)
C           I=SUBSCRIPT FOR INT. GROUND PT
 8320 I=C*(X-SEL(1))+1.5
      IF(I)8330,8330,8340
 8330 I=1
      GO TO 8360
 8340 IF(I-121)8360,8360,8350
 8350 I=121
C
C           OMIT C,E,W IF BELOW INT. GROUND PT
 8360 DO 8380 M=1,3
      IF(X-VAR(M))8380,8370,8370
 8370 J=ISUB(M)
      IT(   J   )=IBL
C
 8380 CONTINUE
      IT(I)=IX
C               CALCULATE INTERPOLATED BRIDGE PTS
      IF(ST-RDST(1)+ZH) 8440,8390,8390
 8390 DO 8430 M=4,5
      VAR(4)=RDEL(NTD)
      VAR(5)=XLCEL(NTD)
      Y=PVAR(M)+(VAR(M)-PVAR(M))*(ST-RDST(NTD-1))/(RDST(NTD)-
     1RDST(NTD-1))
      IF(Y-99999999.) 8394,8430,8430
 8394 I=C*(Y-SEL(1))+1.5
      IF(I) 8430,8430,8400
 8400 IF(I-121) 8410,8410,8430
C               DO NOT PLOT ELLC, ELTRD BELOW GROUND
C           OMIT B,T IF BELOW INT. GROUND PT
 8410 IF(X-Y) 8420,8430,8430
 8420 IT(I)=IVAR(M)
 8430 CONTINUE
C           PRINT INTERPOLATED POINTS AND
C           STORE STD. VALUES IN TEMP. TABLE
 8440 WRITE(7,8450)ST,(IT(I),I=1,121)
 8450 FORMAT(F8.0,1X,121A1)
      DO 8460 I=1,121
 8460 IT(I)=IS(I)
      GO TO 8270
C
C           CALCULATE GIVEN GROUND POINT SUBSCRIPT
 8470 I=C*(EL(N)-SEL(1))+1.5
      IF(I)8480,8480,8490
 8480 I=1
      GO TO 8540
 8490 IF(I-121)8500,8500,8530
C           OMIT C,E,W IF BELOW GIVEN GROUND PT
 8500 DO 8520 M=1,3
      IF(EL(N)-VAR(M))8520,8510,8510
 8510 J=ISUB(M)
      IT(J)=IBL
```

```
C
 8520 CONTINUE
      IT(I)=IX
      GO TO 8570
C
 8530 I=121
 8540 IF(EL(N)-100000.)8550,8500,8500
 8550 WRITE(7,8560)IX,EL(N),STA(N)
C
 8560 FORMAT(12H XSEC POINT-,A1,6X,6HEL,ST-,10F10.2)
      GO TO 8500
 8570 IF(STA(N)-STCHL) 8600,8590,8580
 8580 IF(STA(N)-STCHR) 8600,8590,8600
C
 8590 IT(117)=IB
      IT(118)=IA
      IT(119)=IN
      IT(120)=IK
C
C             PLOT EL NOW, BUT CHECK FOR VERTICAL SIDE FIRST
 8600 IF(ST-STA(N+1)+ZH)8650,8610,8610
 8610 IF(N-NLST) 8620,8650,8650
 8620 IF(PST-ST) 8630,8640,8630
 8630 PEL=EL(N)
      IP=I
 8640 ST=ST-Z
      PST=ST+Z
      GO TO 8940
C
 8650 IF(PST-ST     )8700,8660,8700
 8660 J=IP
      IF(J) 8662,8662,8664
 8662 J=1
      IP=1
 8664 IF(J-121) 8666,8666,8665
 8665 I=121
      IP=121
 8666 IF(I-IP)8670,8700,8680
 8670 J=I
      I=IP
C
C             PLOT GIVEN BRIDGE POINT
C                                            BRANCH TO  8680 FROM  8666.00
 8680 DO 8690 K=J,I
 8690 IT(K)=IX
C             DO I PLOT BRIDGE POINT
C
 8700 IF(ST-RDST(NTD)+ZH)8870,8710,8710
C             COMPUTE SUBSCRIPTS FOR GIVEN BRIDGE PT
 8710 VAR(4)=RDEL(NTD)
      VAR(5)=XLCEL(NTD)
      IVAR(4)=ITT
      IVAR(5)=IB
C
 8720 DO 8810 M=4,5
      I=C*(VAR(M)-SEL(1))+1.5
 8730 IF(I)8790,8790,8740
 8740 IF(I-121)8750,8750,8790
 8750 IT(I)=IVAR(M)
C     CARD 8750+1  REMOVED
```

```
C          OMIT B,T IF BELOW GIVEN GROUND PT
 8760 IF(EL(N)-VAR(M)) 8780,8780,8770
 8770 IT(I)=IBL
      GO TO 8810
 8780 IF(NRD)8785,8785,8810
 8785 IS(I)=IT(I)
      GO TO 8810
 8790 IF(VAR(M)- 9999.) 8800,8810,8810
 8800 WRITE(7,8560)IVAR(M),VAR(M),RDST(NTD)
 8810 CONTINUE
C                                                    *    *    *    *    *    *    *
      IF(NRD)8870,8850,8820
 8820 IF(NRD-NTD)8840,8870,8830
 8830 NTD=NTD+1
      PVAR(4)=VAR(4)
      PVAR(5)=VAR(5)
      GO TO 8870
 8840 NTD=NTD+1
      XLCEL(NTD)=9999999.
      RDEL(NTD)=9999999.
      GO TO 8860
 8850 NTD=2
 8860 PVAR(4)=VAR(4)
      PVAR(5)=VAR(5)
      RDST(NTD)=999999999.
C          PLOT   EL,STA AND/OR BRIDGE POINT   *    *    *    *    *    *    *
C
 8870 WRITE (7,8880)N,ST,(IT(I),I=1,121)
 8880 FORMAT(I3,F5.0,1X,121A1)
C
C     2 CARDS(8880+3)   REMOVED
      PEL=EL(N)
      PST=STA(N)
      DO 8890 I=1,121
 8890 IT(I)=IS(I)
      IF(STA(N)-RDST(NTD)) 8900,8940,8900
C          CHECK IF NEXT BRIDGE POINT IS BEFORE GROUND POINT
 8900 IF(STA(N+1)-RDST(NTD))8940,8940,8910
 8910 DO 8920 I=1,NLST
      IF(STA(I)-RDST(NTD)) 8920,8940,8920
 8920 CONTINUE
      PRINT 8930,RDST(NTD)
 8930 FORMAT(25H 8930,RDST NOT ON GR CARD,F10.2)
      NTD=NTD+1
 8940 CONTINUE
      WRITE(7,8950) NRD,ELLC,ELTRD
 8950 FORMAT(/1X,4HNRD=,I8,6H ELLC=,F12.2,7H ELTRD=,F12.2/)
      IF(NRD) 8980,8980,8960
 8960 N=NRD-1
      WRITE(7,8970)(RDST(I),XLCEL(I),RDEL(I),I=2,N)
 8970 FORMAT(9F10.2)
 8980 J=NUMST-1
      WRITE(7,8982)
 8982 FORMAT(3X,12HEL(I),STA(I))
      WRITE(7,8985)(EL(I),STA(I),I=2,J)
 8985 FORMAT(10F12.2)
      RETURN
      END
```

```
      SUBROUTINE PROF(X,Y,Z,TITLE,IDIR)
C     X,Y,Z=SEL(1),SEL(I)-SEL(I-1),DISTANCE REPRESENTING 1 LINE OF PRINT
C     PLOT ROUTINE FOR BACKWATER PROFILE
C     PLOTS MIN EL,WSEL,BANKS,CRIWS,ELMAX
C     BY BILL EICHERT   NOV 16,1967
C          FORTRAN SOURCE INVENTORY OF BRANCHES PERFORMED 23DEC68
      DIMENSION IT(111),SEL(12),IS(111),IVAR(7),VAR(9),TITLE(6),PVAR(9)
      DIMENSION IDCRD (20)
C          PROF CALLED FROM STATEMENT 1110 IN MAINLINE
      DATA IPER,IBL,IVAR(1),IVAR(2),IVAR(3),IVAR(4),IVAR(5),IVAR(6),
     1IVAR(7)/1H.,1H ,1HM,1HR,1HL,1HC,1HI,1HW,1HE/
      PVAR(5)=0.0
C
 9010 FORMAT(1H )
      IBKSP =0.0
      ST=-7
      REWIND 8
      DO 9020 I=1,111
      IS(I)=IBL
 9020 IT(I)=IBL
      DO 9030 I=1,111,10
      IS(I)=IPER
 9030 IT(I)=IPER
 9040 SEL(1)=X
C
      DO 9050 I=2,12
 9050 SEL(I)=SEL(I-1)+Y
      C=10./(SEL(2)-SEL(1))
C
 9060 PRINT 9070
C
 9070 FORMAT(1H1)
      PRINT 9080,(TITLE(I),I=1,6)
      PRINT 9010
C
 9080 FORMAT(18H PROFILE FOR RIVER,2X,6A4//)
      PRINT 9100
      PRINT 9090,(SEL(I),I=1,11)
C
 9090 FORMAT(/14H ELEVATION-FT-,F7.0,10F10.0/)
C
 9100 FORMAT (123H PLOTTED POINTS (BY PRIORITY)-E-ENERGY GRADIENT,W-WATE
     1R SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,M-MAXI
     2MUM/)
      PRINT 9110
C
 9110 FORMAT (5X,5HSECNO,3X,9HCUMDIS-FT/)
      IC=1
      IF(ST   )9120,9120,9170
C
 9120 IC=1
      IF(IBKSP)9130,9130,9145
C                1      2      3      4      5      6     7      8      9
C        VAR   TELMX  RBEL  XLBEL  CRIWS  ELMIN  WSEL   EG   SECNO  CUMDS
 9130 READ (8,9140)(VAR(I),I=1,9)
 9140 FORMAT (10F12.2)
 9145 DIFF=VAR(6)-VAR(5)
      IBKSP =0.0
      X=SEL(12)-SEL(1)
      IF(DIFF-X) 9160,9150,9150
```

```
 9150 Y=DIFF/10.
      N=Y+1.
      Y=N
      I=VAR(5)/Y
      X=I*N
      IBKSP =1.0
      GO TO 9040
 9160 IF(VAR(6)) 9510,9510,9170
C
 9170 IF(VAR(6)-SEL(12)) 9260,9260,9180
C          SHIFT SCALE TO JUST ABOVE INVERT
C
 9180 TEM=SEL(2)-SEL(1)
 9190 N=TEM
      TEM=N
      X=PVAR(5)
      IF(X-VAR(5)) 9210,9200,9200
 9200 X=VAR(5)
 9210 I=X/TEM
      X=I*N
      Y=TEM
      T=X+11.*Y
      IF(VAR(6)-T) 9040,9220,9220
 9220 TEM=Y*2.
      IBKSP =1.0
      GO TO 9190
 9230 TEM=SEL(2)-SEL(1)
 9240 N=TEM
      I=PVAR(6)/TEM+1.
      X=I*N-11*N
      Y=TEM
      IF(VAR(5)-X) 9250,9250,9040
 9250 TEM=Y*2.
      GO TO 9240
C
 9260 IF(VAR(5)-SEL(1)) 9270,9280,9280
 9270 IF(IDIR) 9180,9180,9230
 9280 SPACE=0.0
 9290 ST=ST+Z
      SPACE=SPACE+1.
      IF(ST)9300,9390,9300
 9300 IF(ST-VAR(9))9310,9390,9390
C          CALCULATE SUBSCRIPTS FOR INTERPOLATED POINTS
 9310 DO 9360 N=1,7
      X=PVAR(N)+(VAR(N)-PVAR(N))*SPACE*Z/(VAR(9)-PVAR(9))
      I=C*(X-SEL(1))+1.5
      IF(I)9320,9320,9330
 9320 I=1
      GO TO 9350
 9330 IF(I-111)9350,9350,9340
 9340 I=111
C
 9350 IT(I)=IVAR(N)
 9360 CONTINUE
C                                          *   *   *   *   *   *   *   *
      PRINT 9370,ST,(IT(I),I=1,111)
 9370 FORMAT(10X,F7.0,2X,111A1)
      DO 9380 I=1,111
 9380 IT(I)=IS(I)
      IC=IC+1
```

```
      GO TO 9290
C
C           CALCULATE SUBSCRIPT FOR GIVEN GROUND POINT
C
 9390 DO 9440 N=1,7
      I=C*(VAR(N)-SEL(1))+1.5
      IF(I)9400,9400,9410
 9400 I=1
      GO TO 9430
 9410 IF(I-111)9430,9430,9420
 9420 I=111
C
 9430 IT(I)=IVAR(N)
 9440 CONTINUE
C                                                    *   *   *   *   *   *   *   *
      PRINT 9450,VAR(8),ST,(IT(I),I=1,111)
 9450 FORMAT(F10.2,F7.0,2X,111A1)
      IC=IC+1
      IF(IC-54)9470,9460,9460
 9460 PRINT 9070
      PRINT 9080,(TITLE(I),I=1,5)
      PRINT 9010
      PRINT 9100
      PRINT 9090,(SEL(I),I=1,11)
      PRINT 9110
      IC=1
 9470 DO 9480 I=1,111
 9480 IT(I)=IS(I)
      DO 9490 I=1,9
 9490 PVAR(I)=VAR(I)
 9500 IF(IC-54)9120,9120,9060
C
C
 9510 REWIND 8
      RETURN
      END
```

Appendix 3

HEC-3
Reservoir System Analysis

HEC-3 RESERVOIR SYSTEM ANALYSIS

COMPUTER PROGRAM 723-X6-L2030

THE HYDROLOGIC ENGINEERING CENTER
CORPS OF ENGINEERS, US ARMY
609 Second Street
Davis, California 95616

FOREWORD

This is the first revision of the program issued in December 1968. The program can now simulate the flood control operation of a reservoir system, accounting for time of flow travel but not for channel storage effects. These effects can be accounted for fully in computer program HEC-1, but that program does not have the capability to draw on upstream reservoirs in such a manner as to maintain a desired balance of remaining storage in the various reservoirs.

This updated version of HEC-3 has increased flexibility in many areas, including optional use of metric units. It also has a routine for automatically solving for the maximum yield at a given point that can be obtained with the specified system controls.

HEC-3
RESERVOIR SYSTEM ANALYSIS

THE HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L2030

CONTENTS

EXHIBITS

HEC-3
RESERVOIR SYSTEM ANALYSIS

THE HYDROLOGIC ENGINEERING CENTER
COMPUTER PROGRAM 723-X6-L2030

1. ORIGIN OF PROGRAM

This program was prepared in The Hydrologic Engineering Center, Corps of Engineers, 609 Second Street, Davis, California. 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 agencies. Programs are furnished by the Government and are accepted and used by the recipient upon the express understanding that the United States Government makes no warranties, expressed or implied, concerning the accuracy, completeness, reliability, usability, or suitability for any particular purpose of the information and data contained in the programs or furnished in connection therewith, and the United States shall be under no liability whatsoever to any person by reason of any use made therof.

The programs belong the the Government. Therefore, the recipient further agrees not to assert any proprietary rights therein or to represent the program to anyone as other than a Government program.

2. PURPOSE OF PROGRAM

a. This program written in FORTRAN IV performs a multipurpose routing of a reservoir system by any number of periods of uniform or varying length per year based on varying flow requirements at reservoirs, diversions and downstream control points and power peaking and energy requirements at reservoirs. It can accept any configuration of reservoirs, diversions, power plants and control points, and will accept system power demands that override individual power plant requirements, but does not provide for channel routings or percolation losses. It can assign economic values to all outputs and summarize and allocate these in various ways. It can automatically iterate to optimize yield at a specified location. Great flexibility of input and output requirements and of computation technique enable the program to solve relatively simple problems with minimum effort or elaborate complex problems with a high degree of accuracy.

b. All requirements are supplied from reservoirs so as to maintain a specified balance of storage in all reservoirs, insofar as possible. At reservoir stages below specified levels, releases from storage at each reservoir are reduced to a secondary specified flow at each control point until all active storage is withdrawn. Provision is included for shortage declaration which will reduce desired flows and diversions covering a period less than 1 year. The shortage declaration is based on total storage at the beginning of a specified period at specified reservoirs. The declared shortage is proportional to the total storage deficiency in these reservoirs at the beginning of that period.

c. Provision is included for changes of basin development or operation plan or demand schedules at the ends of any designated years.

d. The program is capable of performing short-interval flood studies, accounting for travel time between control points but not for channel storage effects. It will provide maximum releases subject to downstream controls whenever there is water in flood control space at a reservoir and will store above full reservoir level to the extent that surcharge storage is possible and permitted. Provision is included for contingency allowances both for flood control and water supply as a function of local inflow above each control point downstream of reservoirs. Diversions out of the stream and into the stream (including return flows) must be specified as fixed amounts for each period, except that return flows for any period can be a ratio of any previously computed diversion for that period.

e. A listing of the source program is given in exhibit 4.

3. DESCRIPTION OF EQUIPMENT

This program was prepared for use in the CDC 6600 computer and is usable on other high-speed computers if dimensions are changed to fit memory size.

4. METHODS OF COMPUTATION

a. All project and requirements data can be entered into the computer in any sequence, but computations are performed in downstream sequence each period. This sequence is specified by the sequence of control point cards.

b. Control points are numbered by integers up to the dimensioned value and must be at or below one or more reservoirs or diversions. All reservoirs and power plants must be numbered the same as the control point at the project location. Diversions are numbered the same as control points at their location, except that diversions from the river immediately below a dam must have a separate control point number and zero local inflows. Relations of storage, elevation, area and outlet capacity at each reservoir are specified by tables. In addition, a specified number of storage levels in acre-feet at each and all reservoirs must be given for each period of the year. The first is minimum pool storage, the second is top of buffer zone, and the last is full reservoir. Remaining intermediate levels are used as a means of controlling the distribution of flood control and conservation-water storage among the reservoirs and must each be as large or larger than the preceding level. Many low-storage levels in reservoirs would cause those reservoirs to be drawn low before drawing on reservoirs with high storage levels. During operation, each level in all reservoirs operating for a given downstream control point is evacuated before going to the next lower level unless a requirement at one or more reservoirs is controlling. Power plants are described by fixed values of tailwater elevation, nameplate and overload capacity. Efficiency can be expressed as a fixed value or in a table versus storage, or it can be included in a table of head versus power generation per unit of outflow.

c. Basin configuration is specified by designating the number and identity of reservoirs above each control point (including any at the point), which of these is to be operated specifically for that control point, the number and identity of diversions in the unregulated area above each control point, and the number and identity of reservoirs above each control point that discharge water directly to that control point (without going through another reservoir except the control point reservoir). Monthly inflows each year to each control point must represent runoff from the area tributary below all upstream reservoirs. This is assumed to be that read into the computer with the respective control point identification, unless data are supplied for computing inflows as a linear function of flows at one or more streamflow locations.

d. For each control point (in downstream sequence), flow requirements to satisfy power and other requirements and maximum permissible flows are first established. Then the water release (QO) necessary to draw each reservoir to a given index level (L), after all diversions are satisfied but with no release from reservoirs further upstream, is determined and the total (QOT) for all reservoirs at or above the control point is determined for each index level. For those reservoirs which are not to be operated specifically for the particular control point, minimum values of QO already set are used in this total. Also in computing this total, minimum and maximum controls at each reservoir are governed by previously set minimum flow requirements and maximum flow limits for all upstream reservoirs.

e. A search is made for a level L to match flow requirements at each control point with the sum of local inflow (reduced by a specified percentage to allow for contingencies) and the reservoir releases corresponding to that level. If this level is above the lowest flood control level, flood releases are required. These are fixed (and modified as necessary as each successive downstream control point is reviewed) to keep storage at the lowest flood control level if possible without exceeding downstream controls. Downstream controls will be exceeded as necessary when a reservoir becomes full. If the desired level is below the next-to-lowest, a shortage of supply is declared. This is accomplished by reducing the withdrawal from storage to supply only a secondary required flow at all downstream locations as long as active storage is available for supply to that location from reservoirs operating specifically for that location. Under these shortage conditions, withdrawals specifically for power generation are made unless a negative index is used for PWRPR. Only at the higher reservoir levels are withdrawals made for desired flows in excess of required flows.

f. Since power and evaporation are based on average reservoir storage for each period and therefore cannot be computed accurately until releases are known, and since releases are not estimated completely until requirements at all control points are examined, average storages determined by a complete basin run for a period are used for these purposes in a second complete run for the same period. Power generation is computed by use of the following equation:

$P = CEHQ$

where:

C = .08464 for English units; 8.9676 for metric units

P = Power in kilowatts

E = Power plant efficiency ratio

H = Effective head on turbine in feet (meters)

Q = Flow in cfs (cms) through turbine

g. The program permits specification of one or more power systems wherein the overall required generation exceeds the sum of required generation at the individual plants within the system. The difference is automatically assigned to plants in such a way as to keep reservoir storages most nearly in balance, subject to other system requirements and maximum system load factor. Accurate system power computation requires three iterations through the entire reservoir system in each period: the first to compute power generation that would occur without system requirements and to obtain information for assigning system power to each plant, the second to establish average heads at each reservoir based on system power generation, and the third to establish exact releases for power based on those average heads.

h. Computation of economic benefits in this program is based on a fixed relationship between the hydrologic quantity for a specified calendar month and location, and associated economic benefit for that month. Such benefits are described in tabular form as outlined on page 10 of exhibit 5. For each month, station, and parameter, the associated benefit is obtained by searching the corresponding table of benefits. The benefits are summarized by location and type of benefit. Five such tables are given, representing project benefits at control points, project benefits as allocated to projects, project plus preproject benefits (not allocated to projects), total potential benefits, and remaining potential benefits not obtained in the system operation. These last two items are based on the highest benefit value given in each table of benefits.

i. Benefits that are a function of streamflow at a specified location are allocated each month to reservoirs at and above that location in direct proportion to the difference between inflow and outflow at that reservoir. No account of diversions has yet been made in this allocation procedure, nor has a provision been included to allocate benefits associated with reservoir stage to upstream reservoirs. A provision has been made to print out monthly allocated benefits for each function and location, in order to permit a detailed examination of benefits.

j. Time translation is not made in the system computation, but is effected by translating inflows and labeling each control point data with a different time scale. System computations are made as though all input inflows were simultaneous. Thus, flows at upstream locations must be those that occur earlier than those at the most downstream location by the amount of time of travel to that downstream location.

k. The routine that solves for the maximum firm yield at one location is based on successively computing the yield increment (or decrement) that would result from surplus water (or shortage) at the end of the most severe drawdown period. If a shortage occurs, the yield is reduced by the largest ratio of shortage at any time to the total demand since all upstream reservoirs were last full. If a shortage does not occur, the yield is increased by the smallest ratio of remaining active storage upstream at any time to the total demand since all upstream reservoirs were last full. The process is repeated until the yield change is less than one percent.

5. INPUT

Input is summarized in exhibits 5 and 6. All data are entered consecutively on each card, using 8 columns (digits, including decimal points, if used) per variable and 10 variables per card unless fewer variables are called for (except for special format described in exhibit 5 for cards M). Column 1 on each card is reserved for card identification and not read by the computer. Consequently, the first field on each card is limited to 7 columns.

6. OUTPUT

Printed output as follows can be suppressed for any or all locations. Selected output is written in binary on auxiliary tapes for printing summaries of rearranged output and for use in the computation of economic benefits.

a. Input data

b. System status for each period including diversions, storages, evaporation, requirements, supplies and shortages at each location, and identification of the governing factor for each reservoir release.

c. Yearly totals of all pertinent items and averages for the entire routing.

d. Shortage indexes for each function at all locations. Annual shortages are the sums of period shortages for each year, neglecting any surpluses in other periods of the same year. A shortage index is the sum of the squares of annual shortages, adjusted to a 100-year routing period, if each annual shortage is expressed as a ratio of the annual requirement.

e. Benefits, if desired, by control point and benefit function.

f. Rearranged summaries of hydrologic output, as desired.

7. OPERATING INSTRUCTIONS

Standard FORTRAN IV operating instructions apply. The size of reservoir system that can be simulated is determined by dimension specification. In order to guard against over-running the dimensions, the initial data statement in the main program must contain dimension values. Standard values are:

Variable	Size	Definition
KCPT	40	Control points
KPWR	20	Power plants
KPWRS	2	Power systems
KRES	30	Reservoirs
KUPST	18	Reservoirs directly upstream
KDIV	25	Diversions
KL	8	Balancing levels
KPER	12	Intervals per year
KQIL	90	References to runoff stations for computing local inflow
KSERV	19	Downstream points served

Dimensions are set up with different numbers for each item in order to facilitate changes. When changing dimensions, all like values should be changed and the data statement changed accordingly. It must be remembered that power plants are at reservoirs, reservoirs are at control points, and dimensions are at control points, and dimensions must relate accordingly. There should be at least NLF + 2 levels and NLF (number of flood control levels) must be at least 2. Also KQIL should be about double KCPT for general application, and the standard dimension 22 is the sum of KPWR and KPWRS.

8. DEFINITION OF TERMS

Terms used in this program are defined in exhibit 3.

9. EXAMPLES

An example of routing is illustrated in exhibits 1 and 2.

10. PROPOSED FUTURE DEVELOPMENT

a. There is need to include a simulation of various types of water quality parameters. This is relatively simple for conservative parameters if complete mixing is assumed for each location. It is anticipated that inclusion of quality simulation features will be restricted to these for the immediate future.

b. There is also need for more general iteration techniques for determining optimum yield and techniques for deriving optimum system configuration and optimum operation rules.

c. It is intended to add power generation routines that will determine capability to sustain system peaking power for all pertinent proportions of time during each computation interval. In a monthly operation study, the power-duration load curve would be supplied as input for each calendar month and water would be released in patterns that would satisfy peaking requirements for all durations.

d. It is requested that any user of this program who finds an inadequacy or desirable addition or modification notify The Hydrologic Engineering Center.

Sample Input

```
A                 HEC-3 RESERVOIR SYSTEM ANALYSIS, TEST DATA
A            HYDROLOGIC ENGINEERING CENTER, CORPS OF ENGINEERS
A                            FEBRUARY 1971
B      2    1926      12       1       3       4       2       7       2       4
B      0       0       0       0       0       1       1       0       0       0
B      2       0       0       0       0       0       0       0       0       0
B      0       0       0       1       0       0       0
1      1
5      2      .5       1       2
C      1       1     .86       0       1       1       0       0       0
D     31      28      31      30      31      30      31      31      30      31
D     30      31
     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT
     NOV     DEC
1      0       0       0    3.91    3.50    5.02    6.36    4.67    2.42    1.74
1      0       0
2      2    1000    1000    1000    1000    1000    1000    1000    1000    1000
2   1000    1000    1000
2  -4.25       2
E      1 RESERVOIR A                           0       0
2      0       0       2       3       0       0       0       0
F      1       1       0       0       0       1   99999       0       0
1      1
E      2 RESERVOIR B                           2       0
1      2       1       1      -1
2      0       0       2       3       4       0       0       0
F      2       2       1       1       0       0   99999       0       0
1      1       2
2      2
3      1
E      3 RESERVOIR C                           0       0
2      0       1       2       0       0       0       0       0
F      3       1       0       0     100       0   99999       0
1      3
E      4 CONFLUENCE                            3       0
1      4       1       1      -1       3      -1
2      1       1       0       0       0       0       0       0
F      4       3       1       2      -1       0    5000     100       0
1      1       2       3
2      4
```

3	2	3								
4	100	100	100	2000	4500	4500	4500	4500	4500	100
4	100	100								
7	1	1225.8	50000	0	0					
8	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2
8	-.2	-.2								
7	2	691.0	100000	0	0					
8	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2	-.2
8	-.2	-.2								
9	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
9	25000	25000								
G	1	156000	.9	0	0	0				
H	107000	107000	107000	107000	107000	107000	107000	107000	107000	107000
H	107000	107000								
H	115000	115000	115000	115000	115000	115000	115000	115000	115000	115000
H	115000	115000								
H	119250	142750	152750	162750	167900	167900	164750	160500	154000	139750
H	119250	119250								
H	131500	178500	198500	218500	228800	228800	222500	214000	201000	172500
H	131500	131500								
H	143750	214250	214250	274250	289700	289700	280250	267500	248000	205250
H	143750	143750								
H	156000	250000	290000	330000	350600	350600	338000	321000	295000	238000
H	156000	156000								
H	356000	356000	356000	356000	356000	356000	356000	356000	356000	356000
H	356000	356000								
I	1373	1414	1444	1464	1476	1495	1517	1543	1548	1560
J	50000	107000	148000	181000	204000	241000	293000	355000	372000	417000
K	1020	1320	1480	1730	1870	2110	2400	2730	2800	2930
L	2000	2000	2000	2000	2000	2000	2000	2000	2000	9000
G	2	106600	1	0	0	0				
H	106600	106600	106600	106600	106600	106600	106600	106600	106600	106600
H	106600	106600								
H	106600	106600	106600	106600	106600	106600	106600	106600	106600	106600
H	106600	106600								
H	109650	146200	164950	184950	190725	190725	184950	176950	166200	141200
H	109650	109650								
H	112700	185800	223300	263300	274850	274850	263300	247300	225800	175800
H	112700	112700								
H	115750	225400	281650	341650	358975	358975	341650	317650	285400	210400

```
H 115750  115750
H 118800  265000  340000  420000  443100  443100  420000  388000  345000  245000
H 118800  118800
H 456000  456000  456000  456000  456000  456000  456000  456000  456000  456000
H 456000  456000
I    785     819     834     849     874     857     890     929     943
J  50000  106000  138000  176000  190000  200000  303000  456000  520000
K   1450    2000    2260    2620    2750    2860    3560    4330    4830
L  15000   15000   15000   15000   15000   15000   15000   15000   15000
G      3   10000       1       0       0       0
H  10000   10000   10000   10000   10000   10000   10000   10000   10000   10000
H  10000   10000
H  10000   10000   10000   10000   20000   20000   20000   20000   20000   10000
H  10000   10000
H  10000   22000   28500   34750   44375   44375   40000   33750   27500   13750
H  10000   10000
H  10000   34000   47000   59500   68750   68750   60000   47500   35000   17500
H  10000   10000
H  10000   46000   65500   84250   93125   93120   80000   61250   42500   21250
H  10000   10000
H  10000   58000   84000  109000  117500  117500  100000   75000   50000   25000
H  10000   10000
H 125000  125000  125000  125000  125000  125000  125000  125000  125000  125000
H 125000  125000
I    710     728   760.2     780   793.2   810.1     830     834     905
J   4000   10000   30000   47830   62000   85000  117500  125000  315000
K    250     440     750     970    1200    1500    1820    1890    2870
L   5000    5000    5000    5000    5000    5000    5000    5000    5000
M  11926  1150  2300  1000   745   630   340   235   234   270   365  1440  1635
M  21926  2920  6430  2630  2050  1660   890   615   610   695   970  3880  4520
M  31926   100  1360   640   100   164    82    29    27    38   165  1080  1130
M  41926  3080 11820  3325  2180  1855   997   723   663   808  1232  5245  5960
M  11927  1600  2600  1610  1275  1680  1570   520   345   433   500  2050  1185
M  21927  4360  7150  4320  3140  3620  3320  1420   715  1075  1660  5720  3280
M  31927  1145  1620  1040   576   578   497    95    35    15   320  1410   820
M  41927  7330 11210  5540  3820  4615  4130  1658   759  1095  2280  7370  6150
N        QUALITY CONTROL
N        FISH
N        RECREATION
N        POWER
```

N WATER SUPPLY
N
N
N

1	4	12	0	2000	2000	0	0	0	0	0
2	4	12	-50	50	50	0	0	0	0	0
1	3	12	0	100	100	0	0	0	0	0
2	3	12	-20	20	20	0	0	0	0	0
1	4	12	0	100	100	0	0	0	0	0
2	4	12	-40	40	40	0	0	0	0	0
1	1	4	0	356000	0	0	0	0	0	0
2	1	4	0	0	0	0	0	0	0	0
1	1	9	0	150000	356000	0	0	0	0	0
2	1	9	0	0	50	0	0	0	0	0
1	1	12	0	356000	0	0	0	0	0	0
2	1	12	0	0	0	0	0	0	0	0
1	2	4	0	456000	0	0	0	0	0	0
2	2	4	0	0	0	0	0	0	0	0
1	2	9	0	200000	456000	0	0	0	0	0
2	2	9	0	0	70	0	0	0	0	0
1	2	12	0	456000	0	0	0	0	0	0
2	2	12	0	0	0	0	0	0	0	0
1	3	4	0	125000	0	0	0	0	0	0
2	3	4	0	0	0	0	0	0	0	0
1	3	9	0	50000	125000	0	0	0	0	0
2	3	9	0	0	30	0	0	0	0	0
1	3	12	0	125000	0	0	0	0	0	0
2	3	12	0	0	0	0	0	0	0	0
1	1	12	0	4000	25000	0	0	0	0	0
2	1	12	-200	12	24	0	0	0	0	0
1	2	12	0	16000	100000	0	0	0	0	0
2	2	12	-800	48	96	0	0	0	0	0
1	2	3	0	9	0	0	0	0	0	0
2	2	3	0	0	0	0	0	0	0	0
1	2	4	0	8	16	0	0	0	0	0
2	2	4	-20	0	4	0	0	0	0	0
1	2	5	0	75	149	0	0	0	0	0
2	2	5	-140	0	35	0	0	0	0	0
1	2	6	0	160	317	0	0	0	0	0
2	2	6	-320	0	80	0	0	0	0	0

1	2	7	0	250	508	0	0	0	0	0
2	2	7	-480	0	120	0	0	0	0	0
1	2	8	0	200	397	0	0	0	0	0
2	2	8	-400	0	100	0	0	0	0	0
1	2	9	0	70	134	0	0	0	0	0
2	2	9	-160	0	40	0	0	0	0	0
1	2	12	0	9	0	0	0	0	0	0
2	2	12	0	0	0	0	0	0	0	0

```
A                      HEC-3 FLOOD CONTROL TEST
A                TWO TANDEM RESERVOIRS PARALLEL WITH A THIRD
A                             LAG ROUTING ONLY
B       3       1      12      12       3       4       0       8       0       4
B       0       0       0       0       0       0       0       0       0       0
B       7     360       0       0       0       0       0       0       0       0
B       0       0       0       0       0       0       0
C       1       1       0       0       1       1       0       0       0
E       1RESERVOIR A (PARALLEL LEG)             0      12
F       1       1       0       0       0       0   12000       0
1       1
E       2RESERVOIR C(U/S TANDEM LEG)            0       6
F       2       1       0       0       0       0    6000       0
1       2
E       3RESERVOIR B (D/S TANDEM LEG)           0       6
F       3       2       0       1       0       0   21000       0
1       2       3
3       2
E       4SYSTEM CONTROL POINT                   0       0
F       4       3       0       2       0       0   25000       0
1       1       2       3
3       1       3
G       1       0       0       0       0       0
H       0       0       0   19850   39700   79400   99250  198500
I       0      10      20      30      40      50     100    5000
J       0   19850   39700   59550   79400   99250  198500  999999
K       3    1000    2000    3000    4000    5000   10000   50000
L   12000   12000   12000   12000   12000   12000   12000  200000
G       2       0       0       0       0       0
H       0       0       0    4960    9920   19480   24800   49600
I       0      10      20      30      40      50     100    5000
J       0    4960    9920   14880   19480   24800   49600  999999
K       0    1000    2000    3000    4000    5000   10000   50000
L    6000    6000    6000    6000    6000    6000    6000  100000
G       3       0       0       0       0       0
H       0       0   27200   54400   81600  108800  136000  272000
I       0      10      20      30      40      50     100    5000
J       0   27200   54400   81600  108800  136000  272000  999999
K       0    1000    2000    3000    4000    5000   10000   50000
L   21000   21000   21000   21000   21000   21000   21000  100000
```

M	1	1	0	0	0	6000	27000	60000	105000	78000	60000	45000	33000	24000
M	2	1	0	0	0	3000	18000	37000	42000	50000	27000	20000	13000	5000
M	3	1	0	0	0	0	6000	20000	57000	100000	90000	70000	50000	37000
M	4	1	0	4000	19000	13000	10000	7000	4000	1000	1000	4000	10000	25000
M	1	2	18000	12000	12000	9000	6000	3000	0	0	0	0	0	0
M	2	2	0	0	0	0	0	0	0	0	0	0	0	0
M	3	2	24000	24000	15000	9000	3000	0	0	0	0	0	0	0
M	4	2	13000	7000	4000	1000	0	0	0	0	0	0	0	0
M	1	3	0	0	0	0	0	0	0	0	0	0	0	0
M	2	3	0	0	0	0	0	0	0	0	0	0	0	0
M	3	3	0	0	0	0	0	0	0	0	0	0	0	0
M	4	3	0	0	0	0	0	0	0	0	0	0	0	0

```
A       METCALF + EDDY - HAZEN AND SAWYER A JOINT VENTURE   HEC-3  TEST
A                                HUDSON RIVER BASIN
A                       CATSKILL AQUEDUCT SYSTEM VAR DEM + CONS REL
B       5    1928      12      10       2       5       4       4       0       1
B       0       0       0       0       0       0       0       0       0       0
B       2       0       0       0       0       0       0       0       0       0
B       0       0       0       0       0       0       1       0       0       0
C       1       1       0       1       1       1       0       0       0
D      31      30      31      31      28      31      30      31      30      31
D      31      30
      OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL
      AUG     SEP
1     1.0     1.0     1.0       0       0     1.0     2.0     2.0     3.0     3.0
1     2.0     2.0
2       1      63      63      63      63      63      63      63      63      63
2      63      63      63
2-2.9999        1
2       3      52      52      52      52      52      52      52      52      52
2      52      52      52
2-4.9999        3
E       1 SCHOHARIE RES                         1
1       6    1.33
F       1       1       1       0       0             928       0       1
1       1
2       1
E       2 DOWNSTREAM                            1
1       6      0.
F       2       0       1       0       0           99999       0       1
2       2
E       3 ASHOKAN RES                           1
1       6    1.09
F       3       2       1       1       0             958       0       1
1       1       3
2       3
3       1
E       4 DOWNSTREAM                            1
1       6      0.
F       4       0       1       0       0           99999       0       1
2       4
E       5 KENSICO INFLOW                        1
```

1	6	0.								
F	5	2	0	1	-1		958	0	1	
1	1	3								
3	3									
4	592	575	575	551	551	530	534	530	580	643
4	625	615								
G	1	64166	1							
H	6140	6140	6140	6140	6140	6140	6140	6140	6140	6140
H	6140	6140								
H	6140	6140	6140	6140	6140	6140	6140	6140	6140	6140
H	6140	6140								
H	66000	66000	66000	66000	66000	66000	66000	66000	66000	66000
H	66000	66000								
H	66000	66000	66000	66000	66000	66000	66000	66000	66000	66000
H	66000	66000								
I	980	1000	1020	1040	1050	1060	1080	1100	1120	1130
J	0	123	1070	3530	6140	9660	21200	36800	55200	66000
K	0	20	80	190	300	440	690	850	1000	1145
L	928	928	928	928	928	928	928	928	928	928
G	3	339016	1							
H	6140	6140	6140	6140	6140	6140	6140	6140	6140	6140
H	6140	6140								
H	6140	6140	6140	6140	6140	6140	6140	6140	6140	6140
H	6140	6140								
H	393000	393000	393000	393000	393000	393000	393000	393000	393000	393000
H	393000	393000								
H	393000	393000	393000	393000	393000	393000	393000	393000	393000	393000
H	393000	393000								
I	404	470	496	510	530	550	570	590		
J	0	1230	6140	15300	55200	138000	254000	393000		
K	0	150	338	1343	3312	4983	6671	8425		
L	960	960	960	960	960	960	960	960		

M	61928	1060	1527	1546	272	545	578	1031	1030	924	708	343	224
M	61929	63	58	111	343	148	1281	1797	887	251	84	18	47
M	61930	626	557	526	519	371	906	575	295	502	63	29	29
M	61931	20	71	75	49	39	365	1805	917	642	454	91	55
M	61932	25	37	184	697	471	389	1391	404	264	95	28	14

```
                     HEC-3 RESERVOIR SYSTEM ANALYSIS, TEST DATA
                   HYDROLOGIC ENGINEERING CENTER, CORPS OF ENGINEERS
                                   FEBRUARY 1971

 NYRS   IYR  NPER  IPER  NRES  NCPT  NDIV   NL  NPWR NFLOW  NSHR  NSHQ NSHDV NSPER ISPER ISMRY NPWRS  NLYR NDVYR  NQYR
    2  1926    12     1     3     4     2    7     2     4     0     0     0     0     0     1     1     0     0     0

  NLF  NMIN IFLOW ICONS METRC IUNIT IPWPR IPRNT IUPDT IDGST IEVYR IPWYR  IPRL IECON IPWKW IPWPK IDVSP
    2     0     0     0     0     0     0     0     0     0     0     0     0     1     0     0     0
RESP 1- 2     1     2
NRESP=  2 PFMAX=  .500

  CNSTI   CNSTO EFFCY DIVPR CLOCL CFLOD    STRSH   RSHQ  RSHDV
   1.00    1.00  .860   .00  1.00  1.00       0.  .0000  .0000

PERIOD                JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP     OCT     NOV     DEC
NDAYS                  31      28      31      30      31      30      31      31      30      31      30      31
EVP                   .00     .00     .00    3.91    3.50    5.02    6.36    4.67    2.42    1.74     .00     .00
DIV 2              1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0  1000.0
DIV 4   DIVR= -.250 TIMES DIVR AT  2

CONTROL POINT SEQUENCE

     1 RESERVOIR A                     NFLW=   0 TIME=    .0
  IE =     0    0    2    3    0    0    0    0
CONTROL PT  1  NRES =  1  NDIV =  0  NUPST =  0  QMN =      0.  SRCHG =      1.  QMAX =  99999.  QMN2 =      0. IPRN=   0
  IRESM   1

     2 RESERVOIR B                     NFLW=   2 TIME=    .0
           2  1.000         1  -1.000
  IE =     0    0    2    3    4    0    0    0
CONTROL PT  2  NRES =  2  NDIV =  1  NUPST =  1  QMN =      0.  SRCHG =      0.  QMAX =  99999.  QMN2 =      0. IPRN=   0
  IRESM   1    2
  IDIVR   2
  IUPST   1

     3 RESERVOIR C                     NFLW=   0 TIME=    .0
  IE =     0    1    2    0    0    0    0    0
CONTROL PT  3  NRES =  1  NDIV =  0  NUPST =  0  QMN =    100.  SRCHG =      0.  QMAX =  99999.  QMN2 =      0. IPRN=  -0
  IRESM   3

     4 CONFLUENCE                      NFLW=   3 TIME=    .0
           4  1.000         1  -1.000       3  -1.000
  IE =     1    1    0    0    0    0    0    0
CONTROL PT  4  NRES =  3  NDIV =  1  NUPST =  2  QMN =     -1.  SRCHG =      0.  QMAX =   5000.  QMN2 =    100. IPRN=   0
  IRESM   1    2    3
  IDIVR   4
  IUPST   2    3
  QMIN     100.     100.     100.    2000.    4500.    4500.    4500.    4500.    4500.     100.     100.     100.

POWER PLANT   1  TLWEL=  1225.8  PWRMX=  50000.  OVLOD= 1.15 IDPR=  0
POWER PLANT   2  TLWEL=   691.0  PWRMX= 100000.  OVLOD= 1.15 IDPR=  0
```

1 RESERVOIR A INITIAL STOR = 156000. CEVAP = .900 STORAGES

TEAK 0. IPOW 0 IEV 0

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LEVEL	7	356000.	356000.	356000.	356000.	356000.	356000.	356000.	356000.	356000.	356000.	356000.	356000.
LEVEL	6	156000.	250000.	290000.	330000.	350600.	350600.	338000.	321000.	295000.	238000.	156000.	156000.
LEVEL	5	143750.	214250.	214250.	274250.	289700.	289700.	280250.	267500.	248000.	205250.	143750.	143750.
LEVEL	4	131500.	178500.	198500.	218500.	228800.	228800.	222500.	214000.	201000.	172500.	131500.	131500.
LEVEL	3	119250.	142750.	152750.	162750.	167900.	167900.	164750.	160500.	154000.	139750.	119250.	119250.
LEVEL	2	115000.	115000.	115000.	115000.	115000.	115000.	115000.	115000.	115000.	115000.	115000.	115000.
LEVEL	1	107000.	107000.	107000.	107000.	107000.	107000.	107000.	107000.	107000.	107000.	107000.	107000.
ELEV		1373.00	1414.00	1444.00	1464.00	1476.00	1495.00	1517.00	1543.00	1548.00	1560.00		
STOR		50000.	107000.	148000.	181000.	204000.	241000.	293000.	355000.	372000.	417000.		
AREA		1020.0	1320.0	1480.0	1730.0	1870.0	2110.0	2400.0	2730.0	2800.0	2930.0		
QCAP		2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.	2000.	9000.		

2 RESERVOIR B INITIAL STOR = 106600. CEVAP = 1.000 STORAGES

TEAK 0. IPOW 0 IEV 0

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LEVEL	7	456000.	456000.	456000.	456000.	456000.	456000.	456000.	456000.	456000.	456000.	456000.	456000.
LEVEL	6	118800.	265000.	340000.	420000.	443100.	443100.	420000.	388000.	345000.	245000.	118800.	118800.
LEVEL	5	115750.	225400.	281650.	341650.	358975.	358975.	341650.	317650.	285400.	210400.	115750.	115750.
LEVEL	4	112700.	185800.	223300.	263300.	274850.	274850.	263300.	247300.	225800.	175800.	112700.	112700.
LEVEL	3	109650.	146200.	164950.	184950.	190725.	190725.	184950.	176950.	166200.	141200.	109650.	109650.
LEVEL	2	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.
LEVEL	1	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.	106600.
ELEV		785.00	819.00	834.00	849.00	874.00	857.00	890.00	929.00	943.00	-.00		
STOR		50000.	106000.	138000.	176000.	190000.	200000.	303000.	456000.	520000.	-0.		
AREA		1450.0	2000.0	2260.0	2620.0	2750.0	2860.0	3560.0	4330.0	4830.0	-.0		
QCAP		15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	15000.	-0.		

3 RESERVOIR C INITIAL STOR = 10000. CEVAP = 1.000 STORAGES

TEAK 0. IPOW 0 IEV 0

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LEVEL	7	125000.	125000.	125000.	125000.	125000.	125000.	125000.	125000.	125000.	125000.	125000.	125000.
LEVEL	6	10000.	58000.	84000.	109000.	117500.	117500.	100000.	75000.	50000.	25000.	10000.	10000.
LEVEL	5	10000.	46000.	65500.	84250.	93125.	93120.	80000.	61250.	42500.	21250.	10000.	10000.
LEVEL	4	10000.	34000.	47000.	59500.	68750.	68750.	60000.	47500.	35000.	17500.	10000.	10000.
LEVEL	3	10000.	22000.	28500.	34750.	44375.	44375.	40000.	33750.	27500.	13750.	10000.	10000.
LEVEL	2	10000.	10000.	10000.	10000.	20000.	20000.	20000.	20000.	20000.	10000.	10000.	10000.
LEVEL	1	10000.	10000.	10000.	10000.	10000.	10000.	10000.	10000.	10000.	10000.	10000.	10000.
ELEV		710.00	728.00	760.20	780.00	793.20	810.10	830.00	834.00	905.00	-.00		
STOR		4000.	10000.	30000.	47830.	62000.	85000.	117500.	125000.	315000.	-0.		
AREA		250.0	440.0	750.0	970.0	1200.0	1500.0	1820.0	1890.0	2870.0	-.0		
QCAP		5000.	5000.	5000.	5000.	5000.	5000.	5000.	5000.	5000.	-0.		

INPUT INFLOWS FOR 1926

STA	1	1150.	2300.	1000.	745.	630.	340.	235.	234.	270.	365.	1440.	1635.
STA	2	2920.	6430.	2630.	2050.	1660.	890.	615.	610.	695.	970.	3880.	4520.
STA	3	100.	1360.	640.	100.	164.	82.	29.	27.	38.	165.	1080.	1130.
STA	4	3080.	11820.	3325.	2180.	1855.	997.	723.	663.	808.	1232.	5245.	5960.

ALL FLOWS IN CFS, STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 RESERVOIR A LEAKAGE 0. SERVED BY 1
SERVING 1 2 4

YR 1926	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	852.	1150.	2300.	1000.	745.	630.	340.	235.	234.	270.	365.	1440.	1635.
UNREG	852.	1150.	2300.	1000.	745.	630.	340.	235.	234.	270.	365.	1440.	1635.
INFLOW	852.	1150.	2300.	1000.	745.	630.	340.	235.	234.	270.	365.	1440.	1635.
EOP STR		140912	268647	289839	291970	258691	118789	107000	107000	107000	107000	156274	221338
EOP EL		1438.81	1506.70	1515.66	1516.56	1502.48	1422.63	1414.00	1414.00	1414.00	1414.00	1449.01	1484.90
EVAPO	3540.	0.	0.	0.	699.	610.	716.	641.	462.	240.	172.	0.	0.
REQ PWR	87600.	7440.	6720.	7440.	7200.	7440.	7200.	7440.	7440.	7200.	7440.	7200.	7440.
SYS 1	114096.	10120.	11136.	10120.	10600.	10120.	10600.	8333.	8333.	8333.	8333.	9576.	8490.
POWER	117840.	16535.	0.	10120.	10600.	17946.	35487.	4340.	2308.	2623.	3692.	6620.	7568.
SHORTGE	23856.	0.	6720.	0.	0.	0.	0.	3100.	5132.	4577.	3748.	580.	0.
SYS SRT	35384.	0.	11136.	0.	0.	0.	0.	3993.	6025.	5710.	4642.	2956.	922.
CASE		202	403	102	102	401	401	102	102	102	102	403	403
LEVEL		4.77	6.18	6.00	5.32	4.49	2.07	1.00	1.00	1.00	1.00	6.00	6.33
CSV REL	757.	1395.	0.	655.	697.	1161.	2679.	416.	226.	266.	362.	612.	577.
RIV FLW	757.	1395.	0.	655.	697.	1161.	2679.	416.	226.	266.	362.	612.	577.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

2 RESERVOIR B LEAKAGE 0. SERVED BY 1 2
SERVING 2 4
LOCAL DIVERSIONS 2

YR 1926	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	1442.	1770.	4130.	1630.	1305.	1030.	550.	380.	376.	425.	605.	2440.	2885.
UNREG	2294.	2920.	6430.	2630.	2050.	1660.	890.	615.	610.	695.	970.	3880.	4520.
INFLOW	2198.	3165.	4130.	2285.	2002.	2191.	3229.	796.	602.	691.	967.	3052.	3462.
REQ DIV	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
DIVERSN	921.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	823.8	589.8	684.2	962.5	1000.0	1000.0
SHORTGE	79.0	.0	.0	.0	.0	.0	.0	176.2	410.2	315.8	37.5	.0	.0
EOP STR		108528	282358	273163	243607	172908	109358	106600	106600	106600	106600	139663	207447
EOP EL		820.18	883.39	880.44	870.97	847.78	820.57	819.28	819.28	819.28	819.28	834.66	859.39
EVAPO	5408.	0.	0.	0.	1067.	845.	952.	1069.	780.	404.	291.	0.	0.
REQ PWR	175200.	14880.	13440.	14880.	14400.	14880.	14400.	14880.	14880.	14400.	14880.	14400.	14880.
SYS 1	185904.	14880.	13864.	14880.	14400.	14880.	14400.	16667.	16667.	16667.	16667.	15424.	16510.
POWER	112243.	14880.	0.	14880.	14400.	21150.	24709.	0.	0.	0.	0.	10662.	11561.
SHORTGE	79537.	0.	13440.	0.	0.	0.	0.	14880.	14880.	14400.	14880.	3738.	3319.
SYS SRT	90241.	0.	13864.	0.	0.	0.	0.	16667.	16667.	16667.	16667.	4762.	4949.
CASE		202	403	202	202	401	401	202	202	202	202	403	403
LEVEL		2.63	6.09	4.85	3.75	2.79	2.03	1.00	1.00	1.00	1.00	6.06	6.26
CSV REL	1131.	2134.	0.	1435.	1481.	2327.	3281.	0.	0.	0.	0.	1496.	1359.
RIV FLW	1131.	2134.	0.	1435.	1481.	2327.	3281.	0.	0.	0.	0.	1496.	1359.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

3 RESERVOIR C LEAKAGE 0. SERVED BY 3
SERVING 3 4

YR 1926	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	403.	100.	1360.	640.	100.	164.	82.	29.	27.	38.	165.	1080.	1130.
UNREG	403.	100.	1360.	640.	100.	164.	82.	29.	27.	38.	165.	1080.	1130.
INFLOW	403.	100.	1360.	640.	100.	164.	82.	29.	27.	38.	165.	1080.	1130.
EOP STR		10000	85530	84000	83517	40278	21405	20000	20000	20000	23906	56710	114164
EOP EL		728.00	810.42	809.37	809.01	771.61	746.36	744.10	744.10	744.10	750.39	788.27	827.96
EVAPO	1905.	0.	0.	0.	483.	344.	314.	321.	232.	120.	91.	0.	0.
CASE		301	403	303	301	401	401	301	301	301	301	403	403
LEVEL		1.00	6.41	6.00	4.97	2.83	2.06	2.00	2.00	2.00	5.71	6.41	6.91
CSV REL	165.	100.	0.	100.	100.	862.	394.	47.	23.	36.	100.	100.	100.
RIV FLW	256.	100.	0.	665.	100.	862.	394.	47.	23.	36.	100.	529.	196.
DES FLW	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
SHORTGE	24.	0.	100.	0.	0.	0.	0.	53.	77.	64.	0.	0.	0.

4 CONFLUENCE LEAKAGE 0. SERVED BY 1 2 3
LOCAL DIVERSIONS 4

YR 1926	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	1841.	1830.	8160.	1685.	1335.	1061.	575.	459.	402.	500.	702.	2725.	3195.
UNREG	4537.	4850.	15950.	4955.	3485.	2885.	1547.	1103.	1039.	1233.	1837.	7685.	8845.
INFLOW	3228.	4064.	8160.	3785.	2916.	4250.	4250.	506.	425.	536.	802.	4750.	4750.
REQ DIV	.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0
DIVERSN	.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-205.9	-147.4	-171.0	-240.6	-250.0	-250.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RIV FLW	3458.	4314.	8410.	4035.	3166.	4500.	4500.	712.	573.	707.	1043.	5000.	5000.
DES FLW	2101.	100.	100.	100.	2000.	4500.	4500.	4500.	4500.	4500.	100.	100.	100.
SHORTGE	967.	0.	0.	0.	0.	0.	0.	3788.	3927.	3793.	0.	0.	0.
MIN FLW	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

SYSTEM 1 POWER SUMMARY

SYSTEM TOTAL													
REQUIRD	300000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.
USABLE	212596.	31415.	0.	25000.	25000.	39096.	42709.	4340.	2308.	2623.	3692.	17282.	19129.
TOTAL	230083.	31415.	0.	25000.	25000.	39096.	60196.	4340.	2308.	2623.	3692.	17282.	19129.
SHORTGE	125625.	0.	25000.	0.	0.	0.	0.	20660.	22692.	22377.	21308.	7718.	5871.

INPUT INFLOWS FOR 1927

STA 1	1600.	2600.	1610.	1275.	1680.	1570.	520.	345.	433.	500.	2050.	1185.
STA 2	4360.	7150.	4320.	3140.	3620.	3320.	1420.	715.	1075.	1660.	5720.	3280.
STA 3	1145.	1620.	1040.	576.	578.	497.	95.	35.	15.	320.	1410.	820.
STA 4	7330.	11210.	5540.	3820.	4615.	4130.	1658.	759.	1095.	2280.	7370.	6150.

ALL FLOWS IN CFS, STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 RESERVOIR A LEAKAGE 0. SERVED BY 1
SERVING 1 2 4

YR 1927	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	1269.	1600.	2600.	1610.	1275.	1680.	1570.	520.	345.	433.	500.	2050.	1185.
UNREG	1269.	1600.	2600.	1610.	1275.	1680.	1570.	520.	345.	433.	500.	2050.	1185.
INFLOW	1269.	1600.	2600.	1610.	1275.	1680.	1570.	520.	345.	433.	500.	2050.	1185.
EOP STR		319718	356000	356000	353255	356000	356000	338000	292567	162868	107000	213471	283776
EOP EL		1528.20	1543.29	1543.29	1542.27	1543.29	1543.29	1535.87	1516.82	1453.01	1414.00	1480.86	1513.10
EVAPO	5290.	0.	0.	0.	800.	716.	1029.	1282.	889.	388.	186.	0.	0.
REQ PWR	87600.	7440.	6720.	7440.	7200.	7440.	7200.	7440.	7440.	7200.	7440.	7200.	7440.
SYS 1	108483.	8333.	8333.	8333.	8516.	8689.	8902.	9931.	10120.	10600.	10120.	8271.	8333.
POWER	220220.	0.	29520.	27683.	21729.	27879.	25836.	13460.	17493.	37044.	15882.	3082.	614.
SHORTGE	18384.	7440.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4118.	6826.
SYS SRT	21241.	8333.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5189.	7720.
CASE		403	403	403	403	403	403	103	401	401	202	403	403
LEVEL		6.82	7.00	7.00	6.89	7.00	7.00	6.00	5.47	3.19	1.00	6.29	6.64
CSV REL	794.	0.	550.	485.	513.	707.	1113.	792.	1069.	2606.	1406.	261.	42.
RIV FLW	1176.	0.	1947.	1610.	1308.	1624.	1553.	792.	1069.	2606.	1406.	261.	42.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

2 RESERVOIR B LEAKAGE 0. SERVED BY 1 2
SERVING 2 4
LOCAL DIVERSIONS 2

YR 1927	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	2014.	2760.	4550.	2710.	1865.	1940.	1750.	900.	370.	642.	1160.	3670.	2095.
UNREG	3283.	4360.	7150.	4320.	3140.	3620.	3320.	1420.	715.	1075.	1660.	5720.	3280.
INFLOW	3190.	2760.	6497.	4320.	3173.	3564.	3303.	1692.	1439.	3248.	2566.	3931.	2137.
REQ DIV	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
DIVERSN	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EOP STR		315664	456000	456000	452199	456000	456000	353886	186723	115785	106600	234301	298042
EOP EL		893.23	929.00	929.00	928.03	929.00	929.00	902.97	868.15	823.59	819.28	867.99	888.41
EVAPO	8698.	0.	0.	0.	1408.	1260.	1811.	2159.	1291.	472.	296.	0.	0.
REQ PWR	175200.	14880.	13440.	14880.	14400.	14880.	14400.	14880.	14880.	14400.	14880.	14400.	14880.
SYS 1	191517.	16667.	16667.	16667.	16484.	16311.	16098.	15069.	14880.	14400.	14880.	16729.	16667.
POWER	268521.	0.	31976.	42792.	27546.	31918.	28343.	28237.	31870.	26339.	12080.	6407.	1013.
SHORTGE	39540.	14880.	0.	0.	0.	0.	0.	0.	0.	0.	2800.	7993.	13867.
SYS SRT	45443.	16667.	0.	0.	0.	0.	0.	0.	0.	0.	2800.	10322.	15653.
CASE		403	403	403	403	403	403	401	401	401	202	403	403
LEVEL		6.58	7.00	7.00	6.89	7.00	7.00	5.16	3.14	2.15	1.00	6.34	6.53
CSV REL	1594.	0.	1548.	1293.	1324.	1647.	1863.	2318.	3137.	3432.	1710.	785.	100.
RIV FLW	2053.	0.	2970.	3320.	2213.	2481.	2272.	2318.	3137.	3432.	1710.	785.	100.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

3 RESERVOIR C LEAKAGE 0. SERVED BY 3
SERVING 3 4

YR 1927	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	672.	1145.	1620.	1040.	576.	578.	497.	95.	35.	15.	320.	1410.	820.
UNREG	672.	1145.	1620.	1040.	576.	578.	497.	95.	35.	15.	320.	1410.	820.
INFLOW	672.	1145.	1620.	1040.	576.	578.	497.	95.	35.	15.	320.	1410.	820.
EOP STR		125000	125000	125000	124855	125000	125000	75276	31894	22494	25000	105602	124967
EOP EL		834.00	834.00	834.00	833.92	834.00	834.00	802.95	762.30	748.12	752.15	822.71	833.98
EVAPO	3474.	0.	0.	0.	616.	551.	791.	874.	410.	139.	95.	0.	0.
CASE		403	403	403	403	403	403	401	401	401	303	403	403
LEVEL		7.00	7.00	7.00	6.99	7.00	7.00	4.76	2.86	2.33	6.00	6.83	7.00
CSV REL	254.	100.	100.	100.	100.	246.	324.	889.	734.	171.	100.	55.	100.
RIV FLW	652.	969.	1620.	1040.	568.	567.	484.	889.	734.	171.	278.	55.	505.
DES FLW	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
SHORTGE	4.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	45.	0.

4 CONFLUENCE LEAKAGE 0. SERVED BY 1 2 3
LOCAL DIVERSIONS 4

YR 1927	AVG	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
LOC FLW	2674.	4585.	6990.	2890.	1969.	2357.	2063.	1043.	379.	647.	1460.	3910.	4145.
UNREG	6630.	10090.	15760.	8250.	5685.	6555.	5880.	2558.	1129.	1737.	3440.	11040.	8245.
INFLOW	5379.	5554.	11580.	7250.	4750.	5405.	4819.	4250.	4250.	4250.	3448.	4750.	4750.
REQ DIV	.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0
DIVERSN	.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0	-250.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RIV FLW	5629.	5804.	11830.	7500.	5000.	5655.	5069.	4500.	4500.	4500.	3698.	5000.	5000.
DES FLW	2101.	100.	100.	100.	2000.	4500.	4500.	4500.	4500.	4500.	100.	100.	100.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MIN FLW	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

SYSTEM 1 POWER SUMMARY

SYSTEM TOTAL													
REQUIRD	300000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.
USABLE	421459.	0.	48776.	55800.	45546.	50518.	46343.	41697.	49363.	44339.	27962.	9489.	1627.
TOTAL	488741.	0.	61496.	70475.	49275.	59797.	54179.	41697.	49363.	63382.	27962.	9489.	1627.
SHORTGE	66684.	25000.	0.	0.	0.	0.	0.	0.	0.	0.	2800.	15511.	23373.

AVERAGES FOR PERIOD OF OPERATION 1926 - 1927

1 RESERVOIR A

LOC FLW	1061.
UNREG	1061.
INFLOW	1061.
EVAPO	4415.
REQ PWR	87600.
SYS 1	111289.

```
POWER   169030.
SHORTGE  21120.

CSV REL    775.
RIV FLW    966.
DES FLW      0.
SHORTGE      0.

 2   RESERVOIR B

LOC FLW   1728.
UNREG     2789.
INFLOW    2694.
REQ DIV  1000.0
DIVERSN   960.5
SHORTGE    39.5
EVAPO     7053.
REQ PWR 175200.
SYS   1 188711.
POWER   190382.
SHORTGE  59539.

CSV REL   1362.
RIV FLW   1592.
DES FLW      0.
SHORTGE      0.

 3   RESERVOIR C

LOC FLW    537.
UNREG      537.
INFLOW     537.
EVAPO     2690.

CSV REL    209.
RIV FLW    454.
DES FLW    100.
SHORTGE     14.

 4   CONFLUENCE

LOC FLW   2257.
UNREG     5583.
INFLOW    4303.
REQ DIV      .0
DIVERSN      .0
SHORTGE      .0
RIV FLW   4544.
DES FLW   2101.
SHORTGE    484.
MIN FLW    100.
SHORTGE      0.

DIVERSION SHORTAGE INDEX      2   .312     4 -1.000
```

POWER SHORTAGE INDEX 1 5.910 2 12.852
POWER SYSTEM 1 SHORTAGE INDEX 11.238 NO. OF SHORTAGES 11 MAX. SHORTAGE = 25000.

WATER SHORTAGE INDEX 1 -1.000 2 -1.000 3 2.943 4 10.598

MIN FLOW SHORTAGE INDEX 1 -1.000 2 -1.000 3 -1.000 4 .000

DES FLOW SHORTAGES STA	NO	MAX	REQ FLOW SHORTAGES NO	MAX	SYS PWR SHORTAGES NO	MAX	AT SITE PWR SHRTGE NO	MAX
1	0	0.	0	0.	10	11136.	9	7440.
2	0	0.	0	0.	11	16667.	11	14880.
3	5	100.	0	0.	0	0.	0	0.
4	3	3927.	0	0.	0	0.	0	0.

STORAGE FREQUENCY PER 2 YEARS AT LOCATION 1

CONS POOL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
95-100 PCT	1	2	2	1	1	1	1	0	0	0	2	2
90- 95 PCT	0	0	0	0	0	0	0	0	0	0	0	0
80- 90 PCT	0	0	0	1	0	0	0	1	0	0	0	0
70- 80 PCT	0	0	0	0	0	0	0	0	0	0	0	0
60- 70 PCT	1	0	0	0	1	0	0	0	0	0	0	0
40- 60 PCT	0	0	0	0	0	0	0	0	0	0	0	0
20- 40 PCT	0	0	0	0	0	0	0	0	1	0	0	0
-0- 20 PCT	0	0	0	0	0	1	1	1	1	2	0	0

STORAGE FREQUENCY PER 2 YEARS AT LOCATION 2

CONS POOL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
95-100 PCT	1	2	1	1	1	1	0	0	0	0	2	2
90- 95 PCT	0	0	0	0	0	0	0	0	0	0	0	0
80- 90 PCT	0	0	0	0	0	0	0	0	0	0	0	0
70- 80 PCT	0	0	1	0	0	0	1	0	0	0	0	0
60- 70 PCT	0	0	0	0	0	0	0	0	0	0	0	0
40- 60 PCT	0	0	0	1	0	0	0	0	0	0	0	0
20- 40 PCT	0	0	0	0	0	0	0	1	0	0	0	0
-0- 20 PCT	1	0	0	0	1	1	1	1	2	2	0	0

STORAGE FREQUENCY PER 2 YEARS AT LOCATION 3

CONS POOL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
95-100 PCT	2	2	2	1	1	1	0	0	0	1	2	2
90- 95 PCT	0	0	0	0	0	0	0	0	0	1	0	0
80- 90 PCT	0	0	0	0	0	0	0	0	0	0	0	0
70- 80 PCT	0	0	0	1	0	0	1	0	0	0	0	0
60- 70 PCT	0	0	0	0	0	0	0	0	0	0	0	0
40- 60 PCT	0	0	0	0	0	0	0	0	0	0	0	0
20- 40 PCT	0	0	0	0	1	0	0	1	2	0	0	0
-0- 20 PCT	0	0	0	0	0	1	1	1	0	0	0	0

CONTROL POINTS IDENTIFIED AS FOLLOWS

1 RESERVOIR A
2 RESERVOIR B
3 RESERVOIR C
4 CONFLUENCE

BENEFIT FUNCTIONS IDENTIFIED AS FOLLOWS

1 QUALITY CONTROL
2 FISH
3 RECREATION
4 POWER
5 WATER SUPPLY
6
7
8

FUNCTIONS FOR BENEFIT 1

4	12	0.	2000.	2000.	0.	0.	0.	0.	0.
4	12	-50.	50.	50.	0.	0.	0.	0.	0.

FUNCTIONS FOR BENEFIT 2

3	12	0.	100.	100.	0.	0.	0.	0.	0.
3	12	-20.	20.	20.	0.	0.	0.	0.	0.
4	12	0.	100.	100.	0.	0.	0.	0.	0.
4	12	-40.	40.	40.	0.	0.	0.	0.	0.

FUNCTIONS FOR BENEFIT 3

1	4	0.	356000.	0.	0.	0.	0.	0.	0.
1	4	0.	0.	0.	0.	0.	0.	0.	0.
1	9	0.	150000.	356000.	0.	0.	0.	0.	0.
1	9	0.	0.	50.	0.	0.	0.	0.	0.
1	12	0.	356000.	0.	0.	0.	0.	0.	0.
1	12	0.	0.	0.	0.	0.	0.	0.	0.
2	4	0.	456000.	0.	0.	0.	0.	0.	0.
2	4	0.	0.	0.	0.	0.	0.	0.	0.
2	9	0.	200000.	456000.	0.	0.	0.	0.	0.
2	9	0.	0.	70.	0.	0.	0.	0.	0.
2	12	0.	456000.	0.	0.	0.	0.	0.	0.
2	12	0.	0.	0.	0.	0.	0.	0.	0.
3	4	0.	125000.	0.	0.	0.	0.	0.	0.
3	4	0.	0.	0.	0.	0.	0.	0.	0.
3	9	0.	50000.	125000.	0.	0.	0.	0.	0.
3	9	0.	0.	30.	0.	0.	0.	0.	0.
3	12	0.	125000.	0.	0.	0.	0.	0.	0.
3	12	0.	0.	0.	0.	0.	0.	0.	0.

FUNCTIONS FOR BENEFIT 4

1	12	0.	4000.	25000.	0.	0.	0.	0.	0.
1	12	-200.	12.	24.	0.	0.	0.	0.	0.
2	12	0.	16000.	100000.	0.	0.	0.	0.	0.
2	12	-800.	48.	96.	0.	0.	0.	0.	0.

FUNCTIONS FOR BENEFIT 5

2	3	0.	9.	0.	0.	0.	0.	0.	0.
2	3	0.	0.	0.	0.	0.	0.	0.	0.
2	4	0.	8.	16.	0.	0.	0.	0.	0.
2	4	-20.	0.	4.	0.	0.	0.	0.	0.
2	5	0.	75.	149.	0.	0.	0.	0.	0.
2	5	-140.	0.	35.	0.	0.	0.	0.	0.
2	6	0.	160.	317.	0.	0.	0.	0.	0.
2	6	-320.	0.	80.	0.	0.	0.	0.	0.
2	7	0.	250.	508.	0.	0.	0.	0.	0.
2	7	-480.	0.	120.	0.	0.	0.	0.	0.
2	8	0.	200.	397.	0.	0.	0.	0.	0.
2	8	-400.	0.	100.	0.	0.	0.	0.	0.
2	9	0.	70.	134.	0.	0.	0.	0.	0.
2	9	-160.	0.	40.	0.	0.	0.	0.	0.
2	12	0.	9.	0.	0.	0.	0.	0.	0.
2	12	0.	0.	0.	0.	0.	0.	0.	0.

FUNCTIONS FOR BENEFIT 6
NONE

FUNCTIONS FOR BENEFIT 7
NONE

FUNCTIONS FOR BENEFIT 8
NONE

AVERAGE ANNUAL BENEFITS IN THOUSAND DOLLARS

PROJECT BENEFITS AT CONTROL POINTS

STA	SUM	FUNCTION 1	2	3	4	5
1	-93.	0.	0.	105.	-198.	0.
2	-501.	0.	0.	91.	-3046.	2454.
3	43.	0.	8.	35.	0.	0.
4	-15.	-15.	0.	0.	0.	0.
SM	-565.	-15.	8.	231.	-3243.	2454.

PROJECT BENEFITS ALLOCATED TO RESERVOIRS

STA	SUM	FUNCTION 1	2	3	4	5
1	-109.	-16.	0.	105.	-198.	0.
2	-516.	-15.	0.	91.	-3046.	2454.
3	23.	-20.	8.	35.	0.	0.
4	36.	36.	0.	0.	0.	0.
SM	-565.	-15.	8.	231.	-3243.	2454.

PROJECT PLUS PREPROJECT BENEFITS AT CONTROL POINTS

STA	SUM	FUNCTION 1	2	3	4	5
1	-93.	0.	0.	105.	-198.	0.
2	-501.	0.	0.	91.	-3046.	2454.
3	207.	0.	172.	35.	0.	0.
4	956.	476.	480.	0.	0.	0.
SM	570.	476.	652.	231.	-3243.	2454.

TOTAL POTENTIAL BENEFITS AT CONTROL POINTS

STA	SUM	FUNCTION 1	2	3	4	5
1	538.	0.	0.	250.	288.	0.
2	1881.	0.	0.	350.	1152.	379.
3	390.	0.	240.	150.	0.	0.
4	1080.	600.	480.	0.	0.	0.
SM	3889.	600.	720.	750.	1440.	379.

REMAINING POTENTIAL BENEFITS AT CONTROL POINTS

STA	SUM	FUNCTION 1	2	3	4	5
1	631.	0.	0.	145.	486.	0.
2	2382.	0.	0.	259.	4198.	-2075.
3	183.	0.	68.	115.	0.	0.
4	124.	124.	0.	0.	0.	0.
SM	3319.	124.	68.	519.	4683.	-2075.

HEC-3 RESERVOIR SYSTEM ANALYSIS, TEST DATA
HYDROLOGIC ENGINEERING CENTER, CORPS OF ENGINEERS
FEBRUARY 1971

UNREGULATED FLOWS IN CFS

1 RESERVOIR A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1926	1150.	2300.	1000.	745.	630.	340.	235.	234.	270.	365.	1440.	1635.	852.
1927	1600.	2600.	1610.	1275.	1680.	1570.	520.	345.	433.	500.	2050.	1185.	1269.
AVERAGE	1375.	2450.	1305.	1010.	1155.	955.	378.	289.	352.	433.	1745.	1410.	1061.

2 RESERVOIR B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1926	2920.	6430.	2630.	2050.	1660.	890.	615.	610.	695.	970.	3880.	4520.	2294.
1927	4360.	7150.	4320.	3140.	3620.	3320.	1420.	715.	1075.	1660.	5720.	3280.	3283.
AVERAGE	3640.	6790.	3475.	2595.	2640.	2105.	1017.	663.	885.	1315.	4800.	3900.	2789.

3 RESERVOIR C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1926	100.	1360.	640.	100.	164.	82.	29.	27.	38.	165.	1080.	1130.	403.
1927	1145.	1620.	1040.	576.	578.	497.	95.	35.	15.	320.	1410.	820.	672.
AVERAGE	623.	1490.	840.	338.	371.	289.	62.	31.	27.	242.	1245.	975.	537.

4 CONFLUENCE

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
1926	4850.	15950.	4955.	3485.	2885.	1547.	1103.	1039.	1233.	1837.	7685.	8845.	4537.
1927	10090.	15760.	8250.	5685.	6555.	5880.	2558.	1129.	1737.	3440.	11040.	8245.	6630.
AVERAGE	7470.	15855.	6603.	4585.	4720.	3713.	1830.	1084.	1485.	2639.	9363.	8545.	5583.

```
                                    HEC-3 FLOOD CONTROL TEST
                          TWO TANDEM RESERVOIRS PARALLEL WITH A THIRD
                                        LAG ROUTING ONLY

 NYRS   IYR  NPER  IPER  NRES  NCPT  NDIV    NL  NPWR NFLOW  NSHR  NSHQ NSHDV NSPER ISPER ISMRY NPWRS  NLYR NDVYR  NQYR
    3     1    12    12     3     4     0     8     0     4     0     0     0     0     0     0     0     0     0     0

  NLF  NMIN IFLOW ICONS METRC IUNIT IPWPR IPRNT IUPDT IDGST IEVYR IPWYR  IPRL IECON IPWKW IPWPK IDVSP
    7   360     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0

  CNSTI   CNSTO EFFCY DTVPR CLOCL CFLOD     STRSH   RSHQ  RSHDV
   1.00    1.00  .000   .00  1.00  1.00        0.  .0000  .0000

CONTROL POINT SEQUENCE

        1RESERVOIR A (PARALLEL LEG)       NFLW=   0 TIME= 12.0
CONTROL PT  1  NRES =  1  NDIV =  0  NUPST =  0  QMN =       0.  SRCHG =       0.  QMAX =  12000.  QMN2 =       0. IPRN=  -0
  IRESM   1

        2RESERVOIR C(U/S TANDEM LEG)      NFLW=   0 TIME=  6.0
CONTROL PT  2  NRES =  1  NDIV =  0  NUPST =  0  QMN =       0.  SRCHG =       0.  QMAX =   6000.  QMN2 =       0. IPRN=  -0
  IRESM   2

        3RESERVOIR B (D/S TANDEM LEG)     NFLW=   0 TIME=  6.0
CONTROL PT  3  NRES =  2  NDIV =  0  NUPST =  1  QMN =       0.  SRCHG =       0.  QMAX =  21000.  QMN2 =       0. IPRN=  -0
  IRESM   2   3
  IUPST   2

        4SYSTEM CONTROL POINT             NFLW=   0 TIME=   .0
CONTROL PT  4  NRES =  3  NDIV =  0  NUPST =  2  QMN =       0.  SRCHG =       0.  QMAX =  25000.  QMN2 =       0. IPRN=  -0
  IRESM   1   2   3
  IUPST   1   3

 1 RESERVOIR A (PARALLEL LEG)      INITIAL STOR =        0.  CEVAP =  .000  STORAGES
  TEAK       0. IPOW        0  IEV        0
 LEVEL  1       0.      0.      0.  19850.  39700.  79400.  99250. 198500.
 ELEV          .00   10.00   20.00   30.00   40.00   50.00  100.00 5000.00     -.00     -.00
 STOR           0.  19850.  39700.  59550.  79400.  99250. 198500. 999999.     -0.      -0.
 AREA          3.0  1000.0  2000.0  3000.0  4000.0  5000.0 10000.0 50000.0     -.0      -.0
 QCAP       12000.  12000.  12000.  12000.  12000.  12000.  12000. 200000.     -0.      -0.

 2 RESERVOIR C(U/S TANDEM LEG)     INITIAL STOR =        0.  CEVAP =  .000  STORAGES
  TEAK       0. IPOW        0  IEV        0
 LEVEL  1       0.      0.      0.   4960.   9920.  19480.  24800.  49600.
 ELEV          .00   10.00   20.00   30.00   40.00   50.00  100.00 5000.00     -.00     -.00
 STOR           0.   4960.   9920.  14880.  19480.  24800.  49600. 999999.     -0.      -0.
 AREA           .0  1000.0  2000.0  3000.0  4000.0  5000.0 10000.0 50000.0     -.0      -.0
 QCAP        6000.   6000.   6000.   6000.   6000.   6000.   6000. 100000.     -0.      -0.

 3 RESERVOIR B (D/S TANDEM LEG)    INITIAL STOR =        0.  CEVAP =  .000  STORAGES
  TEAK       0. IPOW        0  IEV        0
 LEVEL  1       0.      0.  27200.  54400.  81600. 108800. 136000. 272000.
 ELEV          .00   10.00   20.00   30.00   40.00   50.00  100.00 5000.00     -.00     -.00
```

```
STOR          0.  27200.  54400.  81600. 108800. 136000. 272000. 999999.     -0.     -0.
AREA         .0  1000.0  2000.0  3000.0  4000.0  5000.0 10000.0 50000.0     -.0     -.0
QCAP     21000.  21000.  21000.  21000.  21000.  21000.  21000. 100000.     -0.     -0.

INPUT INFLOWS FOR     1
STA   1               0.      0.      0.   6000.  27000.  60000. 105000.  78000.  60000.  45000.  33000.  24000.
STA   2               0.      0.      0.   3000.  18000.  37000.  42000.  50000.  27000.  20000.  13000.   5000.
STA   3               0.      0.      0.      0.   6000.  20000.  57000. 100000.  90000.  70000.  50000.  37000.
STA   4               0.   4000.  19000.  13000.  10000.   7000.   4000.   1000.   1000.   4000.  10000.  25000.
```

GROUP 1

ALL FLOWS IN CFS, STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 RESERVOIR A (PARALLEL LEG) LEAKAGE 0. SERVED BY 1
SERVING 1 4

TIME	AVG	6.	12.	18.	24.	30.	36.	42.	48.	54.	60.	66.	72.
LOC FLW	36500.	0.	0.	0.	6000.	27000.	60000.	105000.	78000.	60000.	45000.	33000.	24000.
UNREG	36500.	0.	0.	0.	6000.	27000.	60000.	105000.	78000.	60000.	45000.	33000.	24000.
INFLOW	36500.	0.	0.	0.	6000.	27000.	60000.	105000.	78000.	60000.	45000.	33000.	24000.
EOP STR		0	0	0	0	7438	31239	77355	110082	135506	154034	167693	179593
EOP EL		.00	.00	.00	.00	3.75	15.74	38.97	55.46	68.27	77.60	84.48	90.48
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		103	103	103	103	103	103	103	103	403	403	403	403
LEVEL		1.00	1.00	1.00	1.00	3.37	4.57	5.95	7.11	7.37	7.55	7.69	7.81
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	6318.	0.	0.	0.	6000.	12000.	12000.	12000.	12000.	8727.	7636.	5455.	0.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.

2 RESERVOIR C (U/S TANDEM LEG) LEAKAGE 0. SERVED BY 2
SERVING 2 3 4

TIME	AVG	12.	18.	24.	30.	36.	42.	48.	54.	60.	66.	72.	78.
LOC FLW	17917.	0.	0.	0.	3000.	18000.	37000.	42000.	50000.	27000.	20000.	13000.	5000.
UNREG	17917.	0.	0.	0.	3000.	18000.	37000.	42000.	50000.	27000.	20000.	13000.	5000.
INFLOW	17917.	0.	0.	0.	3000.	18000.	37000.	42000.	50000.	27000.	20000.	13000.	5000.
EOP STR		0	0	0	0	5950	21322	39173	49600	49600	49600	49600	49600
EOP EL		.00	.00	.00	.00	12.00	43.46	78.98	100.00	100.00	100.00	100.00	100.00
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		203	203	203	203	203	203	203	203	203	203	203	403
LEVEL		1.00	1.00	1.00	1.00	4.20	6.35	7.58	8.00	8.00	8.00	8.00	8.00
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	9581.	0.	0.	0.	3000.	6000.	6000.	6000.	28973.	27000.	20000.	13000.	5000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.

3 RESERVOIR B (D/S TANDEM LEG) LEAKAGE 0. SERVED BY 2 3
SERVING 3 4

TIME	AVG	12.	18.	24.	30.	36.	42.	48.	54.	60.	66.	72.	78.
LOC FLW	35833.	0.	0.	0.	0.	6000.	20000.	57000.	100000.	90000.	70000.	50000.	37000.
UNREG	53750.	0.	0.	0.	3000.	24000.	57000.	99000.	150000.	117000.	90000.	63000.	42000.
INFLOW	45414.	0.	0.	0.	3000.	12000.	26000.	63000.	128973.	117000.	90000.	63000.	42000.
EOP STR		0	0	0	0	4463	14380	41157	99159	149602	187604	214110	234936
EOP EL		.00	.00	.00	.00	1.64	5.29	15.13	36.46	55.00	68.97	78.72	86.37
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		303	303	303	303	403	403	403	403	403	403	403	403
LEVEL		1.00	1.00	1.00	1.00	2.16	2.53	3.51	5.65	7.10	7.38	7.57	7.73
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RIV FLW	5932.	0.	0.	0.	3000.	3000.	6000.	9000.	12000.	15273.	13364.	9545.	0.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.

4 SYSTEM CONTROL POINT LEAKAGE 0. SERVED BY 1 2 3

TIME	AVG	18.	24.	30.	36.	42.	48.	54.	60.	66.	72.	78.	84.
LOC FLW	8167.	0.	4000.	19000.	13000.	10000.	7000.	4000.	1000.	1000.	4000.	10000.	25000.
UNREG	98417.	0.	4000.	19000.	22000.	61000.	124000.	208000.	229000.	178000.	139000.	106000.	91000.
RIV FLW	20417.	0.	4000.	19000.	22000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.

INPUT INFLOWS FOR 2

STA 1	18000.	12000.	12000.	9000.	6000.	3000.	0.	0.	0.	0.	0.	0.
STA 2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STA 3	24000.	24000.	15000.	9000.	3000.	0.	0.	0.	0.	0.	0.	0.
STA 4	13000.	7000.	4000.	1000.	0.	0.	0.	0.	0.	0.	0.	0.

GROUP 2

ALL FLOWS IN CFS. STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 RESERVOIR A (PARALLEL LEG) LEAKAGE 0. SERVED BY 1
SERVING 1 4

TIME	AVG	78.	84.	90.	96.	102.	108.	114.	120.	126.	132.	138.	144.
LOC FLW	5000.	18000.	12000.	12000.	9000.	6000.	3000.	0.	0.	0.	0.	0.	0.
UNREG	5000.	18000.	12000.	12000.	9000.	6000.	3000.	0.	0.	0.	0.	0.	0.
INFLOW	5000.	18000.	12000.	12000.	9000.	6000.	3000.	0.	0.	0.	0.	0.	0.
FOR STR		186355	189050	191224	191359	189826	186805	182298	177790	173282	168774	164267	159759
FOR EL		93.88	95.24	96.33	96.40	95.63	94.11	91.84	89.57	87.30	85.02	82.75	80.48
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	403	403	403
LEVEL		7.88	7.90	7.93	7.93	7.91	7.88	7.84	7.79	7.75	7.70	7.66	7.61
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	8333.	4364.	6545.	7636.	8727.	9091.	9091.	9091.	9091.	9091.	9091.	9091.	9091.
OFS FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.

2 RESERVOIR C(U/S TANDEM LEG) LEAKAGE 0. SERVED BY 2
SERVING 2 3 4

TIME	AVG	84.	90.	96.	102.	108.	114.	120.	126.	132.	138.	144.	150.
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FOR STR		48518	46895	45002	42838	40584	38330	36076	33822	31569	29315	27061	25348
FOR EL		97.82	94.55	90.73	86.37	81.82	77.28	72.73	68.19	63.65	59.10	54.56	51.10
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	403	403	403
LEVEL		7.96	7.89	7.81	7.73	7.64	7.55	7.45	7.36	7.27	7.18	7.09	7.02
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	4076.	2182.	3273.	3818.	4364.	4545.	4545.	4545.	4545.	4545.	4545.	4545.	3454.
OFS FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.

3 RESERVOIR B (D/S TANDEM LEG) LEAKAGE 0. SERVED BY 2 3
SERVING 3 4

TIME	AVG	84.	90.	96.	102.	108.	114.	120.	126.	132.	138.	144.	150.
LOC FLW	6250.	24000.	24000.	15000.	9000.	3000.	0.	0.	0.	0.	0.	0.	0.
UNREG	6250.	24000.	24000.	15000.	9000.	3000.	0.	0.	0.	0.	0.	0.	0.
INFLOW	10326.	26182.	27273.	18818.	13364.	7545.	4545.	4545.	4545.	4545.	4545.	4545.	3454.
FOR STR		244132	251976	254681	253734	249587	243952	238317	232682	227048	221413	215778	209602
FOR EL		89.75	92.64	93.63	93.28	91.76	89.69	87.62	85.55	83.47	81.40	79.33	77.06
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	403	403	403
LEVEL		7.80	7.85	7.87	7.87	7.84	7.79	7.75	7.71	7.67	7.63	7.59	7.54
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RIV FLW	14583.	7636.	11455.	13364.	15273.	15909.	15909.	15909.	15909.	15909.	15909.	15909.	15909.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.

4 SYSTEM CONTROL POINT LEAKAGE 0. SERVED BY 1 2 3

TIME	AVG	90.	96.	102.	108.	114.	120.	126.	132.	138.	144.	150.	156.
LOC FL	2083.	13000.	7000.	4000.	1000.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	13333.	55000.	43000.	31000.	19000.	9000.	3000.	0.	0.	0.	0.	0.	0.
RIV FLW	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.

INPUT INFLOWS FOR 3

STA 1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STA 2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STA 3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
STA 4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

GROUP 3

ALL FLOWS IN CFS, STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 RESERVOIR A (PARALLEL LEG) LEAKAGE 0. SERVED BY 1

SERVING 1 4

TIME	AVG	150.	156.	162.	168.	174.	180.	186.	192.	198.	204.	210.	216.
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EOP STR		155251	150743	146235	141727	137219	132712	128204	123696	119188	113238	107287	101337
EOP EL		78.21	75.94	73.67	71.40	69.13	66.86	64.59	62.32	60.04	57.05	54.05	51.05
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	103	103	103
LEVEL		7.56	7.52	7.47	7.43	7.38	7.34	7.29	7.25	7.20	7.14	7.08	7.02
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	9818.	9091.	9091.	9091.	9091.	9091.	9091.	9091.	9091.	9091.	12000.	12000.	12000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.	12000.

2 RESERVOIR C (U/S TANDEM LEG) LEAKAGE 0. SERVED BY 2

SERVING 2 3 4

TIME	AVG	156.	162.	168.	174.	180.	186.	192.	198.	204.	210.	216.	222.
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
EOP STR		24933	24832	24808	24802	24800	24800	24800	24800	24800	23450	21608	20291
EOP EL		50.27	50.06	50.02	50.00	50.00	50.00	50.00	50.00	50.00	47.46	44.00	41.52
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	403	403	403
LEVEL		7.01	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.75	6.40	6.15
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	850.	837.	203.	49.	12.	3.	1.	0.	0.	0.	2723.	3714.	2657.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.	6000.

3 RESERVOIR B (D/S TANDEM LEG) LEAKAGE 0. SERVED BY 2 3

SERVING 3 4

TIME	AVG	156.	162.	168.	174.	180.	186.	192.	198.	204.	210.	216.	222.
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	850.	837.	203.	49.	12.	3.	1.	0.	0.	0.	2723.	3714.	2657.
EOP STR		202128	194340	186476	178593	170706	162817	154929	147040	139151	134055	129450	124322
EOP EL		74.31	71.45	68.56	65.66	62.76	59.86	56.96	54.06	51.16	49.28	47.59	45.71
EVAPO	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CASE		403	403	403	403	403	403	403	403	403	403	403	403
LEVEL		7.49	7.43	7.37	7.31	7.26	7.20	7.14	7.08	7.02	6.93	6.76	6.57
CSV REL	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

RIV FLW	15182.	15909.	15909.	15909.	15909.	15909.	15909.	15909.	15909.	15909.	13000.	13000.	13000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.	21000.

4 SYSTEM CONTROL POINT LEAKAGE 0. SERVED BY 1 2 3

TIME	AVG	162.	168.	174.	180.	186.	192.	198.	204.	210.	216.	222.	228.
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RIV FLW	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FLW CAP		25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.	25000.

AVERAGES FOR PERIOD OF OPERATION 1 - 3

1 RESERVOIR A (PARALLEL LEG)

LOC FLW	13833.
UNREG	13833.
INFLOW	13833.
EVAPO	0.
CSV REL	0.
RIV FLW	8157.

2 RESERVOIR C(U/S TANDEM LEG)

LOC FLW	5972.
UNREG	5972.
INFLOW	5972.
EVAPO	0.
CSV REL	0.
RIV FLW	4836.

3 RESERVOIR B (D/S TANDEM LEG)

LOC FLW	14028.
UNREG	20000.
INFLOW	18863.
EVAPO	0.
CSV REL	0.
RIV FLW	11899.

4 SYSTEM CONTROL POINT

LOC FLW	3417.
UNREG	37250.
RIV FLW	23472.

STORAGE FREQUENCY PER 3 YEARS AT LOCATION 1

FLOOD POOL	1	2	3	4	5	6	7	8	9	10	11	12
95-100 PCT	0	1	1	1	1	0	0	0	0	0	0	0
90- 95 PCT	1	0	0	0	0	1	1	0	0	0	0	1

80- 90 PCT	0	0	0	0	0	0	0	1	1	1	2	1
70- 80 PCT	1	1	1	1	0	0	0	0	0	1	0	0
60- 70 PCT	0	0	0	0	1	1	1	1	2	0	0	0
40- 60 PCT	0	0	0	0	0	0	0	1	0	1	1	1
20- 40 PCT	0	0	0	0	0	0	1	0	0	0	0	0
-0- 20 PCT	1	1	1	1	1	1	0	0	0	0	0	0

STORAGE FREQUENCY PER 3 YEARS AT LOCATION 2

FLOOD POOL	1	2	3	4	5	6	7	8	9	10	11	12
95-100 PCT	1	0	0	0	0	0	0	1	1	1	1	1
90- 95 PCT	0	1	1	0	0	0	0	0	0	0	0	0
80- 90 PCT	0	0	0	1	1	0	0	0	0	0	0	0
70- 80 PCT	0	0	0	0	0	1	2	0	0	0	0	0
60- 70 PCT	0	0	0	0	0	0	0	1	1	0	0	0
40- 60 PCT	1	1	1	1	1	2	1	1	1	2	2	2
20- 40 PCT	0	0	0	0	0	0	0	0	0	0	0	0
-0- 20 PCT	1	1	1	1	1	0	0	0	0	0	0	0

STORAGE FREQUENCY PER 3 YEARS AT LOCATION 3

FLOOD POOL	1	2	3	4	5	6	7	8	9	10	11	12
95-100 PCT	0	0	0	0	0	0	0	0	0	0	0	0
90- 95 PCT	0	1	1	1	1	0	0	0	0	0	0	0
80- 90 PCT	1	0	0	0	0	1	1	1	1	1	0	1
70- 80 PCT	1	1	0	0	0	0	0	0	0	0	2	1
60- 70 PCT	0	0	1	1	1	0	0	0	0	1	0	0
40- 60 PCT	0	0	0	0	0	1	1	1	2	1	1	1
20- 40 PCT	0	0	0	0	0	0	0	1	0	0	0	0
-0- 20 PCT	1	1	1	1	1	1	1	0	0	0	0	0

CONTROL POINT	DES FLW	UNREG PEAK	RIV FLW PEAK
1	12000.	105000.	12000.
2	6000.	50000.	28973.
3	21000.	150000.	15909.
4	25000.	229000.	25000.

```
                         METCALF + EDDY - HAZEN AND SAWYER A JOINT VENTURE   HEC-3  TEST
                                            HUDSON RIVER BASIN
                                  CATSKILL AQUEDUCT SYSTEM VAR DEM + CONS REL

 NYRS   IYR  NPER  IPER  NRES  NCPT  NDIV    NL  NPWR NFLOW  NSHR  NSHQ NSHDV NSPER ISPER ISMRY NPWRS  NLYR NDVYR  NQYR
    5  1928    12    10     2     5     4     4.    0     1     0     0     0     0     0     0     0     0     0     0

  NLF  NMIN IFLOW ICONS METRC IUNIT IPWPR IPRNT IUPDT IDGST IEVYR IPWYR  IPRL IECON IPWKW IPWPK IDVSP
    2     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     1

  CNSTI   CNSTO EFFCY DIVPR CLOCL CFLOD     STRSH   RSHQ  RSHDV
   1.00    1.00  .000  1.00  1.00  1.00       0.   .0000  .0000

PERIOD              OCT     NOV     DEC     JAN     FEB     MAR     APR     MAY     JUN     JUL     AUG     SEP
NDAYS                31      30      31      31      28      31      30      31      30      31      31      30
EVP                1.00    1.00    1.00     .00     .00    1.00    2.00    2.00    3.00    3.00    2.00    2.00
DIV 1              63.0    63.0    63.0    63.0    63.0    63.0    63.0    63.0    63.0    63.0    63.0    63.0
DIV 2   DIVR=-1.000 TIMES DIVR AT   1
DIV 3              52.0    52.0    52.0    52.0    52.0    52.0    52.0    52.0    52.0    52.0    52.0    52.0
DIV 4   DIVR=-1.000 TIMES DIVR AT   3

CONTROL POINT SEQUENCE

      1 SCHOHARIE RES                 NFLW=   1 TIME=  -.0
          6   1.330
CONTROL PT  1  NRES =  1  NDIV =  1  NUPST =  0  QMN =      0.  SRCHG =    -0.  QMAX =    928.  QMN2 =     0. IPRN=   1
  IRESM   1
  IDIVR   1

      2 DOWNSTREAM                    NFLW=   1 TIME=  -.0
          6    .000
CONTROL PT  2  NRES =  0  NDIV =  1  NUPST =  0  QMN =      0.  SRCHG =    -0.  QMAX =  99999.  QMN2 =     0. IPRN=   1
  IDIVR   2

      3 ASHOKAN RES                   NFLW=   1 TIME=  -.0
          6   1.090
CONTROL PT  3  NRES =  2  NDIV =  1  NUPST =  1  QMN =      0.  SRCHG =    -0.  QMAX =    958.  QMN2 =     0. IPRN=   1
  IRESM   1   3
  IDIVR   3
  IUPST   1

      4 DOWNSTREAM                    NFLW=   1 TIME=  -.0
          6    .000
CONTROL PT  4  NRES =  0  NDIV =  1  NUPST =  0  QMN =      0.  SRCHG =    -0.  QMAX =  99999.  QMN2 =     0. IPRN=   1
  IDIVR   4

      5 KENSICO INFLOW                NFLW=   1 TIME=  -.0
          6    .000
CONTROL PT  5  NRES =  2  NDIV =  0  NUPST =  1  QMN =     -1.  SRCHG =    -0.  QMAX =    958.  QMN2 =     0. IPRN=   1
  IRESM   1   3
  IUPST   3
  QMIN     592.    575.    575.    551.    551.    530.    534.    530.    580.    643.    625.    615.
```

1 SCHOHARIE RES INITIAL STOR = 64166. CEVAP = 1.000 STORAGES

TEAK -0. IPOW -0 IEV -0

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LEVEL	4	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.
LEVEL	3	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.	66000.
LEVEL	2	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.
LEVEL	1	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.
ELEV		980.00	1000.00	1020.00	1040.00	1050.00	1060.00	1080.00	1100.00	1120.00	1130.00		
STOR		0.	123.	1070.	3530.	6140.	9660.	21200.	36800.	55200.	66000.		
AREA		.0	20.0	80.0	190.0	300.0	440.0	690.0	850.0	1000.0	1145.0		
QCAP		928.	928.	928.	928.	928.	928.	928.	928.	928.	928.		

3 ASHOKAN RES INITIAL STOR = 339016. CEVAP = 1.000 STORAGES

TEAK -0. IPOW -0 IEV -0

		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LEVEL	4	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.
LEVEL	3	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.	393000.
LEVEL	2	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.
LEVEL	1	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.	6140.
ELEV		404.00	470.00	496.00	510.00	530.00	550.00	570.00	590.00	-.00	-.00		
STOR		0.	1230.	6140.	15300.	55200.	138000.	254000.	393000.	-0.	-0.		
AREA		.0	150.0	338.0	1343.0	3312.0	4983.0	6671.0	8425.0	-.0	-.0		
QCAP		960.	960.	960.	960.	960.	960.	960.	960.	-0.	-0.		

INPUT INFLOWS FOR 1928

STA 6 1060. 1527. 1546. 272. 545. 578. 1031. 1030. 924. 708. 343. 224.

ALL FLOWS IN CFS, STORAGES AND EVAP IN ACFT, AND POWER IN THOUSAND KWH

1 SCHOHARIE RES LEAKAGE -0. SERVED BY 1
SERVING 1 3 5
LOCAL DIVERSIONS 1

YR 1928	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LOC FLW	1086.	1410.	2031.	2056.	362.	725.	769.	1371.	1370.	1229.	942.	456.	298.
UNREG	1086.	1410.	2031.	2056.	362.	725.	769.	1371.	1370.	1229.	942.	456.	298.
INFLOW	1086.	1410.	2031.	2056.	362.	725.	769.	1371.	1370.	1229.	942.	456.	298.
REQ DIV	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0	63.0
DIVERSN	353.6	450.4	1101.3	1126.6	63.0	63.0	63.0	440.0	438.8	296.1	63.0	63.0	63.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EOP STR		66000	66000	66000	65523	66000	66000	66000	66000	66000	66000	66000	53237
EOP EL		1130.00	1130.00	1130.00	1129.56	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00	1117.87
EVAPO	1702.	94.	95.	95.	0.	0.	95.	191.	191.	286.	286.	191.	177.
CASE		103	103	103	501	103	103	103	103	103	103	103	501
LEVEL		3.00	3.00	3.00	2.99	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.79
CSV REL	386.	0.	533.	534.	307.	246.	265.	480.	477.	515.	525.	303.	446.
RIV FLW	745.	928.	928.	928.	307.	653.	704.	928.	928.	928.	874.	390.	446.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

2 DOWNSTREAM LEAKAGE
LOCAL DIVERSIONS 2

YR 1928	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REQ DIV	.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0	-63.0
DIVERSN	.0	-450.4	-1101.2	-1126.5	-63.0	-63.0	-63.0	-440.0	-438.8	-296.1	-63.0	-63.0	-63.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RIV FLW	354.	450.	1101.	1127.	63.	63.	63.	440.	439.	296.	63.	63.	63.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

3 ASHOKAN RES LEAKAGE -0. SERVED BY 1 3
SERVING 3 5
LOCAL DIVERSIONS 3

YR 1928	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LOC FLW	890.	1155.	1664.	1685.	296.	594.	630.	1124.	1123.	1007.	772.	374.	244.
UNREG	1976.	2565.	3695.	3741.	658.	1319.	1399.	2495.	2493.	2236.	1713.	830.	542.
INFLOW	1635.	2083.	2592.	2613.	603.	1247.	1334.	2052.	2051.	1935.	1646.	764.	691.
REQ DIV	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0	52.0
DIVERSN	671.1	236.5	1622.6	1643.7	52.0	289.3	364.8	1070.2	1069.9	941.8	653.4	52.0	52.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EOP STR		393000	393000	393000	393000	393000	393000	393000	393000	393000	393000	393000	393000
EOP EL		590.00	590.00	590.00	590.00	590.00	590.00	590.00	590.00	590.00	590.00	590.00	590.00

	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
EVAPO	12609.	674.	702.	702.	0.	0.	702.	1404.	1404.	2106.	2106.	1404.	1404.
CASE		303	303	303	501	303	303	303	303	303	303	303	501
LEVEL		3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
CSV REL	575.	592.	575.	575.	551.	551.	530.	534.	530.	580.	643.	625.	615.
RIV FLW	872.	958.	958.	958.	551.	958.	958.	958.	958.	958.	958.	689.	615.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

4 DOWNSTREAM LEAKAGE
LOCAL DIVERSIONS 4

YR 1928	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INFLOW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REQ DIV	.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0	-52.0
DIVERSN	.0	-236.4	-1622.5	-1643.6	-52.0	-289.3	-364.8	-1070.1	-1069.8	-941.7	-653.4	-52.0	-52.0
SHORTGE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
RIV FLW	671.	236.	1622.	1644.	52.	289.	365.	1070.	1070.	942.	653.	52.	52.
DES FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

5 KENSICO INFLOW LEAKAGE 0. SERVED BY 1 3

YR 1928	AVG	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
LOC FLW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
UNREG	1976.	2565.	3695.	3741.	658.	1319.	1399.	2495.	2493.	2236.	1713.	830.	542.
RIV FLW	872.	958.	958.	958.	551.	958.	958.	958.	958.	958.	958.	689.	615.
DES FLW	575.	592.	575.	575.	551.	551.	530.	534.	530.	580.	643.	625.	615.
SHORTGE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

INPUT INFLOWS FOR 1929

STA 6	63.	58.	111.	343.	148.	1281.	1797.	887.	251.	84.	18.	47.

NOTE: Remaining years not shown

AVERAGES FOR PERIOD OF OPERATION 1928 - 1932

1 SCHOHARIE RES

LOC FLW	631.
UNREG	631.
INFLOW	631.
REQ DIV	63.0
DIVERSN	167.8
SHORTGE	.2
EVAPO	1376.
CSV REL	279.
RIV FLW	477.
DES FLW	0.
SHORTGE	0.

2 DOWNSTREAM

LOC FLW	0.
UNREG	0.
INFLOW	0.
REQ DIV	.0
DIVERSN	.0
SHORTGE	.0
RIV FLW	168.
DES FLW	0.
SHORTGE	0.

3 ASHOKAN RES

LOC FLW	517.
UNREG	1148.
INFLOW	994.
REQ DIV	52.0
DIVERSN	259.3
SHORTGE	.0
EVAPO	12235.
CSV REL	575.
RIV FLW	711.
DES FLW	0.
SHORTGE	0.

4 DOWNSTREAM

```
LOC FLW      0.
UNREG        0.
INFLOW       0.
REQ DIV      .0
DIVERSN      .0
SHORTGE      .0
RIV FLW    269.
DES FLW      0.
SHORTGE      0.

 5   KENSICO INFLOW

LOC FLW      0.
UNREG     1148.
RIV FLW    711.
DES FLW    575.
SHORTGE      0.

DIVERSION SHORTAGE INDEX     1   .003    2 -1.000    3   .000    4 -1.000

WATER SHORTAGE INDEX         1 -1.000    2 -1.000    3 -1.000    4 -1.000    5   .000

MIN FLOW SHORTAGE INDEX      1 -1.000    2 -1.000    3 -1.000    4 -1.000    5 -1.000
```

DES FLOW SHORTAGES STA	NO	MAX	REQ FLOW SHORTAGES NO	MAX	SYS PWR SHORTAGES NO	MAX	AT SITE PWR SHRTGE NO	MAX
1	0	0.	0	0.	0	0.	0	0.
2	0	0.	0	0.	0	0.	0	0.
3	0	0.	0	0.	0	0.	0	0.
4	0	0.	0	0.	0	0.	0	0.
5	0	0.	0	0.	0	0.	0	0.

STORAGE FREQUENCY PER 5 YEARS AT LOCATION 1

CONS POOL	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95-100 PCT	1	1	1	2	2	3	5	5	3	2	1	0
90- 95 PCT	0	0	1	0	0	0	0	0	1	0	0	0
80- 90 PCT	0	0	0	0	0	0	0	0	1	0	0	0
70- 80 PCT	0	0	0	0	0	0	0	0	0	0	0	1
60- 70 PCT	0	0	0	0	0	0	0	0	0	0	0	0
40- 60 PCT	0	0	0	0	1	0	0	0	0	0	1	0
20- 40 PCT	2	1	0	1	0	1	0	0	0	3	0	0
-0- 20 PCT	2	3	3	2	2	1	0	0	0	0	3	4

STORAGE FREQUENCY PER 5 YEARS AT LOCATION 3

CONS POOL	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
95-100 PCT	2	2	2	2	2	4	4	5	5	5	2	1
90- 95 PCT	1	1	0	0	1	0	0	0	0	0	3	1
80- 90 PCT	1	0	1	2	1	0	0	0	0	0	0	3
70- 80 PCT	1	1	1	0	0	0	1	0	0	0	0	0
60- 70 PCT	0	1	0	0	0	0	0	0	0	0	0	0
40- 60 PCT	0	0	1	1	0	1	0	0	0	0	0	0
20- 40 PCT	0	0	0	0	1	0	0	0	0	0	0	0
-0- 20 PCT	0	0	0	0	0	0	0	0	0	0	0	0

EXHIBIT 3

DEFINITIONS 723-X6-L2030

A(K)	- Benefit function name
AL	- Storage level at reservoirs above a given point at a given time
ANDYS	- Number of days in a given routing interval
ANYR	- Number of years routed already, excluding current year
ANYRS	- Number of years routed already, including current year
APERD(I) APRD(I)	- Name of time interval
AREA (M,K)	- Table value of area in acres for reservoir M
AREAV	- Average reservoir area in acres during period
ARRAY	- Temporary array for storing items to be rearranged
ATMP	- Temporary variable
AVG	- Temporary location for the average of items to be arranged
BEN(I,J)	- Benefit in dollars
CACFT	- Coefficient to convert from acre-feet (thousand cubic meters for metric system) to desired units
CCFS	- Coefficient to convert from (cms for metric system) cfs to desired units
CEVAP(M)	- Coefficient of basin reference evaporation (EVAPO) for reservoir M
CFLOD	- Coefficient greater than 1 by which local inflow below reservoirs is multiplied to provide contingency allowance for flood control release determination
CKW	- Conversion constant to convert flow times head to power/day at 100% efficiency
CFLOW	- Coefficient to adjust yield toward optimum
CLOCL	- Coefficient less than 1 by which local inflow below reservoirs is multiplied to provide contingency allowance for conservation releases
CNST	- Constant to convert average kilowatts for period to thousand kilowatt hours
CNSTI	- Constant which, when positive, converts inflow rate units to cfs, (cms), and, when negative, converts (without negative sign) inflow volume units to acre-feet (thousand cubic meters)
CNSTO	- Constant similar to CNSTI but applied to all flow requirements
CNTRL(I,M)	- Level of reservoir storage for desired release
CONST	- Conversion constant to convert flow rate to volume per day
CPT(M,K)	- Control point name
CPWR	- Constant to convert cfs-feet or cms-meters to thousand kilowatt hours
CQOEL(IP,K)	- Table value of storage or outflow as index of peak power capacity
CQS	- Constant to convert cfs to acre-feet (cms to thousand cubic meters) for period

CSQ	- Constant to convert acre-feet to cfs (thousand cubic meters to cms) for period
CSTI(I)	- Constant to convert inflows to cfs (cms) for period
CSTO(I)	- Constant to convert water requirements to cfs (cms) for period
CT	- Constant to convert rate for period to average annual rate for same volume
CTX	- Coefficient to convert power units
DINDX(ID)	- Shortage index for a diversion, sum of squares of annual shortages for 100 years, each shortage being expressed as a ratio of the annual requirement
DIVPR	- A value of -1 prevents buffer storage use for diversions
EFCY(M,K)	- Table value of power plant efficiency vs. storage
EFFCY	- Power plant efficiency, including turbine losses, for all plants
EFY(IP)	- Interpolated value of power plant efficiency
EL(M,K)	- Table value of water surface elevation for reservoir M
ELEV(I,M)	- Reservoir water-surface elevation
EVAPO(I)	- Evaporation in inches (mm) for period used as reference for all reservoirs.
EVP(I,M)	- Evaporation in acre-feet (thousand cubic meters) for given period and reservoir
EVPO	- EVAPO expressed in feet (meters)
EVTMP(M)	- Evaporation in storage units
HEAD(IP)	- Head in feet (meters) on power turbine
I	- Index for period
IB	- Indicator
ICND	- Indicates if the item being read off the magnetic tape (or disk) is the first item to be rearranged
ICONS	- Positive value gives priority of conservation release over flood control requirements
ICPT(M)	- Control point number
ICSE(I,M)	- Identification of controlling item for release at reservoir M during period I. Portion of number before last 2 digits is controlling location number and last 2 digits show control as follows: 1. Minimum flow requirement 2. Power requirement 3. Flood control release
ID	- Identification number for diversion (read order number)
IDBAS(ID)	- Station used as base for return flow computation
IDGST	- Indicator, positive value calls for diagnostic printout
IDIV(M)	- Same as ID for diversion located at point M
IDIVR(M,K)	- Same as ID for diversions located in the area tributary above control point M and below all upstream reservoirs, including any diversion at M that takes out directly from the the reservoir, if any, bypassing the power plant, if any

IDPR(IP)	- Identification number of downstream reservoirs that controls tailwater elevation
IDV(ID)	- Control point location number for diversion ID
IDVSP	- Indicator, positive value causes flow in excess of channel capacity to enter diversion
IE(J,M)	- Indicator when positive calls for economic evaluation for function J at station M
IECON	- Indicator, positive value calls for economics computation
IEV(M)	- Indicator, positive value calls for reading different evaporation pattern for the reservoir
IEVYR	- Indicator, positive value calls for reading different evaporation pattern each year
IFC	- Indicator when positive that operation is for flood control
IFLOW	- Control point number for yield optimization
IONE	- Variable format used in rearranging output
IOPER(IR)	- Indicator when negative that reservoir is not operating specifically for the particular control point
IP	- Identification number for power plant (read order number)
IPER(I)	- Identification number of period
IPERA	- Identification number of first period of year
IPNT	- Positive value causes printout
IPR(IP)	- Control point location number for power plant IP
IPOW(M)	- Indicator, positive value calls for peaking capacity as a function of outflow (run-of-river plant)
IPRL	- Indicator, positive value calls for printing storage levels with reservoir operation data each year
IPRN(M)	- Indicator, negative value suppresses printout for this location
IPRNT	- Indicator, negative value suppresses printout for each year
IPWKW	- Indicator, positive value causes power to be computed in kw instead of thousand kwh
IPWPK	- Indicator, positive value calls for evaluating peaking capacity
IPWPR	- Indicator, negative value prevents power demand from drawing on buffer storage
IPWR(M)	- Same as IP for plant located at point M
IPWYR	- Indicator, positive value calls for different power load each year
IPX(M)	- Positive value indicates that the reservoir release is controlled by system power requirement
IR,IRA	- Reservoir index number; reservoir sequence number used for punch-out
IRES(M)	- Reservoir identification number, equal to M (every reservoir must be numbered same as control point at its location)
IRESM(M,K)	- Reservoir identification number for all reservoirs upstream of location M, including reservoir at M, if any, with negative sign for reservoirs not operated specifically for controls at M
IRESP(K)	- Control point number of power reservoir in system
IRG(J)	- Indicator for rearranging output
ISERV(M,K)	- Location number served by reservoir

ISHDV(K)	- Diversion number where shortage is declared
ISHQ(M)	- Location number where shortage is declared
ISHR(M)	- Reservoir number used for shortage declaration
ISMRY	- Indicator calling for summary compilations
ISPER	- Identification number of first shortage period
ISTOR(I)	- Storage converted to integer for printout
ISYSR(M)	- Power system identification
ITEMP	- Temporary integer variable
ITMP, ITP	- Temporary integer variable
ITPA	- Temporary variable
ITRNS	- Transfer indicator (Positive value causes skip of read and other unnecessary repetitions)
ITWO	- Variable format used in rearranging output
IUNIT	- Indicator, if positive, output units are nonstandard
IUPDT	- Indicator, positive value calls for continuing operation study with new system data after NYRS
IUPST(M,K)	- Identification number of reservoirs immediately upstream of control point M (all reservoirs that release water to M which does not pass through intermediate reservoirs)
IX	- Period number
IYEAR	- First year of operation study
IYR	- Year number
IYR1	- First year of operation study
IYRA	- Year number
IZERO	- Variable format used in rearranging output
IRG(1)	- Indicator, when positive, to rearrange unregulated flows
IRG(2)	- Indicator, when positive, to rearrange river flows
IRG(3)	- Indicator, when positive, to rearrange diversions
IRG(4)	- Indicator, when positive, to rearrange diversion shortages
IRG(5)	- Indicator, when positive, to rearrange desired flow shortages
IRG(6)	- Indicator, when positive, to rearrange minimum flow shortages
IRG(7)	- Indicator, when positive, to rearrange end of period storages
IRG(8)	- Indicator, when positive, to rearrange change in storage at end of period
IRG(9)	- Indicator, when positive, to rearrange end of period elevations
IRG(10)	- Indicator, when positive, to rearrange reservoir data
J	- Index for year
JPRNT	- Print control indicator, negative value suppresses printout
JONE	- Variable format used in rearranging output
JTMP	- Temporary variable
JTWO	- Variable format used in rearranging output
JZERO	- Variable format used in rearranging output
K	- Index for table values; control point sequence number used for punch-out
KA	- Temporary index

KCPT	- Largest acceptable (dimension) number of control points, all of which must be numbered by integers KCPT or smaller
KDIV	- Dimension limit of diversions
KL	- Dimension limit of storage levels
KONE	- Variable format used in rearranging output
KPER	- Dimension limit of periods per year
KPWR	- Dimension limit of power plants
KPWRS	- Limit of number of power systems
KQIL	- Dimension limit total number of station references for computing local inflows
KRES	- Largest acceptable (dimension) number of reservoirs, all of which must be numbered by integers KRES and smaller and be identical to control point identification number for the same location
KSERV	- Dimension limit of locations served by any one reservoir
KTWO	- Variable format used in rearranging output
KUPST	- Dimension limit for number of reservoirs (NUPST) directly upstream of any control point
KX	- Temporary index
KZERO	- Variable format used in rearranging output
L	- Index for reservoir levels used for coordinating releases
LA	- Temporary index
LCNS	- Maximum storage level where conservation demands are given priority over flood control
LX	- Temporary index
M	- Control point identification number
METRC	- Positive value calls for metric units
MQ(M)	- Identification number of inflow location
MTH	- Month of benefit function
MX	- Control point index
NC	- Index equal to zero during first approximation and one during final computation for each period
NCPT	- Number of control points used in system
NCYCL	- Number of computation cycles required
NDAYS(I)	- Number of days in period
NDIV	- Number of diversions in system
NDIVR(M)	- Number of diversions located in the area tributary above control point M and below all upstream reservoirs, including any diversion at M that is considered to be taken directly from the reservoir, if any, bypassing power plant, if any
NDVYR	- Number of diversions for which requirements are to be specified annually
NE	- Number of benefit functions
NFL	- Number of lowest flood control level
NFLOW	- Total number of input inflow locations
NFLW(M)	- Number of inflow locations used to compute local inflow at M
NFMT	- Variable format used in rearranging output

NL	- Number of reservoir storage levels
NLF	- Number of flood control levels (normally 2; at least 2)
NLYR	- Number of levels at different reservoirs that are to be specified annually
NMIN	- Number of minutes in computation interval (for flood-control operation)
NPER	- Number of periods per year
NPWR	- Total number of power plants in system
NPWRS	- Number of power systems
NQYR	- Number of locations for which flow requirements are to be specified each year
NR	- Temporary value of NUPST
NRES	- Total number of reservoirs in system
NRESM	- Number of reservoirs upstream of a control point
NRESP(IX)	- Number of reservoirs in power system
NRESR(M)	- Same as NRESM
NSERV(M)	- Number of locations served by reservoir M
NSHDV	- Number of diversions where shortages can be declared
NSHMN(M)	- Number of desired-flow shortages
NSHP(M)	- Number of power plant shortages
NSHPS(IX)	- Number of system power shortages
NSHQ	- Number of control points where shortages can be declared
NSHR	- Number of reservoirs used in shortage declaration
NSH2(M)	- Number of minimum flow shortages
NSPER	- Number of periods of declared shortage
NSRTP(IX)	- Number of power shortages for a system
NSTOR(I,M,K)	- Number of times storage is in designated range
NUPST(M)	- Number of reservoirs immediately upstream of control point M (all reservoirs that release water to M which does not pass through intermediate reservoirs), excluding any reservoir at M
NYRS	- Number of years of routing
OVLOD(IP)	- Coefficient (greater than 1) of power plant name-plate capacity representing maximum plant capability under overload conditions
PFMAX(IX)	- Maximum power factor for system
PG(K,L)	- Power generated
PGAU(K)	- Power generated and usable
PGAUT	- Total power generated and usable
PGT(L)	- Total power generated
PINDX(IP)	- Sum of squares of annual power shortages for 100-year period, each shortage expressed as ratio of required power for year
PKPWR(IP,K)	- Peak power in table
POWER(I,IP)	- Power in thousand KWH generated at plant IP during period I
POWR(I,IP)	- Power requirement in thousand KWH at plant IP during period I
POWRP(I,IP)	- Peak power capacity

POWRT	- Total power requirement
PWER(I,IP)	- Adjusted power requirement
PWERT	- Total required power
PWRMX(IP)	- Name-plate generating capacity in kilowatts at plant IP
PWRS(I,IX)	- System power requirement
Q(I)	- Flow in benefits table
Q2NDX(M)	- Sum of squares for 100-year period of annual shortages in minimum required flow at M, each shortage expressed as a ratio to total annual required flow
QA(I,M)	- Actual average flow in cfs (cms) at point M during period I, excluding any diversion at M
QAMX(M)	- Maximum flow during the run
QASUM	- Sum of releases in cfs (cms) at all reservoirs immediately upstream of M (those making releases to M which do not pass through intermediate reservoirs), excluding release at M
QAX	- Total release at reservoirs immediately upstream
QCAP(M,K)	- Table value of outlet capacity for reservoir M
QCONS(I,M)	- Conservation release
QCX	- Total conservation release at reservoirs immediately upstream
QDIV(I,ID)	- Required diversion in cfs (cms) at ID during period I
QDIVA(I,ID)	- Actual diversion in cfs (cms) at ID during period I
QDIVR(M)	- Total diversion in cfs (cms) during a given period in area tributary above M and below all upstream reservoirs including any diversion at M
QDIVS(I,ID)	- Diversion requirement as modified by any declared shortage
QI(I,M)	- Inflow in cfs (cms) to M during period I
QII(I,M)	- Input inflow for period I at station M
QINDX(M)	- Sum of squares for 100-year period of annual shortages in minimum desired flow at M, each shortage expressed as a ratio to total annual desired flow
QL(I,M)	- Local inflow to M from area tributary below all upstream reservoirs
QMAXA(M)	- Outlet capacity in cfs (cms)
QMIN(I,M)	- Minimum desired flow without random component
QMINA(I,M)	- Minimum desired flow in cfs (cms) at location M during period I, includes random component providing for unpredictable variation from time to time
QMINS(I,M)	- Minimum desired flow as modified by any declared shortage
QMIN2(I,M)	- Minimum required flow at location M during period I. Shortages occur only when all active storage is depleted
QM2(M)	- Minimum required flow at M
QMN	- Minimum desired flow at given location
QMX(I,M)	- Maximum permissible flow at M for period I
QMXX	- Maximum permissible flow (negative value calls for specifying maximum flow by month)
QO(M,L)	- Release in cfs (cms) required at reservoir M to reach level L if no releases are made upstream

QOMN(M)	- Minimum release in cfs (cms) at M, excluding releases at upstream reservoirs, consistent with conservation release determinations at all reservoirs
QOMNA(M)	- Minimum permissible limit of QOMN(M)
QOMNB(M)	- Maximum permissible limit of QOMN(M)
QOT(M,L)	- Sum of QO values in a given period for all reservoirs at or above M corresponding to level L
QOTMN(M)	- Minimum permissible total flow
QOTMX(M)	- Maximum permissible total flow
QPMX(M)	- Maximum preproject flow during the run
QPREP(I,M)	- Unregulated flow in cfs (cms) at M during period I, considered as preproject flow
QT(IP,K)	- Flow in tailwater table
QUNIT	- Name of flow units
RNYRS	- Reciprocal of ANYRS
RSHDV	- Ratio by which storage deficiency must be multiplied to obtain diversion shortage declaration
RSHQ	- Ratio by which storage deficiency must be multiplied to obtain flow shortage declaration
RTIO(K)	- Ratio by which inflow (QII) must be multiplied to obtain local inflow component
RTIOD(ID)	- Ratio by which diversion must be multiplied to obtain return flow
SCNS(M)	- Total conservation flow for year
SDV(ID)	- Average annual required diversion in cfs (cms)
SDVA(ID)	- Average annual actual diversion in cfs (cms) at ID
SEVP(M)	- Average annual evaporation in acre-feet (thousand cubic meters) at M
SHDIV(I,ID)	- Shortage in cfs (cms) during period I at ID
SHMX(M)	- Maximum shortage of desired flow
SHMX2(M)	- Maximum shortage of required flow
SHORT	- Amount of shortage in firm yield (used to optimize yield)
SHPMX	- Maximum power shortage during the run
SHRTA	- Accumulated shortage in desired flow (for optimizing yield)
SHRTP(I,IP)	- Shortage in kwh during period I at IP
SHRTQ(I,M)	- Shortage in cfs (cms) of desired flow during period I at M
SHRT2(I,M)	- Shortage in cfs (cms) of required flow during period I at M
SM(J)	- Sum of benefits for function
SPMX(IP)	- Peak power for period of record
SPR(IP)	- Average annual power requirement in thousand kwh at IP
SPRE(M)	- Average annual preproject flow in cfs (cms) at M
SPSMX(M)	- Maximum power shortage
SPWR(IP)	- Average annual power generation in thousand kwh at IP
SQ(M)	- Average annual desired flow in cfs (cms) at M
SQA(M)	- Average annual actual flow in cfs (cms) at M
SQI(M)	- Average annual inflow in cfs (cms) at M
SQL(M)	- Average annual local flow in cfs (cms) at M
SQMN(M)	- Average annual required flow in cfs (cms) at M
SRCHG(M)	- Positive indicator allows spillway surcharge

SRPLS	- Accumulated surplus (spill) as ratio to desired flow during critical period
SSHD(ID)	- Average annual shortage in cfs (cms) at diversion ID
SSHP(IP)	- Average annual shortage in thousand kwh at power plant IP
SSHQ(M)	- Average annual shortage in cfs (cms) of desired flow at M
SSH2(M)	- Average annual shortage in cfs (cms) of required flow at M
SSP(IP)	- Average annual system power
STOR(M,K)	- Table values of storage in acre-feet (thousand cubic meters) at M
STOR1(M)	- Starting value of storage in acre-feet (thousand cubic meters) at M
STORA(M)	- Storage in acre-feet (thousand cubic meters) at M at start of a given period
STORB(I,M)	- Storage in acre-feet (thousand cubic meters) at M at end of period I
STORL(I,M,L)	- Table value of storage in acre-feet (thousand cubic meters) at M corresponding to level L at end of period I of every year
STRAV(M)	- Average storage in acre-feet (thousand cubic meters) for a given period at M
STRSH	- Aggregate storage below which shortage is declared
SUM	- Sum of various quantities
SUMA	- Sum of benefits
SYCNS(M)	- Total conservation flow for year
SYDV(ID)	- Average required diversion in cfs (cms) at ID during any and all years
SYDVA(ID)	- Average actual diversion in cfs (cms) at ID during a given year
SYDYS	- Total number of days in all periods for a year
SYEVP(M)	- Total evaporation in acre-feet (thousand cm) at M for a given year
SYMSP(IX)	- Maximum system power shortage
SYPMX(IP)	- Peak power for year
SYPR(IP)	- Total required power in thousand kwh for a given year at IP
SYPRE(M)	- Average preproject flow in cfs (cms) at M for a given year
SYPWR(IP)	- Total generated power in thousand kwh for a given year at IP
SYQ(M)	- Average desired flow in cfs (cms) at M for a given year
SYQA(M)	- Average actual flow in cfs (cms) at M for a given year
SYQI(M)	- Average inflow in cfs (cms) at M for a given year
SYQL(M)	- Average local flow in cfs (cms) at M for a given year
SYQMN(M)	- Average required flow in cfs (cms) at M for a given year
SYSHD(ID)	- Average in cfs (cms) of the shortages of diversion in all periods of a given year at ID
SYSHP(IP)	- Total of the shortages in thousand kwh in all periods of a given year at power plant IP. Period surpluses are ignored
SYSHQ(M)	- Average in cfs (cms) of the shortages in desired flow at M for year
SYSH2(M)	- Average in cfs (cms) of the shortage in required flow at M for year
SYSP(IP)	- System power generation for year
SYSSP(I,IP)	- System power shortage
SYSYS(IP)	- System power shortage for year
TEAK(M)	- Leakage at dam in cfs (cms)
TEMP	- Temporary variable
TFLOW	- Accumulated flow during critical period

TIME(M)	- Time of travel to most downstream point in system (for flood-control operation only)
TIMSS(I)	- Time for each period at particular location
TITLE(K)	- Title of study
TL(IP,K)	- Tailwater elevation
TLWEL(IP)	- Tailwater elevation plus hydraulic losses (exclusive of turbine losses) in feet at power plant IP
TMP	- Temporary variable
TMPA	- Temporary variable
TMPG	- Temporary variable
TMPP(M)	- Power release requirement in cfs (cms) at M
TMPPR	- Power release requirement
TMPR(I)	- Maximum desired flow at control point of yield optimization
TMPRS	- Temporary name for power requirement
TMPX(I)	- Temporary variable
TP	- Temporary variable
TPP	- Temporary variable
TSYP	- Average system power generation in kw for year
TWEL(IP)	- Tailwater elevation
V(J,M)	- Total value of benefits
VLEFT(J,M)	- Total value of benefits remaining
VMAX(J,M)	- Maximum value of benefits
VU(J,M)	- Value of benefits unallocated
VUNIT	- Name of volume (storage) units

Source Program Listing

```
C       723-X6-L2030 RESERVOIR SYSTEM ANALYSIS                       FEB 1971
C       INDEXES I=PER J=YEAR K=TABLE L=LEVEL M=LOCATION IP=PWR ID=DIV
        DIMENSION APERD(12),APRD(12),AREA(30,10),CEVAP(30),
       1CNTRL(12,40),CPT(40,8),CQUEL(20,10),CSTI(12),CSTO(12),
       2DINDX(25),EFCY(30,10),EFY(20),EL(30,10),ELEV(12,30),
       3EVAP (12),EVP(12,30),HEAD(20),ICPT(40),ICSE(12,40),IDBAS(25),
       4IDIV(40),IDIVR(40,25),IDPR(20),IDV(25),IE(8,40),IEV(40),IPER(12),
       5IPOW(30),IPR(20),IPRN(40),IPWR(40),IRES(40),
       6IRESM(40,30),IRESP(20),IRG(10),ISERV(30,19),ISHDV(25),
       7ISHQ(40),ISHR(30),ISTOR(12),ISYSR(40),IUPST(40,18),
       8MQ(90),NDAYS(12),NDIVR(40),NFLW(40),NRESP(2),NRESR(40),
       9NSERV(30),NSHMN(40),NSHP(40),NSHPS(40),NSH2(40),NSRTP(2)
        DIMENSION NSTOR(12,40,8),NUPST(40),OVLOD(20),
       1PFMAX(2),PINDX(22),PKPWR(20,30),
       2POWER(12,22),POWRP(12,20),POWR(12,20),PWER(12,22),
       3PWRMX(20),PWRS(12,2),QA(12,40),QAMX(40),QCAP(30,10),
       4QCONS(12,40),QDIV(12,25),QDIVA(12,25),QDIVR(40),QDIVS(12,25),
       5QI(12,40),QII(12,40),QINDX(40),QL(12,40),QMAXA(40),QMIN(12,40),
       6QMINA(12,40),QMINS(12,40),QMIN2(12,40),QMX(12,40),
       7QM2(40),QO(30,8),QOMN(30),QOT(40,8),
       8QPMX(40),QPREP(12,40),QT(20,30),Q2NDX(40),RTIO(90),RTIOD(25),
       9SCNS(40),SDV(25),SDVA(25),SEVP(30),SHDIV(12,25),SHMX(40)
        DIMENSION SHMX2(40),SHPMX(40),SHRTP(12,22),SHRTQ(12,40),
       1SHRT2(12,40),SPMX(22),SPR(22),SPRE(40),SPSMX(40),SPWR(22),
       2SQ(40),SQA(40),SQI(40),SQL(40),SQMN(40),SRCHG(40),
       3SSHD(25),SSHP(22),SSHQ(40),SSH2(40),SSP(22),STOR(30,10),
       4STORA(30),STORB(12,30),STORL(12,40,8),STOR1(30),STRAV(30),
       5SYCNS(40),SYDV(25),SYDVA(25),SYEVP(30),SYMSP(2),SYPMX(22),
       6SYPR(22),SYPRE(40),SYPWR(22),SYQ(40),SYQA(40),SYQI(40),SYQL(40),
       7SYQMN(40),SYSHD(25),SYSHP(22),SYSHQ(40),SYSH2(40),SYSP(22),
       8SYSSP(12,20),SYSYS(22),TEAK(30),TIME(40),TIMSS(12),TITLE(60),
       9TL(20,10),TLWEL(20),TMPP(40),TMPR(12),TMPX(12)
C
        COMMON /ALPHA/
       1 APERD,APRD,IDIV,IPWR,IYR1,KCPT,KDIV,KPWR,KRES,NPWR,NRES,QM2,
       2 TITLE,IPWKW
        COMMON/BETA/
       1 NYRS,IRG,CPT,ICPT,IRES,NCPT,NPER,QUNIT,VUNIT,NMIN
        COMMON/DELTA/
       1 CNTRL,QL,SYQI,QI,STORB,ELEV,SYEVP,EVP,SYPWR,POWER,SYSHP,SHRTP,
       2 SYPMX,POWRP,SYQA,QA,
       3 ANDYS,AREA, CEVAP,CFLOD,CLOCL,CONST,CQUEL, DIVPR, EFCY,EFFCY,
       4 EFY,EL,EVAPO, HEAD, ICONS,ICSE,IDBAS,IDGST,IDPR,IDV,
       5 IDVSP,IEVYR,IPER,IPERA,IPOW,IPR,IPRN,IPWPK,IPWPR,IRESP,
       6 ISHDV,ISHQ,ISHR,ISPER,ISYSR,IUPST,METRC,NCYCL,NDAYS,
       7 NDIV,NDIVR,NFLW,NL,NLF,NPWRS,NRESM,NRESP,
       8 NSH2,NSHDV,NSHMN,NSHP,NSHPS,NSHQ,NSHR,NSPER,NSRTP,
       9 NUPST,OVLOD,PFMAX,PKPWR,POWR,PWER,PWRMX,
       1 PWRS,QAMX,QCAP,QCONS,QDIV,QDIVA,QDIVR,QDIVS,
       2 QMAXA,QMIN2,QMINA,QMINS,QMX,QO,QOMN,QOT,QPMX,QPREP,QT,
       3 RSHDV,RSHQ,RTIOD,SHDIV,SHMX,SHMX2,SHPMX,
       4 SHRT2,SHRTQ,SPSMX,SRCHG,STOR,STORA,STRAV,STRSH,SYCNS,SYDV,
       5 SYDVA,SYDYS,SYMSP,SYPR,SYPRE,SYQ,SYQL,SYQMN,SYSH2,SYSHD,
       6 SYSHQ,SYSP,SYSSP,SYSYS,TEAK,TL,TLWEL
        COMMON /BALT/ IECON,IE,IYEAR,NRESR,NSTOR,QII,STORL,TMPP,TMPX
        COMMON /GAMMA/ IRESM,IDIVR
C =A= LIMIT EQUAL TO DIMENSION
        DATA KCPT,KPWR,KPWRS,KRES,KUPST,KDIV,KL,KPER,KQIL,KSERV
```

```
     1  /  40,  20,   2,   30,  18,  25,   8,   12,   90,   19  /
      DATA QUNIT/4H CFS/
      DATA VUNIT/4HACFT/
C     READ FORMAT STATEMENTS
 1000 FORMAT (1X,F7.0,9F8.0)
 1010 FORMAT (1X,I7,9I8)
 1020 FORMAT (20A4)
 1030 FORMAT (1X,I7,7A4,A2,6X,I4,F8.0)
 1040 FORMAT (5(1X,I7,F8.0))
 1050 FORMAT (1X,I7,3I8,4F8.0,I8)
C     WRITE FORMATS
 1060 FORMAT(1H1)
 1070 FORMAT(1H )
 1080 FORMAT(1X,I7,3F8.0,4I8)
 1090 FORMAT(1X,I7,F8.0,(1X,I7,7I8))
 1100 ITRNS =0
      IPNT=1
      REWIND 7
      REWIND 8
      REWIND 9
      REWIND 10
C         INITIATE SYSTEM AND SUMMARY VARIABLES
      DO 1110 M=1,KRES
      IPWR(M)=0
 1110 STOR1(M)=0.
 1120 DO 1130 M=1,KCPT
      IEV(M)=0
      QAMX(M)=0.
      QPMX(M)=0.
      NSHMN(M)=0
      NSH2(M)=0
      NSHP(M)=0
      NSHPS(M)=0
      SHMX(M)=0.
      SHMX2(M)=0.
      SHPMX(M)=0.
      SPSMX(M)=0.
      Q1NDX(M) = 0.
      Q2NDX(M) = 0.
      SQL(M) = 0.
      SPRE(M) = 0.
      SQI(M) = 0.
      SQMN(M) = 0.
      SCNS(M) = 0.
      SQA(M) = 0.
      SSHQ(M) = 0.
      SSH2(M) = 0.
      SQ(M) = 0.
      TEAK(M)=0.
 1130 TMPP(M) = 0.
      DO 1160 M=1,KRES
      DO 1150 I=1,KPER
      EVP(I,M)=0.
      DO 1140 K=1,8
 1140 NSTOR(I,M,K)=0
 1150 CONTINUE
 1160 SEVP(M) = 0.
      ITMP=KPWR+KPWRS
      DO 1170 IP=1,ITMP
      SPWR(IP) = 0.
```

```
      SSP(IP)=0.
      SSHP(IP) = 0.
      SPR(IP) = 0.
      SPMX(IP)=99999999.
 1170 PINDX(IP) = 0.
      DO 1180 ID=1,KDIV
      SDVA(ID) = 0.
      SSHD(ID) = 0.
      SDV(ID) = 0.
 1180 DINDX(ID) = 0.
      DO 1190 IX=1,KPWRS
      NSRTP(IX)=0
 1190 SYMSP(IX)=0.
      IF(ITRNS.EQ.1) GO TO 2210
C         SLEW PRINTER TO NEW PAGE
 1200 WRITE(6,1060)
      DO 1210 M=1,KCPT
      NRESP(M)=-1
      NDIVP(M) = 0
      IDIV(M)=0
      ICPT(M)=0
      ISYSP(M)=0
      QM2(M)=0.
 1210 IRES(M)=0
C =B=       READ 3 TITLE CARDS
C                                                               **CARD A**
      READ(5,1220)TITLE
 1220 FORMAT(2X,A2,19A4)
C     JOB SPECIFICATION
C                                                               **CARD B**
      READ(5,1010)NYRS,IYR,NPER,IPERA,NRES,NCPT,NDIV,NL,NPWR,NFLOW
C     FOUR BLANK CARDS AT END OF DATA WILL CALL STOP
      IF (NYRS.LE.0) STOP
      WRITE(6,1230)TITLE
 1230 FORMAT(23X,A2,19A4)
      READ(5,1010)
     1NSHR,NSHQ,NSHDV,NSPER,ISPER,ISMRY,NPWRS,NLYR,NDVYR,NQYR,
     2NLF,NMIN,IFLOW,ICONS,METRC,IUNIT,IPWPR,IPRNT,IUPDT,IDGST,
     3IEVYR,IPWYR,IPRL,IECON,IPWKW,IPWPK,IDVSP
      IF(NLF.LT.2)NLF=2
      TMP=NMIN
      ANDYS=TMP/1440.
      IF(NMIN.GT.0)IYR=1
      WRITE(6,1240)NYRS,IYR,NPER,IPERA,NRES,NCPT,NDIV,NL,NPWR,NFLOW,
     1NSHR,NSHQ,NSHDV,NSPER,ISPER,ISMRY,NPWRS,NLYR,NDVYR,NQYR,
     2NLF,NMIN,IFLOW,ICONS,METRC,IUNIT,IPWPR,IPRNT,IUPDT,IDGST,
     3IEVYR,IPWYR,IPRL,IECON,IPWKW,IPWPK,IDVSP
      WRITE(6,1070)
 1240 FORMAT(/120H  NYRS   IYR  NPER  IPER  NRES  NCPT  NDIV    NL  NPWR
     1 NFLOW  NSHR  NSHQ NSHDV NSPER ISPER ISMRY NPWRS  NLYR NDVYR  NQYR
     2/20I6//3X,99HNLF  NMIN IFLOW ICONS METRC IUNIT IPWPR IPRNT IUPDT I
     3DGST IEVYR IPWYR  IPRL IECON IPWKW IPWPK IDVSP/17I6)
      CCFS=1.
      CACFT=1.
      CONST=1.98346
      IF(METRC.GT.0)CONST=86.4
      IYR1=IYR
      IF (NPER.GT.KPER.OR.NRES.GT.KRES.OR.NCPT.GT.KCPT.OR.NDIV.GT.KDIV.
     1 OR.NL.GT.KL.OR.NPWRS.GT.KPWRS.OR.NPWR+NPWRS.GT.KPWR) GO TO 3940
      IYEAR=IYR
```

```
C                                                                **CARD B1**
      IF(ISMRY.GT.0)READ(5,1010)(IRG(K),K=1,10)
      IF(IFLOW.GT.0)IPNT=-1
      IF (NSHR.LE.0) GO TO 1290
C                                                                **CARD B2**
      READ(5,1010)(ISHR(K),K=1,NSHR)
      WRITE(6,1250)(ISHR(K),K=1,NSHR)
 1250 FORMAT(20H SHORTAGE RESERVOIRS 20I5)
      IF (NSHQ.LE.0) GO TO 1270
C                                                                **CARD B3**
      READ(5,1010)(ISHQ(K),K=1,NSHQ)
      WRITE(6,1260)(ISHQ(K),K=1,NSHQ)
 1260 FORMAT(20H SHORTAGE LOCATIONS 20I5)
 1270 IF (NSHDV.LE.0) GO TO 1290
C                                                                **CARD B4**
      READ(5,1010)(ISHDV(K),K=1,NSHDV)
      WRITE(6,1280)(ISHDV(K),K=1,NSHDV)
 1280 FORMAT(20H SHORTAGE DIVERSIONS 20I5)
 1290 IF (NPWRS.LE.0) GO TO 1340
      ITMP=1
      ITEMP=0
      DO 1330 IX=1,NPWRS
C     VARIABLE IPER USED TEMPORARILY
C                                                                **CARD B5**
      READ(5,1090) ITP,PFMAX(IX),(IPER(K),K=1,ITP)
      NRESP(IX)=ITP
      ITEMP=ITEMP+ITP
      IF(ITEMP.GT.KPWR)GO TO 3940
      ITP=0
      DO 1300 K=ITMP,ITEMP
      ITP=ITP+1
      M=IPER(ITP)
      IRESP(K)=M
      ISYSP(M)=IX
 1300 CONTINUE
 1310 FORMAT(7H NRESP=I3,7H PFMAX=F6.3)
      WRITE (6,1320) ITMP,ITEMP,(IRESP(K),K=ITMP,ITEMP)
 1320 FORMAT(5H RESPI2,1H-I2,20I5)
      ITMP=ITEMP+1
 1330 CONTINUE
      WRITE(6,1310)(NRESP(IX),PFMAX(IX),IX=1,NPWRS)
C                                                                **CARD C**
 1340 READ(5,1000)CNSTI,CNSTO,EFFCY,DIVPR,CLOCL,CFLOD,STRSH,RSHQ,RSHDV
      WRITE(6,1350)
 1350 FORMAT(/ 63H   CNSTI   CNSTO EFFCY DIVPR CLOCL CFLOD    STRSH    RS
     1HQ  RSHDV)
      WRITE(6,1360)CNSTI,CNSTO,EFFCY,DIVPR,CLOCL,CFLOD,STRSH,RSHQ,RSHDV
 1360 FORMAT(2F8.2,F6.3,3F6.2,F9.0,2F7.4)
      IF(IUNIT.LE.0)GO TO 1390
C                                                                **CARD C1**
      READ(5,1370)CCFS,QUNIT,CACFT,VUNIT
 1370 FORMAT(1X,F7.0,4X,A4,F8.0,4X,A4)
      WRITE(6,1380)CCFS,QUNIT,CACFT,VUNIT
 1380 FORMAT(/6H CCFS= ,F8.3,2X,A4,4X,6HCACFT= ,F8.3,2X,A4)
 1390 IF (NPWR.LE.0.OR.EFFCY.LT.0) GO TO 1410
      DO 1400 IP=1,NPWR
 1400 EFY(IP)=EFFCY
 1410 RSHQ=RSHQ*.00001
      RSHDV=RSHDV*.00001
C     READ PERIOD DATA
```

```
      IF(NMIN.GT.0) GO TO 1440
C                                                              **CARD D**
      READ(5,1010)(NDAYS(I),I=1,NPER)
 1420 FORMAT (6H NDAYS 10X,(14I8))
      WRITE (6,1070)
C                                                              **CARD * **
      READ(5,1020)(APERD(I),APRD(I),I=1,NPER)
      WRITE (6,1430) (APERD(I),APRD(I),I=1,NPER)
 1430 FORMAT (7H PERIOD 9X,28A4)
      WRITE(6,1420)(NDAYS(I),I=1,NPER)
C =D=            SET JOB CONSTANTS
 1440 K=0
      DO 1510 I=1,NPER
      EVAPO(I)=0.
      IF(NMIN.GT.0) GO TO 1450
      IPER(I) = IPERA+I-1
      IF (IPER(I).GT.NPER) IPER(I)=IPER(I)-NPER
      ANDYS = NDAYS(I)
      K=K+NDAYS(I)
 1450 CSTI(I) = 1.
      IF(CNSTI)1460,1480,1470
 1460 CSTI(I) = (-CNSTI)/(CONST*ANDYS)
      GO TO 1480
 1470 CSTI(I) = CNSTI
 1480 CSTO(I) = 1.
      IF(CNSTO)1490,1510,1500
 1490 CSTO(I) = (-CNSTO)/(CONST*ANDYS)
      GO TO 1510
 1500 CSTO(I) = CNSTO
 1510 CONTINUE
      IF(NMIN.LE.0) GO TO 1520
      TMP=NPER
      SYDYS=ANDYS*TMP
      GO TO 1560
 1520 SYDYS = K
      IF(IEVYR)1570,1530,1570
C                                                              **CARD D1**
 1530 READ(5,1000)(EVAPO(I),I=1,NPER)
      WRITE(6,1540)(EVAPO(I),I=1,NPER)
 1540 FORMAT (6H EVP  10X,(14F8.2))
      DO 1550 I=1,NPER
      IF (EVAPO(I).GT..01) GO TO 1570
 1550 CONTINUE
 1560 NCYCL = 1
      IF(NPWR.LE.0.OR.NMIN.GT.0) GO TO 1580
 1570 NCYCL=2
      IF ( NPWRS.GT.0) NCYCL=3
 1580 IF(NDIV.LE.0) GO TO 1660
C =E= DIVERSIONS INDENTIFIED BY READ ORDER
C     SUBSCRIPTS ID REFER TO THIS IDENTIFICATION
      DO 1650 ID=1,NDIV
C                                                              **CARD D2**
      READ(5,1000)TEMP,(QDIV(I,ID),I=1,9)
      IF (TEMP.LT.0.) GO TO 1590
      IF (NPER.LT.10) GO TO 1610
      READ(5,1000)(QDIV(I,ID),I=10,NPER)
      GO TO 1610
 1590 M = (-TEMP)
      IDIV(M) = (-ID)
      IDV(ID)=M
```

```
      TMP = M
      RTIOD(ID) = TMP+TEMP
      IDBAS(ID)=QDIV(1,ID)
      WRITE (6,1600) M,RTIOD(ID),IDBAS(ID)
 1600 FORMAT (4H DIVI2,8H   DIVR=F6.3,14H TIMES DIVR AT I3)
      GO TO 1640
 1610 M=TEMP
      IDIV(M) = ID
      IDV(ID)=M
      WRITE(6,1620) M,(QDIV(I,ID),I=1,NPER)
 1620 FORMAT (4H DIV I2,10X,(14F8.1))
      DO 1630 I=1,NPER
      QDIV(I,ID)=QDIV(I,ID)*CSTO(I)
 1630 QDIVS(I,ID)=QDIV(I,ID)
 1640 IF (M.GT.KCPT) GO TO 3940
 1650 CONTINUE
 1660 DO 1670 M=1,KRES
      NSERV(M)=0
 1670 IPWR(M) = 0
      WRITE(6,1680)
 1680 FORMAT(/23H CONTROL POINT SEQUENCE )
      KX = 1
      DO 1910 MX=1,NCPT
C =F=                                                      **CARD E**
      READ (5,1030) M,(CPT(M,K),K=1,8),NFLW(M),TIME(M)
      WRITE(6,1070)
      WRITE (6,1690) M,(CPT(M,K),K=1,8),NFLW(M),TIME(M)
 1690 FORMAT (I8,7A4,A2,6H NFLW= I4,6H TIME= ,F5.1)
      IF (M.GT.KCPT) GO TO 3940
      ICPT(MX)=M
      IF (NFLW(M).LE.0) GO TO 1710
      ITMP = KX+NFLW(M)-1
      IF (ITMP.GT.KQIL) GO TO 3940
C                                                          **CARD E1**
      READ (5,1040) (MQ(K),RTIO(K),K=KX,ITMP)
      WRITE(6,1700)(MQ(K),RTIO(K),K=KX,ITMP)
 1700 FORMAT (4X,7(I8,F8.3))
      KX = ITMP+1
 1710 IF(IFCON.LE.0) GO TO 1730
C                                                          **CARD E2**
      READ (5,1010) (IE(J,M),J=1,8)
      WRITE(6,1720)(IE(J,M),J=1,8)
 1720 FORMAT(8H    IE = 8I4)
C     READ SYSTEM LAYOUT DATA
C                                                          **CARD F**
 1730 READ(5,1050)M,NRESR(M),NDIVR(M),NUPST(M),QMN,SRCHG(M),QMXX,
     1 QM2(M),IPRN(M)
      WRITE(6,1740)M,NRESR(M),NDIVR(M),NUPST(M),QMN,SRCHG(M),QMXX,
     1 QM2(M),IPRN(M)
 1740 FORMAT (11H CONTROL PT   I3,8H   NRES =I3,8H   NDIV =I3,9H   NUPST =I3
     1,7H   QMN =F7.0,9H   SRCHG =F7.0,8H   QMAX =F8.0,8H   QMN2 =F7.0,6H IP
     2RN= I4)
      IF (M.GT.KCPT) GO TO 3940
      IF (NUPST(M).GT.KUPST) GO TO 3940
      IF (NRESR(M).LE.0) GO TO 1780
      ITEMP = NRESR(M)
C                                                          **CARD F1**
      READ(5,1010)(IRESM(M,K),K=1,ITEMP)
      WRITE(6,1750)(IRESM(M,K),K=1,ITEMP)
 1750 FORMAT (8H    IRESM,(25I4))
```

```
      DO 1770 K=1,ITEMP
      ITMP=IRESM(M,K)
      ITPA=1
      IF (ITMP.GT.0) GO TO 1760
      ITPA=-1
      ITMP=-ITMP
 1760 NSERV(ITMP)=NSERV(ITMP)+1
      ITP=NSERV(ITMP)
      IF (ITP.GT.KSERV) GO TO 3940
      ISERV(ITMP,ITP)=M*ITPA
 1770 CONTINUE
 1780 IF (NDIVR(M).LE.0) GO TO 1800
      ITMP = NDIVR(M)
C                                                                **CARD F2**
      READ(5,1010)(IDIVR(M,K),K=1,ITMP)
      WRITE(6,1790)(IDIVR(M,K),K=1,ITMP)
 1790 FORMAT (8H   IDIVR,(25I4))
 1800 IF (NUPST(M).LE.0) GO TO 1820
      ITEMP = NUPST(M)
C                                                                **CARD F3**
      READ(5,1010)(IUPST(M,K),K=1,ITEMP)
      WRITE(6,1810)(IUPST(M,K),K=1,ITEMP)
 1810 FORMAT (8H   IUPST,(25I4))
C =G=       ESTABLISH BASIC MONTHLY FLOW REQUIREMENTS
 1820 DO 1830 I=1,NPER
      QMX(I,M)=QMXX
      QMIN(I,M) = QMN
 1830 QMIN2(I,M)=QM2(M)
      IF (QMN.GT.(-.1)) GO TO 1850
C                                                                **CARD F4**
      READ(5,1000)(QMIN(I,M),I=1,NPER)
      WRITE(6,1840)(QMIN(I,M),I=1,NPER)
 1840 FORMAT(8H   QMIN 14F8.0)
 1850 IF (QM2(M).GT.(-.1)) GO TO 1870
C                                                                **CARD F5**
      READ (5,1000) (QMIN2(I,M),I=1,NPER)
      WRITE(6,1860)(QMIN2(I,M),I=1,NPER)
 1860 FORMAT(8H   QMIN2 14F8.0)
 1870 IF(QMXX.GT.(-.1))GO TO 1890
C                                                                **CARD F6**
      READ(5,1000)(QMX(I,M),I=1,NPER)
      WRITE(6,1880)(QMX(I,M),I=1,NPER)
 1880 FORMAT(6H   QMX 14F8.0)
C            CONVERT TO CFS AND OBTAIN ANNUAL REQUIRED FLOW
 1890 DO 1900 I=1,NPER
      TMP=CSTO(I)
      QMX(I,M)=QMX(I,M)*TMP
      QMIN(I,M) =QMIN(I,M)*TMP
      QMIN2(I,M)= QMIN2(I,M)*TMP
      IF(IFLOW.EQ.M)TMPR(I)=QMIN(I,M)
 1900 CONTINUE
 1910 CONTINUE
      IF (NPWR.LE.0) GO TO 1960
      WRITE (6,1070)
      DO 1940 IP=1,NPWR
C =H=                                                            **CARD F7**
      READ(5,1080)M, TLWEL(IP),PWRMX(IP),OVLOD(IP),IDPR(IP)
      IF(OVLOD(IP).LE.0.) OVLOD(IP)=1.15
      WRITE(6,1920)M,TLWEL(IP),PWRMX(IP),OVLOD(IP),IDPR(IP)
 1920 FORMAT (12H POWER PLANT I4,8H  TLWEL= F8.1,8H  PWRMX= F8.0,8H   OVL
```

```
     1OD= F5.2,6H IDPR= I3)
      IF (M.GT.KCPT) GO TO 3940
C     POWER PLANTS INDENTIFIED BY READ ORDER
C     SUBSCRIPTS IP REFER TO THIS IDENTIFICATION
      IPWR(M)=IP
      IPR(IP)=M
      IF(IPWYR.GT.0) GO TO 1940
C                                                           **CARD F8**
      READ(5,1000)(POWR(I,IP),I=1,NPER)
      DO 1930 I=1,NPER
      IF (POWR(I,IP).GT.(-.0001))GO TO 1930
      ANDYS=NDAYS(I)
      POWR(I,IP) = POWR(I,IP)*PWRMX(IP)*(-.024)*ANDYS
 1930 CONTINUE
 1940 CONTINUE
      IF(NPWRS.LE.0.OR.IPWYR.GT.0) GO TO 1960
      DO 1950 IX=1,NPWRS
C                                                           **CARD F9**
 1950 READ(5,1000)(PWRS(I,IX),I=1,NPER)
C =I=         READ RESERVOIR DATA
 1960 DO 2200 IR=1,NRES
C                                                           **CARD G**
      READ(5,1060)M,ATMP,CEVAP(M),TEAK(M),IPOW(M),IEV(M)
      ELEV(NPER,M)=0.
      IF (M.GT.KRES) GO TO 3940
      IF (ATMP.LT.(-.1)) GO TO 1970
      STORA(M) = ATMP
      STORB(NPER,M)=ATMP
 1970 STOR1(M) = STORA(M)
      IRES(M) = M
      WRITE(6,1070)
      WRITE(6,1980)M,(CPT(M,K),K=1,8),STOR1(M),CEVAP(M),TEAK(M),IPOW(M),
     1IEV(M)
 1980 FORMAT (I3,1X7A4,A2,     16H  INITIAL STOR =F9.0,9H  CEVAP =F6.3,
     1 10H  STORAGES,/6H  TEAK,F8.0,6H IPOW ,I8,6H  IEV I8)
      IF(NMIN.GT.0) GO TO 2030
      WRITE(6,1990)(APERD(I),APRD(I),I=1,NPER)
 1990 FORMAT (9X,28A4)
      DO 2000 L=1,NL
C                                                           **CARD H**
 2000 READ(5,1000)(STORL(I,M,L),I=1,NPER)
      DO 2010 L=1,NL
      K = NL-L+1
 2010 WRITE(6,2020) K,(STORL(I,M,K),I=1,NPER)
 2020 FORMAT (6H LEVEL I4,14F8.0)
      GO TO 2060
C                                                           **CARD H1**
 2030 READ(5,1000)(STORL(1,M,L),L=1,NL)
      DO 2050 L=1,NL
      DO 2040 I=2,NPER
 2040 STORL(I,M,L)=STORL(1,M,L)
 2050 CONTINUE
      K=1
      WRITE(6,2020)K,(STORL(1,M,L),L=1,NL)
C                                                           **CARD I**
 2060 READ(5,1000)(EL(M,K),K=1,10)
      WRITE(6,2070)(EL(M,K),K=1,10)
 2070 FORMAT(/5H ELEV 5X,10F9.2)
      IF (IPWR(M).LE.0) GO TO 2160
      IP=IPWR(M)
```

```
      IF(TLWEL(IP)) 2110,2080,2110
C =J=                                                       **CARD I1**
 2080 READ(5,1000)(QT(IP,K),K=1,10)
C                                                           **CARD I2**
      READ(5,1000)(TL(IP,K),K=1,10)
      WRITE(6,2090)(QI(IP,K),K=1,10)
 2090 FORMAT(10H      FLOW 10F9.0)
      WRITE(6,2100)(TL(IP,K),K=1,10)
 2100 FORMAT(10H TAILWATER 10F9.0)
 2110 IF(IPWPK.LE.0.OR.IPOW(M).LT.1) GO TO 2140
C                                                           **CARD I3**
      READ (5,1000)(PKPWR(IP,K),K=1,10)
C                                                           **CARD I4**
      READ(5,1000) (CQOEL(IP,K),K=1,10)
      WRITE (6,2120)(PKPWR(IP,K),K=1,10)
 2120 FORMAT (10H MAX POWER 10F9.0)
      WRITE(6,2130)(CQOEL(IP,K),K=1,10)
 2130 FORMAT(10H VS Q OR S 10F9.0)
 2140 IF (EFFCY.GT.(-.1)) GO TO 2160
C                                                           **CARD I5**
      READ (5,1000) (EFCY(IP,K),K=1,10)
      WRITE (6,2150) (EFCY(IP,K),K=1,10)
 2150 FORMAT (5H EFCY 5X,10F9.3)
C                                                           **CARD J**
 2160 READ(5,1000)(STOR(M,K),K=1,10)
C                                                           **CARD K**
      READ(5,1000)(AREA(M,K),K=1,10)
C                                                           **CARD L**
      READ(5,1000)(QCAP(M,K),K=1,10)
      WRITE(6,2170)(STOR(M,K),K=1,10)
 2170 FORMAT (5H STOR 5X,10F9.0)
      WRITE(6,2180)(AREA(M,K),K=1,10)
 2180 FORMAT (5H AREA 5X,10F9.1)
      WRITE(6,2190)(QCAP(M,K),K=1,10)
 2190 FORMAT (5H QCAP 5X,10F9.0)
 2200 CONTINUE
      IF(IFLOW.GT.0)WRITE(6,1060)
C =K= **************
      CALL ATAPE(NYRS,NFLOW,NPER,IEVYR,NDVYR,IPWYR,NPWR,NPWRS,NLYR,NQYR
     1,NCPT,ICPT,IEV)
C     **************
C =L=           START ROUTING COMPUTATION * * * * * * * * * * * * * * * * *
      CFLOW=1.
 2210 REWIND 8
      SHORT=0.
      SRPLS=.5
      TFLOW=-1.
      DO 2220 M=1,KRES
      STORP(NPER,M)=STOR1(M)
 2220 STORA(M)=STOR1(M)
      DO 3540 J=1,NYRS
      IF(IPNT.GT.0) WRITE (6,2230)IYR
 2230 FORMAT (/18H INPUT INFLOWS FOR I5)
      DO 2250 MX=1,NFLOW
C                                                           **CARD M**
      READ (8) M,(QII(I,M), I=1,NPER)
      IF(IPNT.GT.0) WRITE (6,2240) M,(QII(I,M),I=1,NPER)
 2240 FORMAT (4H STA,I4,8X,14F8.0,(/16X14F8.0))
      IF (M.GT.KCPT) GO TO 3940
 2250 CONTINUE
```

```
      IF(IFVYR) 2270,2310,2260
C                                                         **CARD M1**
 2260 READ(8)(EVAPO(I),I=1,NPER)
      IF(IPNT.GT.0) WRITE(6,1540)(EVAPO(I),I=1,NPER)
      GO TO 2310
 2270 IF(IPNT.GT.0) WRITE(6,2280)IYR
 2280 FORMAT(/18H   EVAPORATION FOR I5)
      DO 2300 MX=1,NCPT
      M=ICPT(MX)
      IF(IFV(M).LE.0) GO TO 2300
C                                                         **CARD M2**
      READ(8)(EVP(I,M),I=1,NPER)
      IF(IPNT.GT.0) WRITE(6,2290)M,(EVP(I,M),I=1,NPER)
 2290 FORMAT(4H STAI4,8X,14F8.2)
 2300 CONTINUE
 2310 IF (NDVYR.LE.0) GO TO 2340
      DO 2330 IX=1,NDVYR
C                                                         **CARD M3**
      READ(8)M,(TMPP(I),I=1,NPER)
      ID=IDIV(M)
      DO 2320 I=1,NPER
      QDIV(I,ID)=TMPP(I)*CSTO(I)
      QDIVS(I,ID)=QDIV(I,ID)
 2320 CONTINUE
 2330 CONTINUE
 2340 IF(IPWYR.LE.0) GO TO 2380
      DO 2360 IP=1,NPWR
C                                                         **CARD M4**
      READ(8)(POWR(I,IP),I=1,NPER)
      DO 2350 I=1,NPER
      IF (POWR(I,IP).GT.(-.1)) GO TO 2350
      ANDYS=NDAYS(I)
      POWR(I,IP)=POWR(I,IP)*PWRMX(IP)*(-.024)*ANDYS
 2350 CONTINUE
 2360 CONTINUE
      IF (NPWRS.LE.0) GO TO 2380
      DO 2370 IX=1,NPWRS
C                                                         **CARD M5**
 2370 READ(8)(PWRS(I,IX),I=1,NPER)
 2380 IF (NLYR.LE.0) GO TO 2400
      DO 2390 IX=1,NLYR
C                                                         **CARD M6**
      READ (8)M,L,(STORL(I,M,L),I=1,NPER)
 2390 CONTINUE
 2400 IF (NQYR.LE.0) GO TO 2430
      DO 2420 IX=1,NQYR
C                                                         **CARD M7**
      READ(8)M,(QMIN(I,M),I=1,NPER)
      DO 2410 I=1,NPER
      QMIN(I,M)=QMIN(I,M)*CSTO(I)
      IF(IFLOW.EQ.M)TMPR(I)=QMIN(I,M)
 2410 CONTINUE
 2420 CONTINUE
 2430 IF(IFLOW.LE.0) GO TO 2450
      DO 2440 I=1,NPER
 2440 QMIN(I,IFLOW)=TMPR(I)*CFLOW
C =M=               CONVERT INPUT FLOWS TO LOCAL INFLOWS
 2450 KX = 1
      DO 2530 MX = 1, NCPT
      M = ICPT(MX)
```

```
      IF (NFLW(M).LE.0) GO TO 2510
      ITMP = NFLW(M)+KX-1
      DO 2460 I= 1, NPER
 2460 QL(I,M) = 0.
      DO 2480 K=KX,ITMP
      ITEMP = MQ(K)
      DO 2470 I=1,NPER
 2470 QL(I,M) = QL(I,M)+QII(I,ITEMP)*RTIO(K)*CSTI(I)
 2480 CONTINUE
      DO 2500 I=1,NPER
      IF(QL(I,M).GE.0.) GO TO 2500
      TEMP=(-QL(I,M))
      WRITE(6,2490)TEMP,M,I
 2490 FORMAT(F8.0,13H CFS ADDED TO I3,11H DURING PER I3)
      QL(I,M)=0.
 2500 CONTINUE
      KX = ITMP + 1
      GO TO 2530
 2510 DO 2520 I=1,NPER
 2520 QL(I,M) = QII(I,M)*CSTI(I)
 2530 CONTINUE
      DO 2560 M=1,KCPT
C     INACTIVE CONTROL POINTS HAVE NEGATIVE NRESR(M)+NDIVR(M)
      IF (NRESR(M)+NDIVR(M).LT.0) GO TO 2560
      DO 2550 I=1,NPER
      IF(QMIN2(I,M).LT.TEAK(M))QMIN2(I,M)=TEAK(M)
      IF(QMIN(I,M).LT.QMIN2(I,M))QMIN(I,M)=QMIN2(I,M)
      QMINA(I,M) = QMIN(I,M)
      QMINS(I,M)=QMINA(I,M)
 2550 CONTINUE
C =N=   INITIATE ANNUAL TOTALS
      SYQL(M)=0.
      SYPRE(M)=0.
      SYQI(M)=0.
      SYQMN(M) = .001
      SYCNS(M)=0.
      SYQA(M)=0.
      SYSHD(M)=0.
      SYSH2(M)=0.
      SYQ(M) = .001
      IF (IRES(M).GT.0) SYEVP(M)=0.
 2560 CONTINUE
      IF (NDIV.LE.0) GO TO 2580
      DO 2570 ID= 1, NDIV
      SYDV(ID) = .001
      SYDVA(ID)=0.
 2570 SYSHD(ID)=0.
 2580 ITMP=KPWR+KPWRS
      DO 2590 IP= 1, ITMP
      SYPWR(IP)=0.
      SYSP(IP)=0.
      SYPR(IP) = .001
      SYPMX(IP)=99999999.
      SYSYS(IP)=0.
 2590 SYSHP(IP) = 0.
      IF(IPNT.GT.0)WRITE(6,1060)
      IF(NMIN.GT.0)WRITE(6,2595)IYR
 2595 FORMAT(6H GROUP I3)
      IF(IPWKW.LE.0) GO TO 2610
      IF(IPNT.GT.0)WRITE(6,2600)QUNIT,VUNIT
```

```
 2600 FORMAT (     25X,14H ALL FLOWS IN A4,23H, STORAGES AND EVAP IN A4,
     124H, AND POWER IN KILOWATTS)
      GO TO 2630
 2610 IF(IPNT.GT.0)WRITE(6,2620)QUNIT,VUNIT
 2620 FORMAT (     25X,14H ALL FLOWS IN A4,23H, STORAGES AND EVAP IN A4,
     127H, AND POWER IN THOUSAND KWH)
C     **************
 2630 CALL COMP (J)
C     **************
C =O=       COMPUTE CUMULATIVE AVERAGES AND SHORTAGE INDEXES,PRINT
      IF(IFLOW.LE.0)GO TO 2680
      DO 2670 I=1,NPER
      ANDYS=NDAYS(I)
      CQS=CONST*ANDYS
      TEMP=0.
      TMP=0.
      TP=0.
      NRESM=NRESR(IFLOW)
      DO 2640 K=1,NRESM
      IR=IRESM(IFLOW,K)
      IF(IR.LT.1) GO TO 2640
      TEMP=TEMP+STORB(I,IR)
      ITP=NL-NLF+1
      TMP=TMP+STORL(I,IR,ITP)
      TP = TP+STORL(I,IR,2)
 2640 CONTINUE
      IF(TEMP+1..LT.TMP) GO TO 2650
      TFLOW=0.
      SHRTA=0.
      GO TO 2670
 2650 IF(TFLOW.LT.(-.5))GO TO 2670
      TFLOW=TFLOW+QMINA(I,IFLOW)
      IF(TFLOW.LE.0.)GO TO 2670
      TMP=QMINA(I,IFLOW)-QA(I,IFLOW)-.1
      IF(TMP.LE.0.)GO TO 2660
      SHRTA=SHRTA+TMP
      TMP=SHRTA/TFLOW
      IF(TMP.GT.SHORT)SHORT=TMP
      GO TO 2670
 2660 TMP=(TEMP-TP)/(TFLOW*CQS)
      IF(TMP.LT.SRPLS)SRPLS=TMP
 2670 CONTINUE
      IF(IPNT.LE.0)GO TO 3540
 2680 ANYRS = J
      RNYRS = 1./ANYRS
      ANYR = ANYRS-1.
      DO 3450 MX=1,NCPT
      M=ICPT(MX)
C =P=            CONVERT OUTPUT UNITS
      IF(IUNIT.LE.0) GO TO 2760
      SYQL(M)=SYQL(M)*CCFS
      SYPRE(M)=SYPRE(M)*CCFS
      SYQI(M)=SYQI(M)*CCFS
      SYQA(M)=SYQA(M)*CCFS
      SYQ(M)=SYQ(M)*CCFS
      SYSHQ(M)=SYSHQ(M)*CCFS
      SYQMN(M)=SYQMN(M)*CCFS
      SYSH2(M)=SYSH2(M)*CCFS
      ID=IDIV(M)
      IF(ID.LT.0) ID=(-ID)
```

```
      IF(ID.LE.0) GO TO 2710
      SYDV(ID)=SYDV(ID)*CCFS
      SYDVA(ID)=SYDVA(ID)*CCFS
      SYSHD(ID)=SYSHD(ID)*CCFS
      DO 2700 I=1,NPER
      QDIV(I,ID)=QDIV(I,ID)*CCFS
      QDIVA(I,ID)=QDIVA(I,ID)*CCFS
 2700 SHDIV(I,ID)=SHDIV(I,ID)*CCFS
 2710 IF(IRES(M).LE.0) GO TO 2740
      STOR1(M)=STOR1(M)*CACFT
      DO 2730 I=1,NPER
      DO 2720 L=1,NL
      IF(J.NE.1.AND.NLYR.LE.0) GO TO 2720
      STORL(I,M,L)=STORL(I,M,L)*CACFT
 2720 CONTINUE
      STORB(I,M)=STORB(I,M)*CACFT
 2730 EVP(I,M)=EVP(I,M)*CACFT
 2740 DO 2750 I=1,NPER
      QCONS(I,M)=QCONS(I,M)*CCFS
      QL(I,M)=QL(I,M)*CCFS
      QPREP(I,M)=QPREP(I,M)*CCFS
      QI(I,M)=QI(I,M)*CCFS
      QA(I,M)=QA(I,M)*CCFS
      QMINA(I,M)=QMINA(I,M)*CCFS
      SHRTQ(I,M)=SHRTQ(I,M)*CCFS
      QMIN2(I,M)=QMIN2(I,M)*CCFS
      IF(QM2(M).LE.0..AND.QM2(M).GT.(-.5))GO TO 2750
      SHRT2(I,M)=SHRT2(I,M)*CCFS
 2750 CONTINUE
C =Q=            LONG-TERM AVERAGES
 2760 SQL(M)  =  (SQL(M)*ANYR+SYQL(M))*RNYRS
      SPRE(M)  =  (SPRE(M)*ANYR+SYPRE(M))*RNYRS
      SQI(M)  =(SQI(M)*ANYR+SYQI(M))*RNYRS
      SQMN(M)  =  (SQMN(M)*ANYR+SYQMN(M))*RNYRS
      SCNS(M)  =  (SCNS(M)*ANYR  +SYCNS(M))*RNYRS
      SQA(M)  =  (SQA(M)*ANYR  +SYQA(M))*RNYRS
      SQ(M)  =  (SQ(M)*ANYR+SYQ(M))*RNYRS
      SSHQ(M)  =(SSHQ(M)*ANYR+SYSHQ(M))*RNYRS
      SSH2(M)=(SSH2(M)*ANYR+SYSH2(M))*RNYRS
      QINDX(M)=QINDX(M)+(SYSHQ(M)/SYQ(M))**2
      Q2NDX(M)=Q2NDX(M)+(SYSH2(M)/SYQMN(M))**2
      JPRNT=IPRN(M)+IPRNT
      ITMP=NRESR(M)
      IF(IFCON.LE.0) GO TO 2890
C                ALLOCATE BENEFITS
      IF(ITMP.LE.0) GO TO 2830
      DO 2810 I=1,NPER
      IF(ITMP.LE.0) GO TO 2810
      SUM=0.
      DO 2770 K=1,ITMP
      IR=IRESM(M,K)
      IF(IR.LT.0)IR=-IR
      TMPP(K)=QA(I,IR)-QI(I,IR)
 2770 SUM=SUM+TMPP(K)
      TMPX(I)=SUM
      TMP=ITMP
      TMP=1./TMP
 2780 DO 2800 K=1,ITMP
      QII(I,K)=TMP
      IF(SUM.LE.0.) GO TO 2800
```

```
      IF(SUM*TMPP(K).GT.(-.0001)) GO TO 2790
      SUM=SUM-TMPP(K)
      TMPP(K)=0.
      GO TO 2780
 2790 QII(I,K)=TMPP(K)/SUM
 2800 CONTINUE
 2810 CONTINUE
      DO 2820 K=1,ITMP
 2820 WRITE (9)   (QII(I,K),I=1,NPER)
      WRITE (9)  (TMPX(I),I=1,NPER)
 2830 DO 2880 K=1,8
      ITP=IE(K,M)
      IF(ITP.LE.0)ITP=5
      GO TO (2840,2850,2860,2870,2880),ITP
 2840 WRITE (9)   (QA(I,M),I=1,NPER)
      WRITE (9)   (QPREP(I,M),I=1,NPER)
      GO TO 2880
 2850 WRITE (9)   (STORB(I,M),I=1,NPER)
      GO TO 2880
 2860 IP=IPWR(M)
      WRITE (9)   (POWER(I,IP),I=1,NPER)
      GO TO 2880
 2870 ID=IDIV(M)
      IF(ID.LT.0)ID=-ID
      WRITE (9)  (QDIVA(I,ID),I=1,NPER)
 2880 CONTINUE
C =R=             PRINT INFLOWS AND DIVERSION
 2890 IF(JPRNT.LE.(-1)) GO TO 3040
      WRITE (6,1070)
      IF (NRESR(M).LE.0) GO TO 2910
      WRITE(6,2900)M,(CPT(M,K),K=1,8),TEAK(M),(IRESM(M,K),K=1,ITMP)
 2900 FORMAT(I4,2X,7A4,A2,9H LEAKAGE F8.0,10H SERVED BY 18I4/(34X,21I4))
      GO TO 2920
 2910 WRITE (6,2900) M,(CPT(M,K),K=1,8)
 2920 IF (IRES(M).LE.0) GO TO 2940
      ITMP=NSERV(M)
      WRITE(6,2930)(ISERV(M,K),K=1,ITMP)
 2930 FORMAT(33X,7HSERVING2X,19I4)
 2940 IF (NDIVR(M).LE.0) GO TO 2960
      ITMP=NDIVR(M)
      WRITE(6,2950) (IDIVR(M,K),K=1,ITMP)
 2950 FORMAT (33X,16HLOCAL DIVERSIONS 17I4)
 2960 IF(NMIN.LE.0) GO TO 2990
      TEMP=NMIN
      TEMP=TEMP/60.
      TMP=NPER*(IYR-1)
      TP=IPERA
      TMP=TMP*TEMP+TP-TIME(M)
      DO 2970 I=1,NPER
      TMP=TMP+TEMP
 2970 TIMSS(I)=TMP
      WRITE(6,2980)(TIMSS(I),I=1,NPER)
 2980 FORMAT(5H TIME 8X,3HAVG (14F8.0))
      GO TO 3010
 2990 WRITE(6,3000)IYR,(APERD(I),APRD(I),I=1,NPER)
 3000 FORMAT(/3H YR I5,4X,4HAVG   (28A4))
 3010 WRITE(6,3020)            SYQL(M),(QL(I,M),I=1,NPER)
 3020 FORMAT (8H LOC FLW  F8.0,(14F8.0))
      WRITE(6,3030)           SYPRE(M),(QPREP(I,M),I=1,NPER)
 3030 FORMAT (8H UNREG   F8.0,(14F8.0))
```

```
 3040 ID=IDIV(M)
      IF(ID.EQ.0.AND.IRES(M).LE.0) GO TO 3060
      IF(JPRNT.LE.(-1)) GO TO 3060
      WRITE(6,3050)SYQI(M),(QI(I,M),I=1,NPER)
 3050 FORMAT (8H INFLOW   F8.0,(14F8.0))
 3060 IF(ID)3070,3120,3080
 3070 ID=(-ID)
 3080 SDV(ID) = (SDV(ID)*ANYR+SYDV(ID))*RNYRS
      SDVA(ID) = (SDVA(ID)*ANYR+SYDVA(ID))*RNYRS
      SSHD(ID) = (SSHD(ID)*ANYR+SYSHD(ID))*RNYRS
      DINDX(ID)=DINDX(ID)+(SYSHD(ID)/SYDV(ID))**2
      IF(JPRNT.LE.(-1)) GO TO 3120
      WRITE (6,3090)          SYDV(ID),(QDIV(I,ID),I=1,NPER)
 3090 FORMAT (8H REQ DIV  F8.1,(14F8.1))
      WRITE(6,3100)SYDVA(ID),(QDIVA(I,ID),I=1,NPER)
 3100 FORMAT (8H DIVERSN  F8.1,(14F8.1))
      WRITE(6,3110)SYSHD(ID),(SHDIV(I,ID),I=1,NPER)
 3110 FORMAT (8H SHORTGE  F8.1,(14F8.1))
 3120 IF (IRES(M).LE.0) GO TO 3380
C =S=          PRINT RESERVOIR DATA
      SEVP(M) = (SEVP(M)*ANYR+SYEVP(M))*RNYRS
      IF(JPRNT.LE.(-1)) GO TO 3210
      IF(IPRL.LE.0) GO TO 3160
      DO 3140 L = 1, NL
      K = NL - L + 1
      DO 3130 I=1,NPER
 3130 ISTOR(I)=STORL(I,M,K)
 3140 WRITE(6,3150)K,(ISTOR(I),I=1,NPER)
 3150 FORMAT (6H LEVEL I4,6X,(14I8))
 3160 DO 3170 I=1,NPER
 3170 ISTOR(I) = STORB(I,M)+.5
      WRITE(6,3180)(ISTOR(I),I=1,NPER)
 3180 FORMAT (/8H EOP STR 8X,(14I8))
      WRITE(6,3190)(ELEV(I,M), I=1,NPER)
 3190 FORMAT (7H EOP EL  9X,(14F8.2))
      WRITE(6,3200)SYEVP(M),(EVP(I,M),I=1,NPER)
 3200 FORMAT (8H EVAPO    F8.0,(14F8.0))
 3210 IF (IPWR(M).LE.0) GO TO 3350
      IP = IPWR(M)
      SPR(IP) = (SPR(IP)*ANYR+SYPR(IP))*RNYRS
      SPWR(IP) = (SPWR(IP)*ANYR+SYPWR(IP))*RNYRS
      SSHP(IP) = (SSHP(IP)*ANYR+SYSHP(IP))*RNYRS
      SSP(IP)=(SSP(IP)*ANYR+SYSP(IP))*RNYRS
      PINDX(IP)=PINDX(IP)+(SYSHP(IP)/SYPR(IP))**2
      IF(IPWKW.LE.0) GO TO 3270
      TEMP=SPR(IP)*.1141
      SYPR(IP)=SYPR(IP)*.1141
      DO 3220 I=1,NPER
      TMP=NDAYS(I)
      TMP=TMP*.024
      TMPX(I)=POWR(I,IP)/TMP
      PWER(I,IP)=PWER(I,IP)/TMP
      POWER(I,IP)=POWER(I,IP)/TMP
      SHRTP(I,IP)=SHRTP(I,IP)/TMP
 3220 CONTINUE
      TEMP=SYSHP(IP)*.1141
      TMP=SYPWR(IP)*.1141
      TSYP=SYSP(IP)*.1141
      IF(JPRNT.LE.(-1)) GO TO 3320
      WRITE(6,3230)SYPR(IP),(TMPX(I),I=1,NPER)
```

```
 3230 FORMAT (7H REQ KW 1X,F8.0,(14F8.0))
      WRITE(6,3240) TSYP,(PWER(I,IP),I=1,NPER)
 3240 FORMAT(4H SYS I4,F8.0,(14F8.0))
      WRITE(6,3250)TMP,(POWER(I,IP),I=1,NPER)
 3250 FORMAT(7H GEN KW 1XF8.0,(14F8.0))
      WRITE(6,3260)TEMP,(SHRTP(I,IP),I=1,NPER)
 3260 FORMAT (8H SHORTGE F8.0,(14F8.0))
      GO TO 3320
 3270 IF(JPRNT.LE.(-1)) GO TO 3310
      WRITE(6,3280)SYPR(IP),(POWR(I,IP),I=1,NPER)
 3280 FORMAT (8H REQ PWR  F8.0,(14F8.0))
      IF(ISYSR(M).GT.0)WRITE(6,3240)ISYSR(M),SYSP(IP),(PWER(I,IP),I=1,
     1 NPER)
      WRITE(6,3290)SYPWR(IP),(POWER(I,IP),I=1,NPER)
 3290 FORMAT (8H POWER   F8.0,(14F8.0))
      WRITE(6,3260)SYSHP(IP),(SHRTP(I,IP),I=1,NPER)
      IF(ISYSR(M).GT.0)WRITE(6,3300)SYSYS(IP),(SYSSP(I,IP),I=1,NPER)
 3300 FORMAT(8H SYS SRT F8.0,(14F8.0))
 3310 TMP=SYPWR(IP)
      TEMP=SYSHP(IP)
 3320 IF(IPWPK.LE.0) GO TO 3350
      DO 3330 I=1,NPER
      TMP=POWRP(I,IP)
      IF (TMP.LT.SYPMX(IP)) SYPMX(IP)=TMP
      IF (TMP.LT.SPMX(IP)) SPMX(IP)=TMP
 3330 CONTINUE
      IF(JPRNT.GT.(-1))
     1WRITE(6,3340) SYPMX(IP),(POWRP(I,IP),I=1,NPER)
 3340 FORMAT (8H PEAK KW F8.0,(14F8.0))
 3350 IF(JPRNT.LE.(-1)) GO TO 3450
      WRITE(6,3360)(ICSE(I,M),I=1,NPER)
 3360 FORMAT (5H CASE 11X,(14I8))
      WRITE(6,3370)(CNTRL(I,M),I=1,NPER)
 3370 FORMAT (6H LEVEL 10X,(14F8.2))
 3380 IF(JPRNT.LE.(-1)) GO TO 3450
C =T=           PRINT OUTFLOWS
      IF (IRES(M).GT.0)
     1 WRITE(6,3390) SYCNS(M),(QCONS(I,M),I=1,NPER)
 3390 FORMAT(/8H CSV REL F8.0,(14F8.0))
      WRITE(6,3400)SYQA(M),(QA(I,M),I=1,NPER)
 3400 FORMAT (8H RIV FLW F8.0,(14F8.0))
      WRITE(6,3410)SYQ(M),(QMINA(I,M),I=1,NPER)
 3410 FORMAT (8H DES FLW F8.0,(14F8.0))
      IF(NMIN.GT.0) WRITE(6,3420) (QMX(I,M),I=1,NPER)
 3420 FORMAT(8H FLW CAP 8X,(14F8.0))
      IF(NMIN.LE.0) WRITE(6,3430) SYSHQ(M),(SHRTQ(I,M),I=1,NPER)
 3430 FORMAT (8H SHORTGE F8.0,(14F8.0))
      IF (QM2(M).LE.0..AND.QM2(M).GT.(-.1)) GO TO 3450
      WRITE(6,3440) SYQMN(M),(QMIN2(I,M),I=1,NPER)
 3440 FORMAT (8H MIN FLW F8.0,(14F8.0))
      WRITE(6,3430)SYSH2(M),(SHRT2(I,M),I=1,NPER)
C              END OF DO LOOP STARTING AT 2680+4
 3450 CONTINUE
      IF(ISMRY.LE.0)GO TO 3460
      IF(IRG(1).GT.0)WRITE(10)SYPRE,QPREP
      IF(IRG(2).GT.0)WRITE(10)SYQA,QA
      IF(IRG(3).GT.0)WRITE(10)SYDVA,QDIVA
      IF(IRG(4).GT.0)WRITE(10)SYSHD,SHDIV
      IF(IRG(5).GT.0)WRITE(10)SYSHQ,SHRTQ
      IF(IRG(6).GT.0)WRITE(10)SYSH2,SHRT2
```

```
      IF(IRG(7).GT.0.OR.IRG(8).GT.0)WRITE(10)STOR1,STORB
      IF(IRG(9).GT.0)WRITE(10)ELEV
      IF(IRG(10).GT.0)WRITE(7)SYQI,QI,STORB,ELEV,SYEVP,EVP,SYPWR,POWER,
     1 SYSHP,SHRTP,SYPMX,POWRP,SYQA,QA
 3460 IYR=IYR+1
      IF (NPWRS.LE.0) GO TO 3540
C               SYSTEM POWER SUMMARY
      DO 3530 IX=1,NPWRS
      WRITE(6,3470)IX
 3470 FORMAT(//49X,6HSYSTEMI2,14H POWER SUMMARY)
 3480 FORMAT(I3,2X,7A4,A2)
      WRITE(6,3490)
 3490 FORMAT(13H SYSTEM TOTAL)
      MX=KPWR+IX
      SPR(MX)=(SPR(MX)*ANYR+SYPR(MX))*RNYRS
      SPWR(MX)=(SPWR(MX)*ANYR+SYPWR(MX))*RNYRS
      SSHP(MX)=(SSHP(MX)*ANYR+SYSHP(MX))*RNYRS
      PINDX(MX)=PINDX(MX)+(SYSHP(MX)/SYPR(MX))**2
      WRITE(6,3500)SYPR(MX),(PWRS(I,IX),I=1,NPER)
 3500 FORMAT(8H REQUIRD 15F8.0)
      WRITE(6,3510)SYSP(MX),(PWER(I,MX),I=1,NPER)
 3510 FORMAT(8H USABLE 15F8.0)
      WRITE(6,3520)SYPWR(MX),(POWER(I,MX),I=1,NPER)
 3520 FORMAT(8H TOTAL  15F8.0)
      WRITE(6,3260)SYSHP(MX),(SHRTP(I,MX),I=1,NPER)
 3530 CONTINUE
C               END OF DO LOOP STARTING AT 2220+1
 3540 CONTINUE
      IF(IPNT.GT.0)GO TO 3600
C =U=           SUCCESSIVE APPROXIMATIONS OF YIELD
      IF(TFLOW.LT.(-.5))SHORT=.3
      IF(SHORT.LE.0.)GO TO 3550
      IF(SHORT.LE..01)GO TO 3570
      IF(SHORT.GT..3) SHORT=.3
      TPP=CFLOW
      CFLOW=CFLOW*(1.-SHORT)
      IF(TPP.GT.1.) GO TO 3560
      GO TO 3580
 3550 IF(SRPLS.LE..01) GO TO 3570
      IF(SRPLS.GT..15) SRPLS=.15
      TPP=CFLOW
      CFLOW=CFLOW*(1.+SRPLS)
      IF(TPP.GT.1.) GO TO 3580
 3560 CFLOW=(CFLOW+TPP)*.5
 3570 IPNT=1
 3580 ITRNS=1
      IYR=IYR1
      WRITE(6,3590)IFLOW,CFLOW
 3590 FORMAT(21H0FLOW REQUIREMENTS AT I3,14H MULTIPLIED BY F6.3)
      GO TO 1120
C               PRINT LONG-TERM AVERAGES
 3600 IYR=IYR-1
      WRITE(6,3610) IYR1,IYR
 3610 FORMAT (/ 33H AVERAGES FOR PERIOD OF OPERATION  I5,2H - I5)
      DO 3690 MX=1,NCPT
      M=ICPT(MX)
      WRITE (6,1070)
      WRITE (6,3480) M, (CPT(M,K),K=1,8)
      WRITE (6,1070)
      WRITE (6,3020) SQL(M)
```

```
      WRITE (6,3030) SPRE(M)
      ID=IDIV(M)
      IF(ID.NE.0.OR.IRES(M).GT.0) WRITE(6,3050)SQI(M)
      IF(ID) 3620,3640,3630
 3620 ID= (-ID)
 3630 WRITE (6,3090) SOV(ID)
      WRITE (6,3100) SOVA(ID)
      WRITE (6,3110) SSHD(ID)
 3640 IF (IRES(M).LE.0) GO TO 3670
      WRITE (6,3200) SEVP(M)
      IF (IPWR(M).LE.0) GO TO 3670
      IP=IPWR(M)
      IF(IPWKW.LE.0) GO TO 3650
      TEMP=SPR(IP)*.1141
      WRITE (6,3230) TEMP
      TEMP=SPWR(IP)*.1141
      WRITE (6,3250) TEMP
      TEMP=SSHP(IP)*.1141
      WRITE (6,3260) TEMP
      GO TO 3660
 3650 WRITE (6,3280) SPR(IP)
      IF(ISYSR(M).GT.0)WRITE(6,3240)ISYSR(M),SSP(IP)
      WRITE (6,3290) SPWR(IP)
      WRITE (6,3260) SSHP(IP)
 3660 IF(IPWPK.LE.0) GO TO 3670
      WRITE (6,3340) SPMX(IP)
 3670 IF (IRES(M).GT.0) WRITE (6,3390) SCNS(M)
      WRITE (6,3400) SQA(M)
      IF(NMIN.GT.0) GO TO 3680
      WRITE (6,3410) SQ(M)
      WRITE (6,3430) SSHQ(M)
 3680 IF(QM2(M).LE.0..AND.QM2(M).GT.(-.1)) GO TO 3690
      WRITE (6,3440) SQMN(M)
      WRITE (6,3430) SSH2(M)
 3690 CONTINUE
      IF(IMPDT.GT.0) GO TO 1200
C =V=         PRINT SHORTAGE INDEXES * * * * * * * * * * * * * * * * * * * *
      IF(NMIN.GT.0) GO TO 3850
      IF (NDIV.LE.0) GO TO 3720
      DO 3700 ID=1,NDIV
      DINDX(ID) = DINDX(ID)*100.*RNYRS
      IF(SOV(ID).LT..002.OR.RTIOD(ID).LT.0.)DINDX(ID)=-1.
 3700 CONTINUE
      WRITE(6,3710)(IDV(ID),DINDX(ID),ID=1,NDIV)
 3710 FORMAT(/26H DIVERSION SHORTAGE INDEX 7(I6,F7.3)/(9(I6,F7.3)))
 3720 DO 3730 MX=1,NCPT
      M = ICPT(MX)
      QINDX(M) = QINDX(M)*100.*RNYRS
      IF(SQ(M).LT..002)QINDX(M)=-1.
      Q2NDX(M) = Q2NDX(M)*100.*RNYRS
      IF(SQMN(M).LT..002)Q2NDX(M)=-1.
C           SQMN AND SSH2 USED AS TEMPORARY VARIABLES
      SQMN(MX)=QINDX(M)
 3730 SSH2(MX)=Q2NDX(M)
      IF (NPWR.LE.0) GO TO 3780
      DO 3740 IP=1,NPWR
 3740 PINDX(IP) = PINDX(IP)*100.*RNYRS
      IF(SPR(IP).LT..002)PINDX(IP)=-1.
      WRITE(6,3750)(IPR(IP),PINDX(IP),IP=1,NPWR)
 3750 FORMAT(/21H POWER SHORTAGE INDEX5X,7(I6,F7.3)/(9(I6,F7.3)))
```

```
      IF (NPWRS.LE.0) GO TO 3780
      DO 3760 IX=1,NPWRS
      MX=KPWR+IX
      PINDX(MX)=PINDX(MX)*100.*RNYRS
 3760 WRITE(6,3770)IX,PINDX(MX),NSRTP(IX),SYMSP(IX)
 3770 FORMAT(13H POWER SYSTEMI2,2X,14HSHORTAGE INDEXF7.3,17H NO. OF SHOR
     1TAGES I3,2X,16H MAX. SHORTAGE = F10.0)
 3780 WRITE(6,3790)(ICPT(M),SQMN(M),M=1,NCPT)
 3790 FORMAT(/21H WATER SHORTAGE INDEX5X,7(I6,F7.3)/(9(I6,F7.3)))
      WRITE(6,3800)(ICPT(M),SSH2(M),M=1,NCPT)
 3800 FORMAT(/24H MIN FLOW SHORTAGE INDEX2X,7(I6,F7.3)/(9(I6,F7.3)))
      WRITE(6,3810)
 3810 FORMAT(/78H DES FLOW SHORTAGES  REQ FLOW SHORTAGES  SYS PWR SHORTA
     1GES  AT SITE PWR SHRTGE)
      WRITE(6,3820)
 3820 FORMAT(4H STA 4(2X,9HNO     MAX 8X))
      DO 3840 MX=1,NCPT
      M=ICPT(MX)
      SHMX(M)=SHMX(M)*CCFS
      SHMX2(M)=SHMX2(M)*CCFS
      WRITE(6,3830)M,NSHMN(M),SHMX(M),NSH2(M),SHMX2(M),NSHPS(M),SPSMX(M)
     1,NSHP(M),SHPMX(M)
 3830 FORMAT(2I4,F7.0,3(I12,F7.0))
 3840 CONTINUE
 3850 DO 3900 MX=1,NCPT
      M=ICPT(MX)
      IF(IRES(M).LE.0) GO TO 3900
C =W=            STORAGE FREQUENCY
      IF(NMIN.GT.0) WRITE(6,3860) NYRS,M,(I,I=1,NPER)
 3860 FORMAT(/22H STORAGE FREQUENCY PER I3,18H YEARS AT LOCATION I3/11H
     1FLOOD POOL ,14I8)
      IF(NMIN.LE.0) WRITE(6,3870) NYRS,M,(APERD(I),APRD(I),I=1,NPER)
 3870 FORMAT(/22H STORAGE FREQUENCY PER I3,18H YEARS AT LOCATION I3/
     1  11H CONS POOL ,28A4)
      ITPA=100
      DO 3890 K=1,8
      ITP=ITPA-5
      IF(K.GT.2) ITP=ITP-5
      IF(K.GT.5) ITP=ITP-10
      WRITE(6,3880) ITP,ITPA,(NSTOR(I,M,K),I=1,NPER)
 3880 FORMAT(I3,1H-,I3,4H PCT,14I8)
      ITPA=ITP
 3890 CONTINUE
 3900 CONTINUE
      IF(NMIN.LE.0) GO TO 3930
      WRITE(6,3910)
 3910 FORMAT(/33H  CONTROL    DES    UNREG   RIV FLW/3X5HPOINT5X19HFLW
     1PEAK    PEAK )
      DO 3920 MX=1,NCPT
      M=ICPT(MX)
 3920 WRITE(6,1080) M,QMX(1,M),QPMX(M),QAMX(M)
 3930 END FILE 9
      IF(IECON.GT.0) CALL ECON
      IF(ISMRY.LE.0)GO TO 1100
      END FILE 7
      END FILE 10
      CALL REARNG
      GO TO 1100
 3940 WRITE(6,3950)
 3950 FORMAT(19H DIMENSION EXCEEDED)
```

```
      STOP
      END




      SUBROUTINE ATAPE(NYRS,NFLOW,NPER,IEVYR,NDVYR,IPWYR,NPWR,NPWRS,NLYR
     1,NQYR,NCPI,ICPT,IEV)
      DIMENSION TEMP(12),ICPT(40),IEV(40)
  100 FORMAT(1X,F7.0,9F8.0)
  110 FORMAT(8X,12F6.0)
  120 FORMAT(1X,I3,4X,12F6.0)
  130 FORMAT(1X,I7,9F8.0)
  140 FORMAT(1X,I7,I8,8F8.0)
      REWIND 8
      DO 280 J=1,NYRS
      DO 150 MX=1,NFLOW
C              READ QII(CARD M)
      READ(5,120)M,(TEMP(I),I=1,12)
      IF(NPER.GT.12) READ(5,110) (TEMP(I),I=13,NPER)
      WRITE(8)M,(TEMP(I),I=1,NPER)
  150 CONTINUE
      IF(IEVYR) 170,190,160
C              READ EVAPO(CARD M1)
  160 READ(5,100)(TEMP(I),I=1,NPER)
      WRITE(8)(TEMP(I),I=1,NPER)
      GO TO 190
  170 DO 180 MX=1,NCPI
      M=ICPT(MX)
      IF(IEV(M).LE.0) GO TO 180
C              READ EVP(CARD M2)
      READ(5,100)(TEMP(I),I=1,NPER)
      WRITE(8)(TEMP(I),I=1,NPER)
  180 CONTINUE
  190 IF(NDVYR.LE.0) GO TO 210
      DO 200 IX=1,NDVYR
C              READ QDIV(CARD M3)
      READ(5,130)M,(TEMP(I),I=1,9)
      IF(NPER.GT.9) READ(5,100)(TEMP(I),I=10,NPER)
      WRITE(8)M,(TEMP(I),I=1,NPER)
  200 CONTINUE
  210 IF(IPWYR.LE.0)GO TO 240
      DO 220 IP=1,NPWR
C              READ POWR(CARD M4)
      READ(5,100)(TEMP(I),I=1,NPER)
      WRITE(8) (TEMP(I),I=1,NPER)
  220 CONTINUE
      IF(NPWRS.LE.0) GO TO 240
      DO 230 IX=1,NPWRS
C              READ PWRS(CARD M5)
      READ(5,100)(TEMP(I),I=1,NPER)
      WRITE(8) (TEMP(I),I=1,NPER)
  230 CONTINUE
  240 IF(NLYR.LE.0)GO TO 260
      DO 250 IX=1,NLYR
C              READ STORL(CARD M6)
      READ(5,140)M,L,(TEMP(I),I=1,8)
      IF(NPER.GT.8) READ(5,100)(TEMP(I),I=9,NPER)
      WRITE(8) M,L,(TEMP(I),I=1,NPER)
```

```
  250 CONTINUE
  260 IF(NQYR.LE.0)GO TO 280
      DO 270 IX=1,NQYR
C              READ QMIN(CARD M7)
      READ(5,130)M,(TEMP(I),I=1,9)
      IF(NPER.GT.9) READ(5,100)(TEMP(I),I=10,NPER)
      WRITE(8)M,(TEMP(I),I=1,NPER)
  270 CONTINUE
  280 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COMP (J)
      DIMENSION
     1 APERD(12),APRD(12),AREA(30,10),CEVAP(30),CNTRL(12,40),CPT(40,8),
     2 CQOEL(20,10),EFCY(30,10),EFY(20),EL(30,10),ELEV(12,30),
     3 EVAPO(12),EVP(12,30),EVTMP(30),HEAD(20),ICPT(40),ICSE(12,40),
     4 IDBAS(25),IDIV(40),IDIVR(40,25),IDPR(20),IDV(25),IE(8,40),
     5 IOPER(40),IPER(12),IPOW(30),IPR(20),IPRN(40),IPWR(40),IPX(20),
     6 IRES(40),IRESM(40,30),IRESP(20),IRG(10),ISHDV(25),ISHQ(40),
     7 ISHR(30),ISYSR(40),IUPST(40,18),
     8 NDAYS(12),NDIVR(40),NFLW(40),NRESP(2),NRESR(40),NSHMN(40),
     9 NSHP(40),NSHPS(40),NSH2(40),NSRTP(2),NSTOR(12,40,8),NUPST(40)
      DIMENSION
     1 OVLOD(20),PFMAX(2),PGAU(20),PG(30,8,2),PGT(8),PKPWR(20,30),
     2 POWER(12,22),POWRP(12,20),POWR(12,20),PWER(12,22),
     3 PWRMX(20),PWRS(12,2),QA(12,40),QAMX(40),QCAP(30,10),
     4 QCONS(12,40),QDIV(12,25),QDIVA(12,25),QDIVR(40),QDIVS(12,25),
     5 QI(12,40),QII(12,40),QL(12,40),QMAXA(40),QMINA(12,40),
     6 QMINS(12,40),QMIN2(12,40),QMX(12,40),QM2(40),QO(30,8),QOMN(30),
     7 QOMNA(30),QOMNB(30),QOTMN(30),QOTMX(40),QOT(40,8),QPMX(40),
     8 QPREP(12,40),QT(20,30),RTIOD(25)
      DIMENSION
     1 SHDIV(12,25),SHMX(40),SHMX2(40),SHPMX(40),SHRTP(12,22),
     2 SHRTQ(12,40),SHRT2(12,40),SPSMX(40),SRCHG(40),STOR(30,10),
     3 STORA(30),STORB(12,30),STORL(12,40,8),STRAV(30),
     4 SYCNS(40),SYDV(25),SYDVA(25),SYEVP(30),SYMSP(2),SYPMX(22),
     5 SYPR(22),SYPRE(40),SYPWR(22),SYQ(40),SYQA(40),SYQI(40),SYQL(40),
     6 SYQMN(40),SYSHD(25),SYSHP(22),SYSHQ(40),SYSH2(40),SYSP(22),
     7 SYSSP(12,20),SYSYS(22),TEAK(30),TITLE(60),
     8 TL(20,10),TLWEL(20),TMPP(40),TMPX(12),TWEL(20)
C
      COMMON /ALPHA/
     1 APERD,APRD,IDIV,IPWR,IYR1,KCPT,KDIV,KPWR,KRES,NPWR,NRES,QM2,
     2 TITLE,IPWKW
      COMMON/BETA/
     1 NYRS,IRG,CPT,ICPT,IRES,NCPT,NPER,QUNIT,VUNIT,NMIN
      COMMON/DELTA/
     1 CNTRL,QL,SYQI,QI,STORB,ELEV,SYEVP,EVP,SYPWR,POWER,SYSHP,SHRTP,
     2 SYPMX,POWRP,SYQA,QA,
     3 ANDYS,AREA, CEVAP,CFLOD,CLOCL,CONST,CQOEL, DIVPR, EFCY,EFFCY,
     4 EFY,EL,EVAPO, HEAD, ICONS,ICSE,IDBAS,IDGST,IDPR,IDV,
     5 IDVSP,IEVYR,IPER,IPERA,IPOW,IPR,IPRN,IPWPK,IPWPR,IRESP,
     6 ISHDV,ISHQ,ISHR,ISPER,ISYSR,IUPST,METRC,NCYCL,NDAYS,
     7 NDIV,NDIVR,NFLW,NL,NLF,NPWRS,NRESM,NRESP,
     8 NSH2,NSHDV,NSHMN,NSHP,NSHPS,NSHQ,NSHR,NSPER,NSRTP,
```

```
     9 NUPST,OVLOD,PFMAX,PKPWR,POWR,PWER,PWRMX,
     1 PWRS,QAMX,QCAP,QCONS,QDIV,QDIVA,QDIVR,QDIVS,
     2 QMAXA,QMIN2,QMINA,QMINS,QMX,QO,QOMN,QOT,QPMX,QPREP,QT,
     3 RSHDV,RSHQ,RTIOD,SHDIV,SHMX,SHMX2,SHPMX,
     4 SHRT2,SHRTQ,SPSMX,SRCHG,STOR,STORA,STRAV,STRSH,SYCNS,SYDV,
     5 SYDVA,SYDYS,SYMSP,SYPR,SYPRE,SYQ,SYQL,SYQMN,SYSH2,SYSHD,
     6 SYSHQ,SYSP,SYSSP,SYSYS,TEAK,TL,TLWEL
      COMMON /BALT/ IECON,IE,IYEAR,NRESR,NSTOR,QII,STORL,TMPP,TMPX
      COMMON /GAMMA/ IRESM,IDIVR
C =A=           START COMPUTATION FOR EACH PERIOD * * * * * * * * * * * *
      NFL=NL-NLF+1
      CKW=.08464
      IF(METRC.GT.0) CKW=8.9676
      TMP=NPER
      CT=1./TMP
      CQS=ANDYS*CONST
      CSQ=1./CQS
      CNST=ANDYS*.001
      DO 6420 I=1,NPER
      NC=0
      IF(NMIN.GT.0) GO TO 5000
      ANDYS = NDAYS(I)
      CT = ANDYS/SYDYS
      CQS = CONST*ANDYS
      CSQ = 1./CQS
      CNST = .024*ANDYS
 5000 IF (NPWR.LE.0) GO TO 5020
      DO 5010 IP=1,NPWR
      IPX(IP)=0
 5010 PWER(I,IP)=POWR(I,IP)
 5020 EVPO= EVAPO(I)/12.
      IF(METRC.GT.0)EVPO=EVAPO(I)*.001
C =B= SHORTAGE DECLARATION
      IF (NSHR.LE.0.OR.ISPER.NE.IPER(I)) GO TO 5090
      TEMP=0.
      DO 5030 MX=1,NSHR
      M=ISHR(MX)
 5030 TEMP=TEMP+STORA(M)
      TMP=STRSH-TEMP
      DO 5080 K=1,NSPER
      IX=ISPER-IPERA + K
      IF (IX.LE.0) IX=IX+NPER
      IF(IX.GT.NPER)IX=IX-NPER
      IF (NSHDV.LE.0) GO TO 5050
      DO 5040 KX=1,NSHDV
      ID=ISHDV(KX)
      ID = IDIV(ID)
      IF (ID.LT.0) ID=(-ID)
      QDIVS(IX,ID) = QDIV(IX,ID)
      IF (QDIV(IX,ID).LE.0..OR.TMP.LE.0.) GO TO 5040
      QDIVS(IX,ID)=QDIV(IX,ID)*(1.-TMP*RSHDV)
      IF (QDIVS(IX,ID).LT.0.) QDIVS(IX,ID)=0.
 5040 CONTINUE
 5050 IF (NSHQ.LE.0) GO TO 5080
      DO 5060 KX=1,NSHQ
      M=ISHQ(KX)
      QMINS(IX,M)=QMINA(IX,M)
      IF (TMP.GT.0.) QMINS(IX,M) = QMINA(IX,M)*(1.-TMP*RSHQ)
 5060 CONTINUE
      DO 5070 KX=1,NSHQ
```

```
      M=ISHQ(KX)
      IF (QMINS(IX,M).LT.QMIN2(IX,M)) QMINS(IX,M)=QMIN2(IX,M)
 5070 CONTINUE
 5080 CONTINUE
C =C= RE-ENTRY FOR SECOND APPROXIMATION  *  *  *  *  *  *  *  *  *  *  *
 5090 NC=NC+1
      DO 5150 MX=1,NCPT
      M=ICPT(MX)
      QMAXA(M) = 999999.
      IF (IRES(M).LE.0) GO TO 5150
C            RESERVOIR EVAPORATION AND OUTLET CAPACITY
      IF (NC.LE.1) STRAV(M)=STORA(M)
      DO 5110 ITMP=2,10
      K = ITMP
      IF(STRAV(M).LE.STOR(M,K)) GO TO 5140
      IF (STOR(M,K).LE.0.) GO TO 5100
      IF (STOR(M,K).GE.STOR(M,K-1).OR.K.LE.2) GO TO 5110
 5100 K = K-1
      GO TO 5120
 5110 CONTINUE
 5120 WRITE(6,5130) M
 5130 FORMAT (35H STORAGE TABLE EXTRAPOLATED FOR RES I4)
 5140 TEMP = 0.
      IF (STOR(M,K).GT.STOR(M,K-1))
     1TEMP = (STRAV(M)-STOR(M,K-1))/(STOR(M,K)-STOR(M,K-1))
      AREAV = TEMP*(AREA(M,K)-AREA(M,K-1))+AREA(M,K-1)
      IF(IEVYR.LE.(-1))EVPO=EVP(I,M)/12.
      EVTMP(M) = EVPO*AREAV *CEVAP(M)
      TMP=TEMP*(QCAP(M,K)-QCAP(M,K-1))+QCAP(M,K-1)
      IF(NC.LT.3)QMAXA(M)=TMP
      IF(NC.GE.3)QMAXA(M)=(QMAXA(M)+TMP)*.5
      ELEV(I,M)=TEMP*(EL(M,K)-EL(M,K-1))+EL(M,K-1)
      IF(J.EQ.1.AND.I.EQ.1)ELEV(NPER,M)=ELEV(I,M)
      IF (EFFCY.GT.(-.1).OR.IPWR(M).LE.0) GO TO 5150
      IP=IPWR(M)
      EFY(IP)=TEMP*(EFCY(IP,K)-EFCY(IP,K-1))+EFCY(IP,K-1)
 5150 CONTINUE
      DO 5900 MX = 1, NCPT
      M=ICPT(MX)
      NRESM=NRESR(M)
C =D= DESIRED FLOW AT CONTROL POINT
      QA(I,M) = QMINS(I,M)
      ICSE(I,M) = 1+100*M
C                   TOTAL DIVERSION FROM LOCAL AREA
      TMPP(M) = QA(I,M)
      QDIVR(M)=0.
      IF (NDIVR(M).LE.0) GO TO 5200
      ID=IDIV(M)
      IF(ID) 5160,5180,5170
 5160 ID=(-ID)
      ITMP=IDBAS(ID)
      ITMP=IDIV(ITMP)
      QDIVS(I,ID)=QDIVA(I,ITMP)*RTIOD(ID)
      QDIV(I,ID)=QDIV(I,ITMP)*RTIOD(ID)
 5170 QDIVA(I,ID)=QDIVS(I,ID)
 5180 ITMP = NDIVR(M)
      DO 5190 K=1, ITMP
      ITEMP=IDIVR(M,K)
      ID=IDIV(ITEMP)
      IF (ID.LT.0) ID=(-ID)
```

```
      QDIVR(M)=QDIVR(M)+QDIVA(I,ID)
 5190 CONTINUE
C =E=           LIMIT FLOW TO RIVER BY CHANNEL CAPACITY
 5200 TEMP=QMAXA(M)
      IF(QMX(I,M).LT.TEMP)TEMP=QMX(I,M)
      QOTMX(M)=TEMP-QL(I,M)*(CFLOD-CLOCL)
      IF (QOTMX(M).LT.0.) QOTMX(M)=0.
      IF(IRES(M).GT.0)QOTMX(M)=TEMP
      ITMP=NUPST(M)
      IF(ITMP.LE.0) GO TO 5250
      AL=1.
      TEMP=0.
      DO 5220 L=1,NL
      TMP=TEMP
      TEMP=QL(I,M)*CLOCL-QDIVR(M)
      IF(IRES(M).GT.0)TEMP=QL(I,M)-QDIVR(M)+(STORA(M)-STORL(I,M,NL)-
     1 EVTMP(M))*CSQ
      DO 5210 K=1,ITMP
      IR=IUPST(M,K)
      TMPA=QOT(IR,L)
      IF(TMPA.GT.QOTMX(IR))TMPA=QOTMX(IR)
      IF(L.LE.NFL.AND.TMPA.LT.QOTMN(IR))TMPA=QOTMN(IR)
      IF(ICONS.GT.0.AND.TMPA.LT.QOTMN(IR))TMPA=QOTMN(IR)
      IF(TMPA.LT.TEAK(IR))TMPA=TEAK(IR)
      QOT(IR,L)=TMPA
 5210 TEMP=TEMP+TMPA
      IF(L.EQ.1.OR.TEMP.GT.QOTMX(M)) GO TO 5220
      IF(TEMP.GE.TMP) AL=(-1.)
      IF(TEMP.LT.TMP)AL=(QOTMX(M)-TMP)/(TEMP-TMP)
      GO TO 5230
 5220 CONTINUE
      L=NL
 5230 IF(AL.LT.0.) GO TO 5250
      DO 5240 K=1,NRESM
      IR=IRESM(M,K)
      IF(IR.LT.0)IR=(-IR)
      IF(IR.EQ.M) GO TO 5240
      QOTMX(IR)=QOT(IR,L-1)*(1.-AL)+QOT(IR,L)*AL
 5240 CONTINUE
 5250 IF(IRES(M).LE.0) GO TO 5380
      ID=IDIV(M)
      TMP=0.
      IF(ID.GT.0)TMP=QDIVA(I,ID)
      QOTMN(M)=TEAK(M)-TMP
C =F=           POWER RELEASE
      TMPPR=0.
      IF (IPWR(M).LE.0) GO TO 5360
      IP = IPWR(M)
      TWEL(IP)=TLWEL(IP)
      ITEMP=0
      IF (TLWEL(IP)) 5320,5270,5320
 5260 ITEMP=1
 5270 DO 5280 K=2,10
      IF(TMPP(M).LE.QT(IP,K)) GO TO 5300
      IF(QT(IP,K).LE.0) GO TO 5290
 5280 CONTINUE
      K=10
      GO TO 5300
 5290 K=K-1
      IF(K.EQ.1) GO TO 5310
```

```
 5300 IF (QT(IP,K).LE.QT(IP,K-1)) GO TO 5310
      TEMP=(TMPP(M)-QT(IP,K-1))/(QT(IP,K)-QT(IP,K-1))
      TWEL(IP)=TL(IP,K)*TEMP+TL(IP,K-1)*(1.-TEMP)
      GO TO 5320
 5310 TWEL(IP)=TL(IP,K)
C     TAILWATER AS LEVEL OF DOWNSTREAM RESERVOIR + 2 FEET
 5320 IF(IDPR(IP).LT.1) GO TO 5340
      ITMP=IDPR(IP)
      TEMP=TLWEL(IP)
      IF(TEMP.LT.(.1))TEMP=TWEL(IP)
      IX=I
      IF (MC.GT.1) GO TO 5330
      IX=I-1
      IF (IX.LE.0) IX=NPER
 5330 TWEL(IP)=ELEV(IX,ITMP)+2.
      IF(METRC.GT.0)TWEL(IP)=TWEL(IP)-1.4
      IF(TWEL(IP).GT.TEMP)TWEL(IP)=TEMP
 5340 HEAD(IP) = ELEV(I,M)-TWEL(IP)
      CPWR = EFY(IP)*CKW*CNST
      TMPP(M) = PWER(I,IP)/(CPWR*HEAD(IP))+TEAK(M)
      IF(EFFCY.LT.(-1.5))TMPP(M)=PWER(I,IP)/(EFY(IP)*CNST)+TEAK(M)
      TMPPR=TMPP(M)
      IF (QA(I,M).GE.TMPP(M)) GO TO 5360
      QA(I,M) = TMPP(M)
      IF(ITEMP.EQ.1) GO TO 5350
      IF(TLWEL(IP))5350,5260,5350
 5350 ICSE(I,M)=2 + 100 * M
C =G= RELEASE TO REACH EACH LEVEL,NEGLECTING UPSTREAM RELEASE
 5360 DO 5370 L=1,NL
 5370 QO(M,L) = QL(I,M)-QDIVR(M)+(STORA(M)-STORL(I,M,L)-EVTMP(M))*CSQ
      QOMN(M) = QO(M,NL)
      QOMNA(M)=QO(M,1)
      QOMNB(M)=QOMN(M)
 5380 QCONS(I,M)=QA(I,M)
      IF (NRESR(M)) 5900,5390,5400
C     LIMIT DIVERSION TO RUNOFF IN AREAS WITHOUT RESERVOIRS
 5390 QA(I,M)=QL(I,M)-QDIVR(M)
      IF (QL(I,M).GE.QDIVR(M)) GO TO 5900
      IF (ID.LT.0) ID=(-ID)
      IF(ID.LE.0) GO TO 5900
      TMP=QDIVA(I,ID)
      QDIVA(I,ID)=QL(I,M)-QDIVR(M)+TMP
      QDIVR(M)=QDIVR(M)+QDIVA(I,ID)-TMP
      QA(I,M)=0.
      GO TO 5900
C =H=           RESERVOIRS NOT OPERATING SPECIFICALLY,IOPER=-1
 5400 DO 5420 K=1,NRESM
      IRA=IRESM(M,K)
      IF (IRA.LE.(-1)) GO TO 5410
      IOPER(IRA) = 1
      GO TO 5420
 5410 IRA = -IRA
      IOPER(IRA) = -1
 5420 CONTINUE
C     TOTAL RELEASE FOR EACH LEVEL ABOVE EACH CONTROL POINT
      LCNS=NFL
      IF(ICONS.GT.0)LCNS=NL-1
      DO 5550 KA=1,NRESM
      IRA=IRESM(M,KA)
      IF(IRA.LT.0)IRA=-IRA
```

```
      ID=INDIV(IRA)
      NR=NUPST(IRA)
      DO 5545 LX=1,NL
      L=NL-LX+1
      QOT(IRA,L)=QO(IRA,L)
      IF(NPWRS.LE.0) GO TO 5450
C               USE PG FOR QOT FOR LATER SYSTEM POWER ALLOCATION
      DO 5440 IX=1,NPWRS
      PG(IRA,L,IX)=QO(IRA,L)
      IF(IRA.EQ.M) GO TO 5430
      PG(IRA,L,IX)=QOMN(IRA)
      IF(ISYSR(IRA).NE.IX.AND.IOPER(IRA).LT.0) GO TO 5430
      PG(IRA,L,IX)=QO(IRA,L)
      IF(PG(IRA,L,IX).LT.QOMN(IRA))PG(IRA,L,IX)=QOMN(IRA)
      IF(L.NE.1) GO TO 5430
C               CHECK AVAILABILITY OF BUFFER STORAGE
      TMPG=QOMN(IRA)
      IF(TMPG.LT.PG(IRA,2,IX))TMPG=PG(IRA,2,IX)
      IF(IPWPR.LT.0)  PG(IRA,L,IX) = TMPG
 5430 IF(IPWR(IRA).LE.0.OR.NR.GT.0) GO TO 5440
      IP = IPWR(IRA)
      CPWR = EFY(IP) * CKW
C               LIMIT POWER TO MAX LOAD FACTOR
      TEMP = PWRMX(IP) * PFMAX(IX) / (CPWR * HEAD(IP))+TEAK(IRA)
      IF(EFFCY.LT.(-1.5))TEMP=PWRMX(IP)*PFMAX(IX)/EFY(IP)+TEAK(IRA)
      IF(PG(IRA,L,IX).GT.TEMP) PG(IRA,L,IX) = TEMP
 5440 CONTINUE
 5450 IF(IOPER(IRA).LT.0)QOT(IRA,L)=QOMN(IRA)
      IF(NR.LT.1) GO TO 5480
      DO 5470 K=1,NR
      IR=IUPST(IRA,K)
      IF(NPWRS.LE.0) GO TO 5470
      DO 5460 IX=1,NPWRS
      PG(IRA,L,IX)=PG(IRA,L,IX)+PG(IR,L,IX)
      IF(IPWR(IRA).LE.0) GO TO 5460
C               LIMIT POWER TO MAX LOAD FACTOR
      IP = IPWR(IRA)
      CPWR = EFY(IP) * CKW
      TEMP = PWRMX(IP) * PFMAX(IX) / (CPWR * HEAD(IP))+TEAK(IR)
      IF(EFFCY.LT.(-1.5))TEMP=PWRMX(IP)*PFMAX(IX)/EFY(IP)+TEAK(IR)
      IF(PG(IRA,L,IX).GT.TEMP) PG(IRA,L,IX) = TEMP
 5460 CONTINUE
 5470 QOT(IRA,L)=QOT(IRA,L)+QOT(IR,L)
C =I=           FREEZE SYSTEM POWER RELEASES
 5480 IP=IPWR(IRA)
      IF(ISYSR(IRA).LE.0.OR.IRA.EQ.M.OR.NC.EQ.1.OR.L.EQ.NL)GO TO 5500
      IF(IPX(IP).LE.0.AND.L.LE.2)GO TO 5500
      ITMP=NRESR(IRA)
      DO 5490 K=1,ITMP
      IR=IRESM(IRA,K)
      IF(IR.LT.0)IR=(-IR)
 5490 QOT(IR,L)=QA(I,IR)
      GO TO 5540
 5500 IF(QOT(IRA,L).LT.TEAK(IRA).AND.IRA.NE.M)QOT(IRA,L)=TEAK(IRA)
      IF(L.EQ.NL) GO TO 5510
      IF(QOT(IRA,L).LT.QOTMN(IRA).AND.L.LE.NFL)QOT(IRA,L)=QOTMN(IRA)
      IF(QOT(IRA,L).GT.QOTMX(IRA))QOT(IRA,L)=QOTMX(IRA)
      IF(QOT(IRA,L).LT.QOT(IRA,L+1))QOT(IRA,L)=QOT(IRA,L+1)
      GO TO 5540
C               CONSTRAIN MINIMUM RELEASE
```

```
 5510 TEMP=0.
      IF(ID.GT.0) TEMP=QDIVA(I,ID)
      TEMP=TEAK(IRA)-TEMP
      IF(QOT(IRA,L).LT.TEMP)QOT(IRA,L)=TEMP
      IF(SRCHG(IRA).GT..5.AND.QOT(IRA,L).GT.QMAXA(IRA))QOT(IRA,L)=QMAXA
     1 (IRA)

      IF(ICONS.GT.0.AND.QOT(IRA,L).LT.QOTMN(IRA))QOT(IRA,L)=QOTMN(IRA)
      IF(IDVSP.GT.0) GO TO 5520
      IF(QOTMX(IRA).LT.QOT(IRA,NL))QOTMX(IRA)=QOT(IRA,NL)
      GO TO 5540
C                SPILL THRU DIVERSION
 5520 IF(QOT(IRA,L).LE.QOTMX(IRA)) GO TO 5540
      ID=IDIV(IRA)
      IF(ID.LE.0)GO TO 5540
      TEMP=QOT(IRA,L)-QOTMX(IRA)
      QDIVA(I,ID)=QDIVA(I,ID)+TEMP
      QDIVR(IRA)=QDIVR(IRA)+TEMP
      DO 5530 LA=1,NL
 5530 QO(IRA,LA)=QO(IRA,LA)-TEMP
      QOT(IRA,L)=QOTMX(IRA)
 5540 IF(IRA.NE.M.AND.QOT(IRA,L).LT.0.) QOT(IRA,L)=0.
 5545 CONTINUE
 5550 CONTINUE
      IF(IRES(M).GT.0) GO TO 5580
C =J=            COMPUTE QOT, NON-RES
      ITMP=NUPST(M)
      DO 5570 LX=1,NL
      L=NL-LX+1
      QOT(M,L)=QL(I,M)*CLOCL-QDIVR(M)
      DO 5560 K=1,ITMP
      IR=IUPST(M,K)
 5560 QOT(M,L)=QOT(M,L)+QOT(IR,L)
      IF(IDVSP.LE.0.OR.L.LT.NL) GO TO 5570
      TMP=QMX(I,M)
      IF(TMP.GT.QMAXA(M))TMP=QMAXA(M)
      IF(QOT(M,L).LE.TMP) GO TO 5570
      ID=IDIV(M)
      IF(ID.LE.0)GO TO 5570
      TEMP=QOT(M,L)-TMP
      QDIVA(I,ID)=QDIVA(I,ID)+TEMP
      QDIVR(M)=QDIVR(M)+TEMP
      QOT(M,L)=TMP
 5570 CONTINUE
C            DIAGNOSTIC
 5580 IF(IDGST.GT.0)
     1WRITE (6,5590)M,I,QA(I,M),(QOT(M,N),N=1,NL)
 5590 FORMAT (3H M=I3,5H    I=I3,6H    QA=F8.0,7H    QOT=10F8.0)
C                DIVERSION SHORTAGE
      IF(IDIV(M).LE.0) GO TO 5610
      TMP=QOT(M,1)-TEAK(M)
      IF(DIVPR.LT.(-.5))TMP=QOT(M,2)-TEAK(M)
      IF(TMP.GE.0.) GO TO 5610
      TEMP=-TMP
      ID=IDIV(M)
      IF(TEMP.GT.QDIVA(I,ID))TEMP=QDIVA(I,ID)
      QDIVA(I,ID)=QDIVA(I,ID)-TEMP
      IF(IRES(M).GT.0)QOMNA(M)=QOMNA(M)+TEMP
      IF(IRES(M).GT.0)QOMNB(M)=QOMNB(M)+TEMP
      IF(QOMN(M).LT.QOMNB(M))QOMN(M)=QOMNB(M)
```

```
      DO 5600 L=1,NL
      QOT(M,L)=QOT(M,L)+TEMP
      IF(IRES(M).GT.0)QO(M,L)=QO(M,L)+TEMP
 5600 CONTINUE
      IF(QOT(M,1).LT.0.)QOT(M,1)=0.
      QDIVR(M)=QDIVR(M)-TEMP
      IF(QOTMX(M).GT.QOT(M,1))QOTMX(M)=QOT(M,1)
C =K= LOCATE LEVEL FOR DESIRED RELEASE
 5610 TEMP =QA(I,M)
      IFC=0
      DO 5630 L =1,NL
      IF (TEMP .LT.QOT(M,L)) GO TO 5630
      IF (L.GT.1) GO TO 5620
      AL = 1.
      GO TO 5650
 5620 TMP = L-1
      AL = (TEMP -QOT(M,L-1))/(QOT(M,L)-QOT(M,L-1))+TMP
      GO TO 5640
 5630 CONTINUE
      AL = NL
 5640 IF (AL.GE.2.) GO TO 5680
C     SHORTAGE IN BOTTOM BUFFER ZONE
 5650 TMP = QMIN2(I,M)
      IF(IPWPR.GT.(-1).AND.TMPPR.GT.TMP)TMP=TMPPR
      IF (QOT(M,2) .GE. QOT(M,1)) GO TO 5660
      AL = (TMP-QOT(M,1))/(QOT(M,2)-QOT(M,1))+1.
      IF (AL-1.) 5660,5810,5670
 5660 AL= 1.
      GO TO 5810
 5670 IF (AL.GT.2.) AL=2.
      GO TO 5810
 5680 ITP=NFL
      TMP=ITP
      IF (AL.LE.TMP) GO TO 5810
C =L= FLOOD RELEASES * * * * * * * * * * * * * * * * * * * * * * * * * *
      IFC=1
      GO TO 5810
C               ENTRY FROM 5870+1
 5690 TEMP=0.
      ITP=NFL
      IF (IRES(M).LE.0) TEMP=CFLOD-CLOCL
      TMP=QMX(I,M)
      IF(TMP.GT.QMAXA(M))TMP=QMAXA(M)
      TEMP=TMP-QL(I,M)*TEMP
      TMP = 0.
      L=NL
      IF(QOT(M,NL).GT.TEMP) GO TO 5730
C               MINOR FLOOD CONTROL RELEASES, TMP=0.
      L=ITP+1
      IF (QOT(M,ITP).LT.TEMP.OR.QOT(M,NL).GE.QOT(M,ITP)) GO TO 5720
C             FULL FLOOD CONTROL RELEASES
      ITP=ITP+1
      DO 5700 L=ITP,NL
      IF(TEMP.GE.QOT(M,L)) GO TO 5710
 5700 CONTINUE
      L=NL
 5710 TMP=0.
      TMPG=QOT(M,L)-QOT(M,L-1)
      IF(TMPG.LT.0.) TMP=(TEMP-QOT(M,L-1))/TMPG
C     FLOOD CONTROL RELEASES - BALANCE WITH UPSTREAM RESERVOIRS
```

```
 5720 IF (TMP.LT.0.) TMP=0.
      IF (TMP.LE.1.) GO TO 5740
 5730 TMP = 1.
 5740 AL=L-1
      AL = AL+TMP
      DO 5800 K=1, NRESM
      IR=IRESM(M,K)
      IF (IR.LE.0) IR=(-IR)
      TEMP=QOT(IR,L-1)*(1.-TMP)+QOT(IR,L)*TMP
      TMPA=TEMP
      ITMP=NUPST(IR)
      IF(ITMP.LE.0) GO TO 5760
      DO 5750 ITP=1,ITMP
      IRA=IUPST(IR,ITP)
 5750 TMPA=TMPA-QA(I,IRA)
 5760 IF(IR.EQ.M) GO TO 5770
      IF (QA(I,IR).GE.TEMP+.1) GO TO 5770
      IF (QA(I,IR).GE.TEMP-.1) GO TO 5780
 5770 ICSE(I,IR) =3+100*M
      QA(I,IR) = TEMP
 5780 IF(QCONS(I,IR).GT.TEMP)QCONS(I,IR)=TEMP
      QOMN(IR)=TMPA
      IF(QOMN(IR).GT.QOMNA(IR))QOMN(IR)=QOMNA(IR)
      IF(QOMN(IR).LT.QOMNB(IR))QOMN(IR)=QOMNB(IR)
      IF(QOTMN(IR).GT.TEMP)QOTMN(IR)=TEMP
C           DIAGNOSTIC
      IF(IDGST.GT.0)
     1WRITE (6,5790)IR,I,QA(I,IR),AL,(QOT(IR,N), N=1,NL),QOTMN(IR),
     2QOTMX(IR)
 5790 FORMAT (4H IR=I3,5H   I=I3,6H   QA=F8.0,6H   AL=F6.3,7H   QOT=
     1  10F8.0)
 5800 CONTINUE
      GO TO 5880
C =M=        CONSERVATION RELEASES - BALANCE WITH UPSTREAM RESERVOIRS * *
 5810 DO 5870 K=1,NRESM
      IR = IRESM(M,K)
      IF(IR.LE.0) IR=(-IR)
      L = AL
      TMP=L
      TMP = AL-TMP
      TEMP=QOT(IR,L)
      IF(L.LT.NL)TEMP=QOT(IR,L)*(1.-TMP)+QOT(IR,L+1)*TMP
      IF(TEMP.LT.QOTMN(IR)) GO TO 5840
      QASUM=0.
      IF(NUPST(IR).LE.0) GO TO 5830
      ITMP=NUPST(IR)
      DO 5820 ITP=1,ITMP
      IRA=IUPST(IR,ITP)
 5820 QASUM=QASUM+QA(I,IRA)
 5830 QOMN(IR)=TEMP-QASUM
      QOTMN(IR)=TEMP
 5840 IF(IFC.GT.0) GO TO 5870
      IF(IR.EQ.M) GO TO 5850
      IF (QA(I,IR).GE.TEMP+.1) GO TO 5850
      IF (QA(I,IR).GE.TEMP-.1) GO TO 5860
 5850 ICSE(I.IR) = ICSE(I,M)
      QA(I.IR) = TEMP
      QCONS(I,IR)=TEMP
C           DIAGNOSTIC
 5860 IF(IDGST.GT.0)
```

```
     1WRITE(6,5790)IR,I,QA(I,IR),AL,(QOT(IR,N),N=1,NL),QOTMN(IR),QOTMX(I
     1R)
 5870 CONTINUE
      IF(IFC.GT.0) GO TO 5690
 5880 IF(NUPST(M).LE.0.OR.IRES(M).GT.0) GO TO 5900
      QASUM=0.
      ITMP=NUPST(M)
      DO 5890 ITP=1,ITMP
      IRA=IUPST(M,ITP)
      QASUM=QASUM+QA(I,IRA)
 5890 CONTINUE
      QA(I,M)=QL(I,M)-QDIVR(M)+QASUM
      IF(QA(I,M).GE.0..OR.IDIV(M).LE.0) GO TO 5900
C                DIVERSION SHORTAGE
      ID=IDIV(M)
      QDIVA(I,ID)=QDIVA(I,ID)+QA(I,M)
      QDIVR(M)=QDIVR(M)+QA(I,M)
      QA(I,M)=0.
      QCONS(I,M)=0.
C                DO LOOP STARTS AT 5150+1
 5900 CONTINUE
C =N=        COMPUTE FLOWS AND STORAGES * * * * * * * * * * * * * * * * *
      DO 6050 MX=1,NCPT
      M= ICPT(MX)
      QPREP(I,M)=QL(I,M)
      QI(I,M) = QL(I,M)-QDIVR(M)
      TEMP = 0.
      ID=IDIV(M)
      IF (ID) 5910,5930,5920
 5910 ID=(-ID)
 5920 QI(I,M)=QI(I,M)+QDIVA(I,ID)
      TEMP = QDIVA(I,ID)
 5930 IF (NUPST(M).LE.0) GO TO 5950
      NR= NUPST(M)
      DO 5940 K=1,NR
      IR = IUPST(M,K)
      QPREP(I,M) = QPREP(I,M)+QPREP(I,IR)
 5940 QI(I,M) = QI(I,M)+QA(I,IR)
      IF(IRES(M).LE.0) QA(I,M)=QI(I,M)-TEMP
 5950 IF (IRES(M).LE.0) GO TO 6050
      STORB(I,M) = STORA(M)-EVTMP(M)+(QI(I,M)-QA(I,M)-TEMP)*CQS
C          ELIMINATE POSSIBLE NEGATIVE STORAGES
      IF (STORB(I,M).GT.(-.1)) GO TO 5960
      EVTMP(M)=EVTMP(M)+STORB(I,M)
      STORB(I,M) = 0.
 5960 STRAV(M) = (STORA(M)+STORB(I,M))*.5
      DO 5970 K=2,10
      IF (STORB(I,M).LE.STOR(M,K)) GO TO 5980
 5970 CONTINUE
      K = 10
 5980 TEMP = 0.
      IF(STOR(M,K).GT.STOR(M,K-1))
     1TEMP = (STORB(I,M)-STOR(M,K-1))/(STOR(M,K)-STOR(M,K-1))
      ELEV(I,M) = EL(M,K-1)*(1.-TEMP)+EL(M,K)*TEMP
      IF (IPWR(M).LE.0) GO TO 6050
      IP=IPWR(M)
      POWRP(I,IP)=PWRMX(IP)*OVLOD(IP)
      IF(IPWPK.LE.0) GO TO 6050
      IF(IPOW(M).GT.1) GO TO 6010
      DO 5990 K=2,10
```

```
      IF (STRAV(M).LE.CQOEL(IP,K)) GO TO 6000
 5990 CONTINUE
      K=10
 6000 TEMP=0.
      IF (CQOEL(IP,K).GT.CQOEL(IP,K-1))
     1 TEMP=(STRAV(M)-CQOEL(IP,K-1))/(CQOEL(IP,K)-CQOEL(IP,K-1))
      GO TO 6040
 6010 DO 6020 K=2,10
       IF (QA(I,M).LE.CQOEL(IP,K)) GO TO 6030
 6020 CONTINUE
      K=10
 6030 TEMP=0.
      IF (CQOEL(IP,K).GT.CQOEL(IP,K-1))
     1 TEMP=(QA(I,M)-CQOEL(IP,K-1))/(CQOEL(IP,K)-CQOEL(IP,K-1))
 6040 POWRP(I,IP)=PKPWR(IP,K-1)*(1.-TEMP)+PKPWR(IP,K)*TEMP
 6050 CONTINUE
C =O=           ALLOCATE CONSERVATION RELEASES TO UPSTREAM RESERVOIRS
      DO 6080 MX=1,NCPT
      ITMP = NCPT-MX+1
      M=ICPT(ITMP)
      IF(QCONS(I,M).GT.QA(I,M)) QCONS(I,M)=QA(I,M)
      IF (NUPST(M).LE.0) GO TO 6080
      NR=NUPST(M)
      TEMP=1.
      IF (IRES(M).LE.0) TEMP=CLOCL
      QAX=0.
      QCX=0.
      DO 6060 K=1,NR
      IR=IUPST(M,K)
      QAX=QAX+QA(I,IR)
 6060 QCX=QCX+QCONS(I,IR)
      IF (QAX.LE.QCX) GO TO 6080
      TMP=(QCONS(I,M)+QDIVR(M)-QL(I,M)*TEMP-QCX)/(QAX-QCX)
      IF (TMP.LE.0.) GO TO 6080
      IF (TMP.GT.1.) TMP=1.
      DO 6070 K=1,NR
      IR=IUPST(M,K)
 6070 QCONS(I,IR)=QCONS(I,IR)+(QA(I,IR)-QCONS(I,IR))*TMP
 6080 CONTINUE
      IF (NPWR.LE.0) GO TO 6100
C              COMPUTE POWER
      DO 6090 IP=1,NPWR
      M = ITPR(IP)
      CPWR=EFY(IP)*CKW
      TEMP=TEAK(M)+.000000001
      IF (QA(I,M).LT.TEMP) QA(I,M)=TEMP
      POWER(I,IP) = CPWR*HEAD(IP)*(QA(I,M)-TEAK(M))
C              USE KW/CFS TABLE
      IF(EFFCY.LT.(-1.5))POWER(I,IP)=(QA(I,M)-TEAK(M))*EFY(IP)
      TMPP(IP)=POWER(I,IP)-.1
      IF(IPWPK.LE.0) GO TO 6090
      IF(POWER(I,IP).GT.POWRP(I,IP)) POWER(I,IP)=POWRP(I,IP)
 6090 POWER(I,IP)=POWER(I,IP)*CNST
 6100 IF(NPWRS.LE.0.OR.NC.GE.NCYCL) GO TO 6220
C =P=           DISTRIBUTE SYSTEM POWER * * * * *
      ITEMP=0
      DO 6210 IX=1,NPWRS
      ITMP=ITEMP+1
      ITEMP=ITEMP+NRESP(IX)
      TMPRS=PWRS(I,IX)
```

```
      DO 6110 L = 1,NL
 6110 PGT(L)=0.
      PGAUT=0.
      PWERT=0.
      POWRT=0.
      DO 6130 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
      PGAU(K)=POWER(I,IP)
      TMP=POWRP(I,IP)*CNST
      TEMP=PWRMX(IP)*PFMAX(IX)*CNST
      IF(TMP.GT.TEMP)TMP=TEMP
      IF(PGAU(K).GT.TMP)PGAU(K)=TMP
      IF(NC.EQ.1) PWER(I,IP)=PGAU(K)
      IF(PWER(I,IP).LT.POWR(I,IP))PWER(I,IP)=POWR(I,IP)
C               SEARCH FOR LEVEL TO DEVELOP SYSTEM POWER
      DO 6120 L=1,NL
      TEMP=POWER(I,IP)*(PG(M,L,IX)-TEAK(M))/(QA(I,M)-TEAK(M))
      IF(TEMP.GT.TMP)TEMP=TMP
      ITP=2
      IF(IPWPR.GT.0) ITP=1
      IF(L.LE.ITP) GO TO 6115
      TMPA=PG(M,ITP,IX)
      IF(TMPA.GT.POWR(I,IP)) TMPA=POWR(I,IP)
      IF(TEMP.LT.TMPA) TEMP=TMPA
 6115 PG(M,L,IX)=TEMP
      PGT(L)=PGT(L)+TEMP
 6120 CONTINUE
      PWERT=PWERT+PWER(I,IP)
      POWRT=POWRT+POWR(I,IP)
 6130 PGAUT=PGAUT+PGAU(K)
      TEMP=0.
      DO 6140 L=2,NL
      IF(TMPRS.LT.PGT(L)) GO TO 6140
      IF(PGT(L).LT.PGT(L-1)) TEMP=(TMPRS-PGT(L))/(PGT(L-1)-PGT(L))
      IF(TEMP.GT.1.)TEMP=1.
      GO TO 6150
 6140 CONTINUE
      L=NL
C =Q=           ASSIGN SYSTEM POWER
 6150 PWERT=0.
      DO 6160 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
      PWER(I,IP)=PG(M,L,IX)*(1.-TEMP)+PG(M,L-1,IX)*TEMP
      PWERT=PWERT+PWER(I,IP)
      IPX(IP)=1
      IF(PWER(I,IP).LT.TMPP(IP))IPX(IX)=0
 6160 CONTINUE
      IF(PWERT.GT.(TMPRS-.01).AND.PWERT.LT.(TMPRS+.01)) GO TO 6210
      TMPA=0.
      TMP=0.
      TEMP=0.
      DO 6170 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
      TMPA=TMPA+PWRMX(IP)*PFMAX(IX)*CNST
      TMP=TMP+POWR(I,IP)
 6170 TEMP=TEMP+PWER(I,IP)
      IF(TEMP.GE.PWRS(I,IX)) GO TO 6190
```

```
      TMP=(PWRS(I,IX)-TEMP)/(TMPA-TEMP)
      IF(TMP.GT.1.)TMP=1.
      DO 6180 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
      PWER(I,IP)=PWRMX(IP)*PFMAX(IX)*CNST*TMP+PWER(I,IP)*(1.-TMP)
      IPX(IP)=1
      IF(PWER(I,IP).LT.TMPP(IP))IPX(IX)=0
 6180 CONTINUE
      GO TO 6210
 6190 TMP=(PWRS(I,IX)-TMP)/(TEMP-TMP)
      IF(TMP.LT.0.)TMP=0.
      DO 6200 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
      PWER(I,IP)=PWER(I,IP)*TMP+POWR(I,IP)*(1.-TMP)
      IPX(IP)=1
      IF(PWER(I,IP).LT.TMPP(IP))IPX(IX)=0
 6200 CONTINUE
 6210 CONTINUE
C           BRANCH BACK FOR SECOND APPROXIMATION  *  *  *  *  *  *  *  *
 6220 IF (NC.LT.NCYCL) GO TO 5090
C =R= COMPUTE POWER, SHORTAGES AND ANNUAL SUMS
      IF (NPWR.LE.0) GO TO 6280
      CTX=1.
      IF(IPWKW.GT.0) CTX=CT
      IF(NPWRS.LE.0) GO TO 6240
      DO 6230 IX=1,NPWRS
 6230 TMPP(IX)=0.
 6240 DO 6250 IP=1,NPWR
      M=IPR(IP)
      IF (POWER(I,IP).GT.PWRMX(IP)*OVLOD(IP)*CNST)
     1 POWER(I,IP)=PWRMX(IP)*OVLOD(IP)*CNST
      SYPWR(IP) = SYPWR(IP)+POWER(I,IP)*CTX
      SYPR(IP) = SYPR(IP)+POWR(I,IP)*CTX
      SYSP(IP)=SYSP(IP)+PWER(I,IP)*CTX
      SHRTP(I,IP) = POWR(I,IP)-POWER(I,IP)
      SYSSP(I,IP)=PWER(I,IP)-POWER(I,IP)
      IF(SYSSP(I,IP).LT.0.)SYSSP(I,IP)=0.
      IF(SYSSP(I,IP).GT..01)NSHPS(M)=NSHPS(M)+1
      IF(SYSSP(I,IP).GT.SPSMX(M))SPSMX(M)=SYSSP(I,IP)
      IF(SHRTP(I,IP).GT.1.)NSHP(M)=NSHP(M)+1
      IF(SHRTP(I,IP).GT.SHPMX(M)) SHPMX(M)=SHRTP(I,IP)
      IF (SHRTP(I,IP).LT.0.) SHRTP(I,IP)=0.
      IX=ISYSR(M)
      IF(IX.LE.0)GO TO 6250
      TMPP(IX)=TMPP(IX)+SHRTP(I,IP)
      SYSYS(IP)=SYSYS(IP)+SYSSP(I,IP)*CTX
 6250 SYSHP(IP) = SYSHP(IP)+SHRTP(I,IP)*CTX
      IF (NPWRS.LE.0) GO TO 6280
      ITEMP=0
      DO 6270 IX=1,NPWRS
      MX=KPWR+IX
      POWER(I,MX)=0.
      PWER(I,MX)=0.
      ITMP = ITEMP+1
      ITEMP=ITEMP+NRESP(IX)
      DO 6260 K=ITMP,ITEMP
      M=IRESP(K)
      IP=IPWR(M)
```

```
      TEMP=POWER(I,IP)
      POWER(I,MX)=POWER(I,MX)+TEMP
      ATMP=PWRMX(IP)*PFMAX(IX)*CNST
      IF(TEMP.GT.ATMP) TEMP=ATMP
      PWER(I,MX)=PWER(I,MX)+TEMP
 6260 CONTINUE
      SYPWR(MX)=SYPWR(MX)+POWER(I,MX)*CTX
      SYPR(MX)=SYPR(MX)+PWRS(I,IX)*CTX
      SHRTP(I,MX)=PWRS(I,IX)-PWER(I,MX)
      IF(SHRTP(I,MX).LT.TMPP(IX))SHRTP(I,MX)=TMPP(IX)
      SYSP(MX)=SYSP(MX)+PWER(I,MX)*CTX
      IF(SHRTP(I,MX).LT.0.) SHRTP(I,MX)=0.
      IF(SHRTP(I,MX).GT.1.)NSRTP(IX)=NSRTP(IX)+1
      IF(SHRTP(I,MX).GT.SYMSP(IX))SYMSP(IX)=SHRTP(I,MX)
      SYSHP(MX)=SYSHP(MX)+SHRTP(I,MX)*CTX
 6270 CONTINUE
C =S=           FLOW AND STORAGE SUMMARY
 6280 DO 6400 MX=1,NCPT
      M= ICPT(MX)
      IF(QA(I,M).GT.QAMX(M))QAMX(M)=QA(I,M)
      IF(QPREP(I,M).GT.QPMX(M))QPMX(M)=QPREP(I,M)
      IF (TRES(M).LE.0) GO TO 6380
      EVP(I,M)=EVTMP(M)
      SYEVP(M) = SYEVP(M)+EVP(I,M)
      STORA(M) = STORB(I,M)
      TMP=1.
      ITP=NFL
      TMPG=STORL(I,M,1)
      IF(NMIN.LE.0) GO TO 6290
      IX=ITP
      ITP=NL
      TMPG=STORL(I,M,IX)
 6290 TEMP=STORL(I,M,ITP)-TMPG
      IF(TEMP.LE.0.) GO TO 6350
      TMP=(STORA(M)-TMPG)/TEMP
      IF(TMP-.7) 6300,6300,6330
 6300 IF(TMP-.4) 6310,6310,6320
 6310 IF(TMP.LE..2) NSTOR(I,M,8)=NSTOR(I,M,8)+1
      IF(TMP.GT..2) NSTOR(I,M,7)=NSTOR(I,M,7)+1
      GO TO 6360
 6320 IF(TMP.LE..6)NSTOR(I,M,6)=NSTOR(I,M,6)+1
      IF(TMP.GT..6)NSTOR(I,M,5)=NSTOR(I,M,5)+1
      GO TO 6360
 6330 IF(TMP-.9) 6340,6340,6350
 6340 IF(TMP.LE..8)NSTOR(I,M,4)=NSTOR(I,M,4)+1
      IF(TMP.GT..8)NSTOR(I,M,3)=NSTOR(I,M,3)+1
      GO TO 6360
 6350 IF(TMP.LE..95)NSTOR(I,M,2)=NSTOR(I,M,2)+1
      IF(TMP.GT..95)NSTOR(I,M,1)=NSTOR(I,M,1)+1
 6360 CNTRL(I,M)=NL
      DO 6370 L=2,NL
      IF(STORA(M).GT.STORL(I,M,L)+.1) GO TO 6370
      CNTRL(I,M) = L-1
      IF (STORL(I,M,L).LE.STORL(I,M,L-1)) GO TO 6380
      AL = L-1
      CNTRL(I,M) = AL+(STORA(M)-STORL(I,M,L-1))/(STORL(I,M,L)-STORL(I,M,
     1 L-1))
      GO TO 6380
 6370 CONTINUE
 6380 SHRTQ(I,M) =QMINA(I,M)-QA(I,M)
```

```
      IF  (SHRTQ(I,M).LT.0.) SHRTQ(I,M)=0.
      IF(SHRTQ(I,M).GT..01)NSHMN(M)=NSHMN(M)+1
      IF(SHRTQ(I,M).GT.SHMX(M))SHMX(M)=SHRTQ(I,M)
      IF(QM2(M).LE.0..AND.QM2(M).GT.(-.5))GO TO 6390
      SHRT2(I,M)=QMIN2(I,M)-QA(I,M)
      IF  (SHRT2(I,M).LT.0.) SHRT2(I,M)=0.
      IF(SHRT2(I,M).GT..01)NSH2(M)=NSH2(M)+1
      IF(SHRT2(I,M).GT.SHMX2(M))SHMX2(M)=SHRT2(I,M)
      SYSH2(M)=SYSH2(M)+SHRT2(I,M)*CT
 6390 SYQL(M)  =  SYQL(M)+QL(I,M)*CT
      SYPREP(M)  =  SYPREP(M)+QPREP(I,M)*CT
      SYQI(M)  =  SYQI(M)+QI(I,M)*CT
      SYQMN(M)  =  SYQMN(M)+QMIN2(I,M)*CT
      SYQ(M)  =  SYQ(M)+QMINA(I,M)*CT
      SYCNS(M)  =  SYCNS(M)+QCONS(I,M)*CT
      SYQA(M)  =  SYQA(M)+QA(I,M)*CT
      SYSHQ(M)  =  SYSHQ(M)+SHRTQ(I,M)*CT
 6400 CONTINUE
      IF  (NDIV.LE.0)  GO  TO 6420
      DO 6410 ID=1,NDIV
      SHDIV(I,ID)=0.
      IF(RTIOD(ID).LT.0.)GO TO 6410
      SHDIV(I,ID)  =  QDIV(I,ID)-QDIVA(I,ID)
      IF  (SHDIV(I,ID).LT.0.)  SHDIV(I,ID)=0.
      SYDV(ID)  =  SYDV(ID)+QDIV(I,ID)*CT
      SYDVA(ID)  =  SYDVA(ID)+QDIVA(I,ID)*CT
      SYSHD(ID)  =  SYSHD(ID)+SHDIV(I,ID)*CT
 6410 CONTINUE
 6420 CONTINUE
      RETURN
      END



      SUBROUTINE ECON
C     ECONOMIC EVALUATION OF MULTI-RESERVOIR OPERATION
      DIMENSION CPT(40,8),ICPT(40),IE(8,40),IRESM(40,30),NRESR(40),
     1PSTOR(12,40,8),QII(12,40),STORL(12,40,8),TMPP(40)
      DIMENSION A(15),BEN(12,8),Q(12),SM(12),V(8,40),
     1VLEFT(8,40),VMAX(8,40),IRES(40),VU(8,40),TMPX(12),IRG(10)
      COMMON/BETA/
     1 NYRS,IRG,CPT,ICPT,IRES,NCPT,NPER,QUNIT,VUNIT,NMIN
      COMMON /BALT/ IECON,IE,IYEAR,NRESR,PSTOR,QII,STORL,TMPP,TMPX
      COMMON /GAMMA/ IRESM
  100 FORMAT(1H1)
  110 FORMAT(1X15A4)
  120 FORMAT (I3,2X,7A4,A2)
  130 FORMAT(1X,I7,I8,8F8.0)
  140 FORMAT(I3,2X15A4)
  150 FORMAT(I3,13F9.0)
  160 FORMAT( 11H STA     SUM 12I9)
  170 FORMAT(/3H SM 13F9.0)
  180 FORMAT (1H+,I3,14F8.1)
C =A=  * * * * JOB AND STATION SPECIFICATION * * * * * * * * * * * * * *
      NL=8
      NE=NL
      WRITE ( 6,100)
      WRITE ( 6,190)
```

```
  190 FORMAT(37H CONTROL POINTS IDENTIFIED AS FOLLOWS )
      DO 200 MX=1,NCPT
      M=ICPT(MX)
  200 WRITE ( 6,120)M,(CPT(M,K),K=1,8)
      WRITE ( 6,210)
  210 FORMAT(40H0BENEFIT FUNCTIONS IDENTIFIED AS FOLLOWS)
      DO 220 J=1,NE
C                                                             **CARD N**
      READ ( 5,110)(A(K),K=1,15)
  220 WRITE ( 6,140)J,(A(K),K=1,15)
C   * * * * * * READ ECONOMIC FUNCTIONS * * * * * * * * * * * * * * * * *
      NEA=0
      DO 630 J=1,NE
      IYRA=IYEAR
      REWIND 9
      WRITE ( 6,230)J
  230 FORMAT(/22H FUNCTIONS FOR BENEFIT I2)
      JTMP=0
      DO 280 MX=1,NCPT
      M=ICPT(MX)
      V(J,M)=0.
      VU(J,M)=0.
      VMAX(J,M)=0.
      VLEFT(J,M)=0.
      IF(IF(J,M).LE.0) GO TO 280
      JTMP=1
      MTH=0
      DO 270 I=1,NPER
      IF(I.LE.MTH) GO TO 270
C                                                             **CARD N1**
      READ ( 5,130) ITMP,   MTH,(STORL(I,M,L),L=1,NL)
      IF(M.NE.ITMP) GO TO 890
      WRITE ( 6,130)ITMP,   MTH,(STORL(I,M,L),L=1,NL)
C                                                             **CARD N2**
      READ ( 5,130) ITMP,   MTH,(PSTOR(I,M,L),L=1,NL)
      IF(M.NE.ITMP) GO TO 890
      WRITE ( 6,130)ITMP,   MTH,(PSTOR(I,M,L),L=1,NL)
      TMP=0.
      DO 240 L=1,NL
      IF(PSTOR(I,M,L).GT.TMP)TMP=PSTOR(I,M,L)
  240 CONTINUE
      VMAX(J,M)=VMAX(J,M)+TMP
      IF(MTH.LE.I) GO TO 270
      ITP=I+1
      DO 260 IX=ITP,MTH
      VMAX(J,M)=VMAX(J,M)+TMP
      DO 250 L=1,NL
      STORL(IX,M,L)=STORL(I,M,L)
  250 PSTOR(IX,M,L)=PSTOR(I,M,L)
  260 CONTINUE
  270 CONTINUE
      TEMP=NYRS
      VLEFT(J,M)=VMAX(J,M)*TEMP
  280 CONTINUE
      IF(JTMP.EQ.1) GO TO 300
      WRITE ( 6,290)
  290 FORMAT(5H NONE)
      GO TO 630
C =B=  * * * * COMPUTE BENEFIT VALUES  * * * * * * * * * * * * * * * * *
  300 DO 620 IY=1,NYRS
```

```
      IF(IFCON.LE.1.OR.NMIN.GT.0) GO TO 340
      WRITE ( 6,310)IYRA,J
  310 FORMAT(/39X,32HMONTHLY UNALLOCATED BENEFITS FOR I5,10H, FUNCTION
     1 I2)
      WRITE ( 6,320)(I,I=1,NPER)
  320 FORMAT (4H+STA 14I8)
      WRITE ( 6,330)
  330 FORMAT (119X,5HTOTAL)
  340 SUMA=0.
      DO 350 I=1,NPER
  350 SM(I)=0.
      DO 590 MX=1,NCPT
      M=ICPT(MX)
      ITMP=NRESR(M)
      IF(ITMP.LE.0) GO TO 370
      DO 360 K=1,ITMP
  360 READ (9)  (QII(I,K),I=1,NPER)
      READ (9)  (TMPX(I),I=1,NPER)
  370 DO 580 ITP=1,NE
      IF(IF(ITP,M).LE.0) GO TO 580
C =C=             FIRST PASS THRU ROUTINE
      IB=-1
      SUM=0.
      GO TO 410
  380 IB=0
      DO 390 I=1,NPER
      Q(I)=Q(I)-TMPX(I)
  390 CONTINUE
      GO TO 420
  400 IB=1
  410 READ (9)  (Q(I),I=1,NPER)
      IF(ITP.EQ.J) GO TO 420
      IF(IF(ITP,M).EQ.1)READ (9)(Q(I),I=1,NPER)
      GO TO 580
  420 DO 500 I=1,NPER
      DO 430 L=2,NL
      IF(STORL(I,M,L-1).GT.STORL(I,M,L))GO TO 440
      IF(Q(I)-STORL(I,M,L)) 450,450,430
  430 CONTINUE
      L=NL
      GO TO 450
  440 L=L-1
  450 TMP=1.
      IF(STORL(I,M,L-1).LT.STORL(I,M,L))
     1TMP=(Q(I)-STORL(I,M,L-1))/(STORL(I,M,L)-STORL(I,M,L-1))
      TMPP(I)=PSTOR(I,M,L-1)*(1.-TMP)+PSTOR(I,M,L)*TMP
C              IB=-1 REG,IB=0 NO RES,IB=1 NO RES OR DIV
      IF  (IB) 460,470,480
  460 IF(NMIN.GT.0) GO TO 490
      V(J,M)=V(J,M)+TMPP(I)
      VU(J.M)=VU(J.M)+TMPP(I)
      BEN(I,J)=TMPP(I)
      SUM=SUM+TMPP(I)
      SM(I)=SM(I)+TMPP(I)
      VLEFT(J,M)=VLEFT(J,M)-TMPP(I)
      GO TO 500
  470 IF(NMIN.GT.0) GO TO 500
      BEN(I,J)=BEN(I,J)-TMPP(I)
      GO TO 500
  480 IF(NMIN.GT.0) GO TO 485
```

```
      BEN(I,J)=BEN(I,J)-TMPP(I)
      SUM=SUM-TMPP(I)
      SM(I)=SM(I)-TMPP(I)
      V(J,M)=V(J,M)-TMPP(I)
      VU(J.M)=VU(J,M)-TMPP(I)
      GO TO 500
  485 IF(V(J,M).LT.TMPP(I))V(J,M)=TMPP(I)
      GO TO 500
  490 IF(VU(J,M).LT.TMPP(I)) VU(J,M)=TMPP(I)
  500 CONTINUE
  510 IF (IE(J,M).NE.1) GO TO 520
      IF (IB) 380,550,520
  520 IF(IFCON.LE.1.OR.NMIN.GT.0) GO TO 540
      WRITE ( 6,180) M,(BEN(I,J),I=1,NPER)
      WRITE ( 6,530) SUM
  530 FORMAT (116X,F9.1)
  540 SUMA=SUMA+SUM
      GO TO 580
  550 ITMP=NRESR(M)
      IF(ITMP.LE.0.OR.NMIN.GT.0) GO TO 400
      DO 570 I=1,NPER
      DO 560 K=1,ITMP
      IR=IRESM(M,K)
      IF(IR.LT.0)IR=-IR
  560 V(J,IR)=V(J,IR)+BEN(I,J)*QII(I,K)
      V(J,M)=V(J,M)-BEN(I,J)
      BEN(I,J)=BEN(I,J)+TMPP(I)
  570 CONTINUE
      GO TO 400
  580 CONTINUE
  590 CONTINUE
      IF(IFCON.LE.1.OR.NMIN.GT.0) GO TO 610
      WRITE ( 6,600)(SM(I),I=1,NPER)
  600 FORMAT (/1H+,3HTOT,14F8.1)
      WRITE ( 6,530) SUMA
  610 IYRA=IYRA+1
  620 CONTINUE
      IF(NEA.LT.J)NEA=J
  630 CONTINUE
      NE=NEA
C =D=  * * * * PRINT RESULTS * * * * * * * * * * * * * * * * * * * * * * * * *
      WRITE ( 6,100)
      IF(NMIN.GT.0) GO TO 660
      WRITE ( 6,640)
  640 FORMAT(20X43HAVERAGE ANNUAL BENEFITS IN THOUSAND DOLLARS)
      WRITE ( 6,650)
  650 FORMAT (/27X,34HPROJECT BENEFITS AT CONTROL POINTS)
      GO TO 680
  660 WRITE ( 6,670)
  670 FORMAT(//21X,41HDAMAGES IN THOUSAND DOLLARS WITH PROJECTS)
  680 WRITE ( 6,730)
      WRITE ( 6,160)(J,J=1,NE)
      DO 690 J=1,NE
  690 SM(J)=0.
      SUMA=0.
      TMP=NYRS
      TMP=1./TMP
      IF(NMIN.GT.0) TMP=1.
      DO 710 MX=1,NCPT
      M=ICPT(MX)
```

```
      SUM=0.
      DO 700 J=1,NE
      IF(IF(J,M).LE.0) GO TO 700
      VU(J,M)=VU(J,M)*TMP
      SM(J)=SM(J)+VU(J,M)
      SUM=SUM+VU(J,M)
  700 CONTINUE
      WRITE ( 6,150)M,SUM,(VU(J,M),J=1,NE)
  710 SUMA=SUMA+SUM
      WRITE ( 6,170)SUMA,(SM(J),J=1,NE)
      IF(NMIN.GT.0) GO TO 722
      WRITE ( 6,720)
  720 FORMAT (/22X,40HPROJECT BENEFITS ALLOCATED TO RESERVOIRS)
      GO TO 726
  722 WRITE(6,724)
  724 FORMAT(/20X,44HDAMAGES IN THOUSAND DOLLARS WITHOUT PROJECTS)
  726 WRITE(6,730)
  730 FORMAT(38X 8HFUNCTION)
      WRITE ( 6,160)(J,J=1,NE)
      DO 740 J=1,NE
  740 SM(J)=0.
      SUMA=0.
      DO 760 MX=1,NCPT
      M=ICPT(MX)
      SUM=0.
      DO 750 J=1,NE
      V(J,M)=V(J,M)*TMP
      VLEFT(J,M)=VLEFT(J,M)*TMP
      SM(J)=SM(J)+V(J,M)
      SUM=SUM+V(J,M)
  750 CONTINUE
      WRITE ( 6,150)M,SUM,(V(J,M),J=1,NE)
  760 SUMA=SUMA+SUM
      WRITE ( 6,170)SUMA,(SM(J),J=1,NE)
      IF(NMIN.GT.0) RETURN
      WRITE ( 6,770)
  770 FORMAT(/17X,50HPROJECT PLUS PREPROJECT BENEFITS AT CONTROL POINTS)
      WRITE ( 6,730)
      WRITE ( 6,160) (J,J=1,NE)
      DO 780 J=1,NE
  780 SM(J)=0.
      SUMA=0.
      DO 800 MX=1,NCPT
      M=ICPT(MX)
      SUM=0.
      DO 790 J=1,NE
      V(J,M)=VMAX(J,M)-VLEFT(J,M)
      SM(J)=SM(J)+V(J,M)
      SUM=SUM+V(J,M)
  790 CONTINUE
      WRITE ( 6,150)M,SUM,(V(J,M),J=1,NE)
  800 SUMA=SUMA+SUM
      WRITE ( 6,170)SUMA,(SM(J),J=1,NE)
      WRITE ( 6,810)
  810 FORMAT (/21X,42HTOTAL POTENTIAL BENEFITS AT CONTROL POINTS)
      WRITE ( 6,730)
      WRITE ( 6,160) (J,J=1,NE)
      DO 820 J=1,NE
  820 SM(J)=0.
      SUMA=0.
```

```
      DO 840 MX=1,NCPT
      M=ICPT(MX)
      SUM=0.
      DO 830 J=1,NE
      SM(J)=SM(J)+VMAX(J,M)
      SUM=SUM+VMAX(J,M)
  830 CONTINUE
      WRITE ( 6,150)M,SUM,(VMAX(J,M),J=1,NE)
  840 SUMA=SUMA+SUM
      WRITE ( 6,170)SUMA,(SM(J),J=1,NE)
      WRITE ( 6,850)
  850 FORMAT (/19X,46HREMAINING POTENTIAL BENEFITS AT CONTROL POINTS)
      WRITE ( 6,730)
      WRITE ( 6,160)  (J,J=1,NE)
      DO 860 J=1,NE
  860 SM(J)=0.
      SUMA=0.
      DO 880 MX=1,NCPT
      M=ICPT(MX)
      SUM=0.
      DO 870 J=1,NE
      SM(J)=SM(J)+VLEFT(J,M)
      SUM=SUM+VLEFT(J,M)
  870 CONTINUE
      WRITE ( 6,150)M,SUM,(VLEFT(J,M),J=1,NE)
  880 SUMA=SUMA+SUM
      WRITE ( 6,170)SUMA,(SM(J),J=1,NE)
      RETURN
  890 WRITE ( 6,900)
  900 FORMAT(13H WRONG STA NO)
      RETURN
      END
      SUBROUTINE REARNG
C     SUMMARY OF OUTPUT FROM PROG 723-X6-L2030
      DIMENSION  IZERO(5),IONE(5),ITWO(5),JZERO(5),JONE(5),JTWO(5),
     1 KZERO(5),KONE(5),KTWO(5),NFMT(5),APRD(12),APERD(12),TITLE(60)
      DIMENSION  IDIV(40),QM2(40),IRES(40),IPWR(40),CPT(40,8)
      DIMENSION  ARRAY(12,40,2),AVG(40,30),SYQI(40),QI(12,40),
     1 STORB(12,30),ELEV(12,30),SYEVP(30),EVP(12,30),SYPWR(22),
     2 POWER(12,22),SYSHP(22),SHRTP(12,22),SYPMX(22),POWRP(12,20),
     3 SYQA(40),QA(12,40),ICPT(40)
      COMMON /ALPHA/
     1 APERD,APRD,IDIV,IPWR,IYR ,KCPT,KDIV,KPWR,KRES,NPWR,NRES,QM2,
     2 TITLE,IPWKW
      COMMON/BETA/
     1 NYRS,I1,I2,I3,I4,I5,I6,I7,I8,I9,I10,CPT,ICPT,IRES,NCPT,NPER,
     2 QUNIT,VUNIT
      COMMON/DELTA/
     1 ARRAY,SYQI,QI,STORB,ELEV,SYEVP,EVP,SYPWR,POWER,SYSHP,SHRTP,
     2 SYPMX,POWRP,SYQA,QA
C             I1 -- UNREGULATED FLOWS
C             I2 -- RIVER FLOWS
C             I3 -- DIVERSION
C             I4 -- DIVERSION SHORTAGE
C             I5 -- DESIRED-FLOW SHORTAGE
C             I6 -- MINIMUM-FLOW SHORTAGE
C             I7 -- END-OF-PERIOD STORAGE
C             I8 -- CHANGE IN STORAGE AT END OF PERIOD
C             I9 -- END-OF-PERIOD ELEVATION
C             I10-- RESERVOIR DATA
```

```
      COMMON /GAMMA/ AVG
      DATA IZERO/18H(1H+,I6,2X,14F8.0)/,IONE/18H(1H+,I6,2X,14F8.1)/,
     1       ITWO/18H(1H+,I6,2X,14F8.2)/
      DATA JZERO/11H(120X,F8.0)/,JONE/11H(120X,F8.1)/,
     1       JTWO/11H(120X,F8.2)/
      DATA KZERO/20H(9H+AVERAGE ,14F8.0)/,KONE/20H(9H+AVERAGE ,14F8.1)/,
     1       KTWO/20H(9H+AVERAGE ,14F8.2)/
      DATA NFMT/20H(9H+   SUM  ,14F8.0)/
  100 FORMAT (1H1)
  110 FORMAT (1X,I7,9I8)
  120 FORMAT (23X,A2,19A4)
      WRITE ( 6,100)
      ICND=0
      IF (NYRS.LE.50) GO TO 140
      NYRS=50
      WRITE ( 6,130)
  130 FORMAT (45H 50 YEAR LIMIT - REARRANGES FIRST 50 YRS ONLY///)
  140 IF (T1.LE.0) GO TO 170
      CALL BINTP (ICND,KCPT)
  150 WRITE ( 6,120) TITLE
      WRITE ( 6,160)QUNIT
  160 FORMAT(/47X,22H UNREGULATED FLOWS IN A4)
      CALL OUTPT (I1,1,IZERO,JZERO,KZERO)
      IF (T1.LE.2) GO TO 170
      I1=2
      GO TO 150
  170 IF (T2.LE.0) GO TO 200
      CALL BINTP (ICND,KCPT)
  180 WRITE ( 6,120) TITLE
      WRITE ( 6,190)QUNIT
  190 FORMAT(/45X,27H RIVER FLOW (REGULATED) IN A4)
      CALL OUTPT (I2,1,IZERO,JZERO,KZERO)
      IF (T2.LE.2) GO TO 200
      I2=2
      GO TO 180
  200 IF (T3.LE.0) GO TO 230
      CALL BINTP (ICND,KDIV)
  210 WRITE ( 6,120) TITLE
      WRITE ( 6,220)QUNIT
  220 FORMAT(/51X,14H DIVERSION IN A4)
      CALL OUTPT (I3,2,IONE,JONE,KONE)
      IF (T3.LE.2) GO TO 230
      I3=2
      GO TO 210
  230 IF (T4.LE.0) GO TO 260
      CALL BINTP (ICND,KDIV)
  240 WRITE ( 6,120) TITLE
      WRITE ( 6,250)QUNIT
  250 FORMAT(/47X,23H DIVERSION SHORTAGE IN A4)
      CALL OUTPT (I4,2,IONE,JONE,KONE)
      IF (T4.LE.2) GO TO 260
      I4=2
      GO TO 240
  260 IF (T5.LE.0) GO TO 290
      CALL BINTP (ICND,KCPT)
  270 WRITE ( 6,120) TITLE
      WRITE ( 6,280)QUNIT
  280 FORMAT(/46X,26H DESIRED FLOW SHORTAGE IN A4)
      CALL OUTPT (I5,1,IZERO,JONE,KZERO)
      IF (T5.LE.2) GO TO 290
```

```
      I5=2
      GO TO 270
  290 IF (I6.LE.0) GO TO 320
      CALL BINTP (ICND,KCPT)
  300 WRITE ( 6,120) TITLE
      WRITE ( 6,310)QUNIT
  310 FORMAT(/46X,26H MINIMUM FLOW SHORTAGE IN A4)
      CALL OUTPT (I6,3,IZERO,JONE,KZERO)
      IF (I6.LE.2) GO TO 320
      I6=2
      GO TO 300
  320 IF (NRES.LE.0) RETURN
      IF (I7.LE.0) GO TO 350
      CALL BINTP (ICND,KRES)
  330 WRITE ( 6,120) TITLE
      WRITE ( 6,340)VUNIT
  340 FORMAT(/43X,26H END OF PERIOD STORAGE IN A4)
      CALL OUTPT (I7,5,IZERO,JZERO,KZERO)
      IF (I7.LE.2) GO TO 350
      I7=2
      GO TO 330
  350 IF (I8.LE.0) GO TO 430
      IF(I7.LE.0) CALL BINTP(ICND,KRES)
      DO 370 J=2,NYRS
      DO 360 MX=1,NCPT
      M=ICPT(MX)
      IF(IRES(M).LE.0) GO TO 360
      AVG(M,J)=ARRAY(NPER,M,J-1)
  360 CONTINUE
  370 CONTINUE
      DO 400 J=1,NYRS
      DO 390 MX=1,NCPT
      M=ICPT(MX)
      IF (IRES(M).LE.0) GO TO 390
      TMP=AVG(M,J)
      AVG(M,J)=ARRAY(NPER,M,J)-TMP
      DO 380 I=1,NPER
      TEMP=ARRAY(I,M,J)
      ARRAY(I,M,J)=TEMP-TMP
      TMP=TEMP
  380 CONTINUE
  390 CONTINUE
  400 CONTINUE
  410 WRITE ( 6,120) TITLE
      WRITE ( 6,420)VUNIT
  420 FORMAT(/46X,19H STORAGE CHANGE IN A4)
      CALL OUTPT (I8,4,IZERO,JZERO,NFMT)
      IF (I8.LE.2) GO TO 430
      I8=2
      GO TO 410
  430 IF (I9.LE.0) GO TO 470
      CALL BINTP (ICND,KRES)
  440 WRITE ( 6,120) TITLE
      WRITE ( 6,450)
  450 FORMAT(/45X,32H END OF PERIOD ELEVATION IN FEET)
      CALL OUTPT (I9,5,ITWO,JTWO,KTWO)
      IF (I9.LE.2) GO TO 470
      I9=2
      GO TO 440
  460 FORMAT(/52X,15H RESERVOIR DATA )
```

```
470 IF(I10.LE.0) RETURN
    WRITE ( 6,120)TITLE
    WRITE ( 6,460)
    DO 670 MX=1,NCPT
    M=ICPT(MX)
    IF(IRES(M).LE.0) GO TO 670
    IYEAR=IYR
    GO TO (490,480),I10
480 IF(IPWR(M).LE.0) GO TO 670
490 REWIND 7
    WRITE ( 6,500) M,(CPT(M,I),I=1,8)
500 FORMAT(/I4,2X,7A4,A2)
    IF(IPWKW.LE.0) GO TO 520
    WRITE ( 6,510)
510 FORMAT(/13X,77H MONTH     STORAGE     ELEV       INFLOW    OUTFLOW
   1 EVAP      AVG GEN     GEN PK/23X,68H AC-FT         FT          CFS
   2CFS        AC-FT     MEGAWATT   KILOWATT )
    GO TO 540
520 WRITE ( 6,530)
530 FORMAT(/13X,77H MONTH     STORAGE     ELEV       INFLOW    OUTFLOW
   1 EVAP      GEN PWR            /23X,68H AC-FT         FT          CFS
   2CFS        AC-FT     1000 KWH              )
540 DO 660 J=1,NYRS
    READ(7)SYQI,QI,STORB,ELEV,SYEVP,EVP,SYPWR,POWER,SYSHP,SHRTP,SYPMX,
   1POWRP,SYQA,QA
    WRITE ( 6,550)IYEAR
550 FORMAT(/3H+YR,I5)
    IF(IPWR(M).LE.0) GO TO 620
    K=IPWR(M)
    IF(IPWKW.LE.0) GO TO 590
    SYPWR(K)=SYPWR(K)*.1141
    SYSHP(K)=SYSHP(K)*.1141
    DO 560 I=1,NPER
    POWER(I,K)=POWER(I,K)*0.001
560 CONTINUE
    SYPWR(K)=SYPWR(K)*0.001
    WRITE ( 6,570) (APERD(I),APRD(I),STORB(I,M),ELEV(I,M),QI(I,M),QA(I
   1,M),EVP(I,M),POWER(I,K),POWRP(I,K),I=1,NPER)
570 FORMAT(10X,2A4,F12.0,F10.2,F10.0,F9.0,F8.0,F12.2,F10.0)
    WRITE ( 6,580) SYQI(M),SYQA(M),SYEVP(M),SYPWR(K),SYPMX(K)
580 FORMAT(13X,5H YEAR 22X,F10.0,F9.0,F8.0,F12.2,F10.0)
    GO TO 640
590 WRITE ( 6,600) (APERD(I),APRD(I),STORB(I,M),ELEV(I,M),QI(I,M),QA(I
   1,M),EVP(I,M),POWER(I,K),I=1,NPER)
600 FORMAT(10X,2A4,F12.0,F10.2,F10.0,F9.0,F8.0,F12.0)
    WRITE ( 6,610) SYQI(M),SYQA(M),SYEVP(M),SYPWR(K)
610 FORMAT(13X,5H YEAR 22X,F10.0,F9.0,F8.0,F12.0)
    GO TO 640
620 DO 630 I=1,NPER
    WRITE ( 6,600) APERD(I),APRD(I),STORB(I,M),ELEV(I,M),QI(I,M),QA(I,
   1M), EVP(I,M)
630 CONTINUE
    WRITE ( 6,610) SYQI(M),SYQA(M),SYEVP(M)
640 IYEAR=IYEAR+1
650 CONTINUE
660 CONTINUE
670 CONTINUE
    RETURN
    END
```

```
      SUBROUTINE OUTPT (IND,ITST,IFMT,JFMT,KFMT)
      DIMENSION APERD(12),APRD(12),ARRAY(12,40,2),AVE(12),AVG(40,30),
     1 CPT(40,8),IFMT(5),IPWR(40),IRES(40),JFMT(5),KFMT(5),QM2(40),
     2 ICPT(40),IDIV(40),TITLE(60),IRG(10)
      COMMON /ALPHA/
     1 APERD,APRD,IDIV,IPWR,IYR ,KCPT,KDIV,KPWR,KRES,NPWR,NRES,QM2,
     2 TITLE,IPWKW
      COMMON/BETA/
     1 NYRS,IRG,CPT,ICPT,IRES,NCPT,NPER
      COMMON /DELTA/ ARRAY
      COMMON /GAMMA/ AVG
  100 FORMAT (1H1)
  110 FORMAT(1H )
  120 FORMAT (/8H+  YEAR ,28A4)
  130 FORMAT (124X,4H AVG)
  140 FORMAT (/I4,2X,7A4,A2//)
  150 FORMAT (/5H YEAR,I5)
  160 FORMAT (/8H+  CP NO,28A4)
  170 FORMAT (122X,6H TOTAL)
      ANYRS=NYRS
      GO TO (180,340,180),IND
  180 DO 330 MX=1,NCPT
      M=ICPT(MX)
      GO TO (220,190,210,200,200),ITST
  190 IF(IDIV(M)) 220,330,220
  200 IF (IRES(M)) 330,330,220
  210 IF (QM2(M).LE.0..AND.QM2(M).GT.(-.1)) GO TO 330
  220 WRITE ( 6,140) M,(CPT(M,K),K=1,8)
      WRITE ( 6,120) (APERD(I),APRD(I),I=1,NPER)
      IF (ITST.EQ.4) GO TO 240
      IF(ITST.EQ.5) GO TO 230
      IF(ITST.EQ.2)M=IABS(IDIV(M))
      WRITE ( 6,130)
      GO TO 250
  230 WRITE ( 6,110)
      GO TO 250
  240 WRITE ( 6,170)
  250 DO 260 I=1,NPER
  260 AVE(I)=0.
      TAVE = 0.
      IYEAR = IYR
      DO 290 J=1,NYRS
      WRITE(6,IFMT)IYEAR,(ARRAY(I,M,J),I=1,NPER)
      IYEAR=IYEAR+1
      DO 270 I=1,NPER
  270 AVE(I)=AVE(I)+ARRAY(I,M,J)
      IF (ITST.EQ.5) GO TO 280
      WRITE(6,JFMT)AVG(M,J)
      TAVE = TAVE+AVG(M,J)
      GO TO 290
  280 WRITE ( 6,110)
  290 CONTINUE
      IF (ITST.EQ.4) GO TO 310
      DO 300 I=1,NPER
  300 AVE(I)=AVE(I)/ANYRS
  310 WRITE(6,KFMT)(AVE(I),I=1,NPER)
```

```
      TAVE = TAVE/ANYRS
      IF (ITST.EQ.5) GO TO 320
      WRITE(6,JFMT)TAVE
      GO TO 330
  320 WRITE ( 6,110)
  330 CONTINUE
      WRITE ( 6,100)
      RETURN
  340 IYEAR=IYR
      DO 440 J=1,NYRS
      WRITE ( 6,150) IYEAR
      WRITE ( 6,160) (APERD(I),APRD(I),I=1,NPER)
      IF(ITST.EQ.5) GO TO 350
      WRITE ( 6,130)
      GO TO 360
  350 WRITE ( 6,110)
  360 DO 430 MX=1,NCPT
      M=ICPT(MX)
      GO TO (400,370,390,380,380),ITST
  370 IF(IDIV(M)) 410,430,410
  380 IF (TRES(M)) 430,430,400
  390 IF (QM2(M).LE.0..AND.QM2(M).GT.(-1.)) GO TO 430
  400 PRINT IFMT,M,(ARRAY(I,M,J),I=1,NPER)
      IF (ITST.EQ.5) GO TO 420
      WRITE(6,JFMT)AVG(M,J)
      GO TO 430
  410 M=IABS(IDIV(M))
      WRITE(6,IFMT)ICPT(MX),(ARRAY(I,M,J),I=1,NPER)
      WRITE(6,JFMT)AVG(M,J)
      GO TO 430
  420 WRITE(6,110)
  430 CONTINUE
      IYEAR=IYEAR+1
  440 CONTINUE
      WRITE(6,100)
      RETURN
      END


      SUBROUTINE BINTP(ICND,LMT)
      DIMENSION  IRG(10),IND(9),ARRAY(12,40,2),AVG(40,30)
      COMMON/BETA/NYRS,IRG
      COMMON/DELTA/ARRAY
      COMMON/GAMMA/AVG
      IF(ICND.EQ.1)GO TO 130
      DO 100 I=1,9
  100 IND(I)=0
      ID=0
      DO 110 I=1,6
      IF(IRG(I).LE.0)GO TO 110
      ID=ID+1
      IND(I)=ID
  110 CONTINUE
      IF(IRG(7).LE.0.AND.IRG(8).LE.0) GO TO 120
      ID=ID+1
      IND(7)=ID
  120 IF(IRG(9).LE.0)GO TO 130
```

```
      ID=ID+1
      IND(9)=ID
  130 DO 140 I=1,6
      IF(IRG(I).GT.0.AND.IND(I).GT.0)GO TO 160
  140 CONTINUE
      IF((IRG(7).LE.0.AND.IRG(8).LE.0).OR.IND(7).LE.0)GO TO 150
      I=7
      GO TO 160
  150 IF(IRG(9).LE.0.OR.IND(9).LE.0)RETURN
      I=9
  160 IDN=0
      IDNN=ID-IND(I)
      IF(ICND.EQ.0) GO TO 180
      DO 170 J=1,I
      IF(IRG(J).GT.0.AND.IND(J).EQ.0)IDN=IDN+1
  170 CONTINUE
      IF(I.EQ.9.AND.IRG(7).GT.0.AND.IRG(8).GT.0)IDN=IDN-1
  180 IND(I)=0
      REWIND 10
      DO 240 J=1,NYRS
      IF(ICND.EQ.0) GO TO 200
      DO 190 K=1,IDN
  190 READ(10)
  200 IF(I.EQ.9)GO TO 210
      READ(10)(AVG(M,J),M=1,LMT),((ARRAY(K,M,J),K=1,12),M=1,LMT)
      GO TO 220
  210 READ(10)((ARRAY(K,M,J),K=1,12),M=1,LMT)
  220 IF(IDNN.EQ.0)GO TO 240
      DO 230 K=1,IDNN
      READ(10)
  230 CONTINUE
  240 CONTINUE
      ICND=1
      RETURN
      END
```

EXHIBIT 4

HEC-3
RESERVOIR SYSTEM ANALYSIS

INPUT DATA[a] - 723-X6-L2030

A. Three Output Title Cards (columns 1 & 2 blank)

B. Job Specification (all integer numbers)

1. NYRS - Number of years of routing. Where NMIN (B-22) is positive, NYRS is number of groups of NPER (B-3) intervals needed in run.
2. IYR - Number of first year of routing (1926, for example), use 1 if NMIN is positive.
3. NPER - Number of routing periods per year (months, irregular intervals, etc.; dim 12; 14 max for good output format).
4. IPERA - Number of first routing period in year (10 for October, 1 for January, for example); starting time in hours at most downstream location if NMIN (B-22) is positive.
5. NRES - Number of reservoirs in system (dim. 30).
6. NCPT - Number of control points, including reservoirs (dim. 40).
7. NDIV - Number of diversions in system including return flows (dim. 25).
8. NL - Number of storage balancing levels (dim. 8).
9. NPWR - Number of power plants in reservoir system (dim. 18).
10. NFLOW - Number of locations for which inflows are provided (dim. 40).
11. NSHR - Number of reservoirs whose storages are added for shortage declaration.
12. NSHQ - Number of control points at which flow shortage is declared.
13. NSHDV - Number of diversions at which shortage is declared.
14. NSPER - Duration of declared shortage as number of routing periods (up to 1 year).
15. ISPER - Identification number of first shortage period, at the start of which storages are added for shortage declaration criterion (6 for June 1, in a monthly routing, for example).
16. ISMRY - Positive value will rearrange output by items (see last item page 2 of this exhibit).
17. NPWRS - Number of power systems for which total requirements exceed sum of plant requirements (dim. 2).
18. NLYR - Total number of storage levels at all reservoirs to be changed each year
19. NDVYR - Number of diversions for which requirements will be changed each year.
20. NQYR - Number of control points for which desired flows will be changed each year.
21. NLF - Number of storage balancing levels used in the flood control space.
22. NMIN - Number of minutes in each computation interval. Leave blank for long - interval routing where NDAYS (D cards) is specified.

[a]All data (except M card) are read using 10 fields of 8 columns each except that column 1 of each card is reserved for identification of the card (A-N, 1-0), so first item on each card is limited to 7 columns.

Legend: (A-2) - Second field on A card
D2 - "2" card following D card

23. IFLOW - Control point number for location where maximum yield is to be computed by iteration process.
24. ICONS - Zero or negative value restricts conservation releases to channel capacities; positive value overrides channel capacities.
25. METRC - Positive value calls for metric units in input and output.
26. IUNIT - Positive value allows use of nonstandard output units of flow and storage as specified on C1 cards.
27. IPWPR - Negative if power shortages are to be declared when operating in buffer zone above minimum pool.
28. IPRNT - Negative value causes suppression of monthly and annual printout.
29. IUPDT - Positive value causes complete revised set of system data to be read at the end of NYRS (B-1) of routing and continuation of routing with updated system data.
30. IDGST - Indicator, when positive, causes diagnostic printout
31. IEVYR - Indicator, when positive: New evaporation rates will be read each year and applied to all reservoirs. When negative: The rates will be read each year only for reservoirs with a positive IEV. When zero: A constant rate for the entire period will be read and applied to all reservoirs.
32. IPWYR - Indicator, when positive, that different power requirement will be used each year, otherwise leave blank.
33. IPRL - Indicator, when positive, causes printout of storage levels each year at each reservoir for ready checking of computations.
34. IECON - Positive value causes economic evaluation, a value of 2 will call for monthly printout of economic values.
35. IPWKW - Positive value causes power output in kilowatts instead of thousand kw-hr.
36. IPWPK - Positive value calls for reading peak power curve and printing peaking capacity, 1 as a function of storage and 2 as a function of flow.
37. IDVSP - Positive value calls for spill to be added to diversion at reservoir instead of to river flow.

1. Specification Card for Rearrangement of Output, omit if ISMRY (B-16) is zero or negative.

   1. IRG (1) - Rearranges unregulated flows
   2. IRG (2) - Rearranges river flows
   3. IRG (3) - Rearranges diversion
   4. IRG (4) - Rearranges diversion shortage
   5. IRG (5) - Rearranges desired flow shortage
   6. IRG (6) - Rearranges minimum flow shortage
   7. IRG (7) - Rearranges end of period storage
   8. IRG (8) - Rearranges change in storage at end of period
   9. IRG (9) - Rearranges end of period elevation
   10. IRG (10)- Rearranges reservoir data (prints storage, elevation, inflow, outflow, evaporation and generated power)

For above items use 1 to rearrange by control points, 2 by years, and 3 both ways. Zero or negative value will skip respective item. In the case of reservoir data (10th field, IRG (10)) the value 1 will consider all reservoirs and 2 only reservoirs with a power plant.

2. Storage Deficiency Specification for Shortage Declaration, omit if NSHR (B-11) is zero or negative.

   ISHR - Control point numbers of all reservoirs used to determine storage deficiency

3. Declared Flow Shortage Specification, omit if NSHQ (B-12) or NSHR (B-11) is zero or negative.

   ISHQ - Control point numbers of all locations where desired flow shortages are to apply.

4. Declared Diversion Shortage Specification, omit if NSHDV (B-13) or NSHR (B-11) is zero or negative.

   ISHDV - Control point numbers of all locations where diversion shortages are to apply.

5. Power Systems, NPWRS (B-17) Sets

   1. NRESP - Number of power reservoirs in system.
   2. PFMAX - Maximum plant factor for system.
   3. IRESP - Power reservoir control point number, NRESP items in successive fields.

C. Job Data

   1. CNSTI - Ratio to multiply inflows to convert to cfs (cms for metric system) or, if CNSTI is negative, to acre-feet (thousand cubic meters). For example, 1 when inflows are already in cfs (cms), -1 if already in acre-feet, -1000 if in thousand acre-feet, etc., for the English system.
   2. CNSTO - Constant to multiply flow requirements to convert to cfs (cms) or, if negative, to convert to acre-feet (thousand cubic meters).
   3. EFFCY - Power plant efficiency ratio for all plants, -1 if to be specified as a function of storage, -2 if table of KW/CFS (KW/CMS) to be used.
   4. DIVPR - Value of -1 causes shortage in diversion at reservoir when storage is below top of buffer zone.
   5. CLOCL - Coefficient less than or equal to 1 by which local inflow is multiplied as a contingency allowance for the purpose of computing conservation releases upstream.
   6. CFLOD - Coefficient greater than or equal to 1 by which local inflow is multiplied as a contingency allowance for the purpose of computing flood releases upstream.

7. STRSH - Total storage at the NSHR reservoirs at the beginning of INSPER (B-15) used for shortage declaration.
8. RSHQ - Factor by which storage deficiency below STRSH (C-7) in thousand acre-feet (million cubic meters) is multiplied to obtain shortage in percent to be applied to NSHQ (B-12) control points during the next NSPER (B-14) periods.
9. RSHDV - Similar factor to be applied to NSHDV (B-13) diversion locations.

1. Unit specification card (omit if IUNIT (B-26) is zero or negative).

1. CCFS - Coefficient to convert from cfs (cms for metric system) to desired flow unit.
2. QUNIT - Desired flow unit.
3. CACFT - Coefficient to convert to acre-feet (thousand cubic meters for metric system) to desired volume unit.
4. VUNIT - Desired volume unit.

D. Period Specification, Omit if NMIN (B-22) is positive.

NDAYS(I) - Number of days in each successive period, NPER (B-3) items, must be right-justified in each field of 8 digits (no decimal points).

Period Identification, Omit NMIN (B-22) is positive.

APERD(I) - Name of period, NPER items (column 1 is not reserved for identification).

1. Evaporation, omit if IEVYR (B-31) or NMIN (B-22) is not zero.

EVAPO(I) - Net index evaporation in inches (mm) for each successive period, NPER (B-3) items.

2. Diversion Data for Each of NDIV (B-7) Diversions in Any Order (preferably numerical).

1. M - Diversion number same as control point number (see item E) at that location. If located immediately below a reservoir, must have a different number than the reservoir, and local inflow cards (showing zero flows) must be supplied each year. Return flows can be computed as a fixed ratio of another diversion by entering the negative sum of the control point number where return flow enters the stream and positive ratio less than 1.0 to be applied.
2. QDIV (I,ID) - Diversion, in units corresponding to CNSTO (C-2), for each successive period, NPER (B-3) values. For return flows, the first value is the (control point) number which is multiplied by above ratio (point from which diversion is made) and remaining values are supplied as zeros or blanks.

##E Control Point Order and Identification

1. M - Control point number (integer ending in column 8).

2. CPT(MX) - Name in columns 9-38. Cards in sequence of treatment (downstream) in routing, numbers in ascending order of magnitude, if convenient.

3. NFLW(M) - Number of inflow locations involved in computing QL (inflow above control point and below upstream reservoirs), columns 45-48. Omit if QL equals input inflow.

4. TIME(M) - Time of travel in hours to most downstream point in system, used only when NMIN (B-22) is positive.

##1 Inflow Identification, omit if NFLW on preceding card is not positive.

1. MQ - Identification number of input inflow (see item M).
2. RTIO - Ratio of input inflow used to comprise QL.
3. - Items 1 and 2 repeated in order to obtain a total of NFLW pairs (NFLW(M) on last E card).

##2 Economic Function Identification, omit if IECON (B-34) is not positive.

IE(J) - Identification Code of Hydrologic Parameters in card field corresponding to each benefit function on Card N as follows:

0 No function
1 River flow and unregulated flow in cfs
2 Reservoir storage in acre-feet
3 Power generation in KWH
4 Diversion in cfs

##F Control Point Specification

1. M - Control point number (see item E).
2. NRESR(M) - Total number of reservoirs at or upstream of control point.
3. NDIVR(M) - Number of diversions at or upstream of control point and below upstream reservoirs.
4. NUPST(M) - Number of upstream reservoirs whose outflows must be added to local flow to obtain inflow (dim. 18).
5. QMN - Minimum desired flow in units corresponding to CNSTO (C-2) -1 if to be specified by period.
6. SRCHG(M) - Indicator, positive value allows spillway surcharge (usually zero).
7. QMXX - Maximum permissible flow in cfs (cms).

Cards repeated in sequence for NCPT (B-6) sets.

8. QM2(M) - Minimum required flow in units corresponding to CNSTO (C-2), -1 if to be specified by period. **This flow will be supplied from buffer storage (below level** 2 in item H) whereas QMN (F-5) will not.

9. IPRN(M) - Negative value causes suppression of monthly and annual printout for the one control point.

##1 All Upstream Reservoirs, omit if previous NRESR (F-2) is zero or negative.

IRESM(M,K) - Control point numbers of reservoirs at and upstream of control point in upstream-to-downstream order. Those not to be operated specifically for this control point must be preceded by a minus sign. Numbers must be right-justified in fields of 8 digits (no decimal points).

##2 Upstream Diversions, omit if previous NDIVR (F-3) is zero or negative.

IDIVR(M,K) - Identification (control point) numbers of all upstream diversions that are below upstream reservoirs, including diversion at control point that does not divert below a dam at the control point. Numbers must be right-justified in fields of 8 digits (no decimal points), NDIVR(M) values.

##3 Reservoirs Contributing to Inflow, omit if previous NUPST (F-4) is zero or negative.

IUPST(M,K) - Control point numbers of reservoirs whose releases must be added to local flow to obtain inflow. Numbers must be right-justified in fields of 8 digits (no decimal points), NUPST(M) values.

##4 Minimum Desired Flows, omit if previous QMN (F-5) is zero or positive.

QMIN(I,M) - Minimum desired flow for each successive period in units corresponding to CNSTO (C-2), NPER (B-3) values.

##5 Minimum Required Flows, omit if previous QM2 (F-8) is zero or positive.

QMIN2(I,M) - Minimum required flow for each successive period in units corresponding to CNSTO (C-2), NPER (B-3) values.

##6 Maximum Permissible Flows, omit if previous QMXX (F-7) is zero or positive.

QMX(I,M) - Maximum permissible flow in cfs (cms) at M for period I.

Cards repeated in sequence for NCPT (B-6) sets.

7. Power Data for Each of NPWR (B-9) Plants in Any Order (preferably numerical).

   1. M - Control point number (see item E) at power plant.
   2. TLWEL(IP) - Tailwater elevation plus hydraulic loss in feet (meters).
   3. PWRMX(IP) - Power plant name plate capacity in kilowatts.
   4. OVLOD(IP) - Overload ratio, usually 1.15 in United States, if blank assumes 1.15.
   5. IDPR(IP) - Control point number of downstream reservoir affecting tailwater.

8. Power Requirement Following Each F7 Card, omit if IPWYR (B-32) is positive.

   POWR(I,IP) - Power requirement for each successive period in thousand kilowatt-hours or, if negative, plant factor ratio, NPER (B-3) values.

9. Power System Requirement, NPWRS (B-17) Sets (limited to 2 maximum).

   PWRS - System power requirement in thousand kilowatt-hours, NPER (B-3) items.

*G. Reservoir Specification.

   1. M - Control point number (see item E) at reservoir.
   2. STOR1(M) - Initial storage in acre-feet (thousand cubic meters), -1 if continuation of routing using ending storage for previous year (when update was called by (C-9) in preceding set of data).
   3. CEVAP(M) - Ratio of net reservoir evaporation to index evaporation (see cards D1 or M1).
   4. TEAK(M) - Leakage at dam or power house in cfs (cms).
   5. IPOW(M) - Indicator, positive value calls for peaking capacity as a function of outflow as in a run-of-river plant.
   6. IEV(M) - Indicator, positive value calls for reading evaporation pattern (M2 cards) for reservoir at M. Omit if IEVYR (B-31) is zero or positive.

*H. Storage Levels for Each of NL (B-8) Levels in Turn in Increasing Order. If NMIN (B-22) is positive provide a single card with levels in increasing order.

   STORL(I,M,L) - Storage in acre-feet (thousand cubic meters) for NPER (B-3) periods used for balancing storages among reservoirs. Bottom 2 levels define buffer space and top NLF levels define flood control space. Top level is full pool level.

* Items G through L repeated in sequence for each of NRES (B-5) reservoirs in any order, preferably in control point number sequence.

*1. Storage Levels. Omit if NMIN (B-22) is zero or negative.

STORL(1,M,L) - Storage in acre-feet (thousand cubic meters) for NL (B-8) levels used for balancing storage among reservoirs. Bottom 2 levels define buffer space and top NLF levels define flood control space. Top level is full pool level.

*I. Reservoir Elevations.

EL(M,K) - Elevations in feet (meters) corresponding to storages on card J.

*1. Tailwater Rating, omit if no power plant at (M) or if TLWEL (F7-2) is not blank or zero.

QT(IP,K) - Outflow in cfs (cms), up to 10 values.

*2. Elevation, omit if QT card is omitted.

TL(IP,K) - Tailwater elevation in feet (meters) corresponding to QT values.

*3. Peak Power Capacity, omit if no power plant at (M) or if IPWPK (B-36) is not positive.

PKPWR(IP,K) - Maximum power in kilowatts that can be generated at specified WS elevation, up to 10 values.

*4. Storages or Flows.

CQOEL(IP,K) - Corresponding storage to card 3 in acre-feet (thousand cubic meters) or flow in cfs (cms), the latter if IPWPK (B-36) equals 2.

*5. Power Plant Efficiencies or Generation Coefficients, omit if no power plant at (M) or if EFFCY (C-3) is zero or positive.

EFCY(M,K) - If EFFCY is -2, kw/cfs coefficient; if EFFCY is -1, power plant efficiency ratio; corresponding to storages on card J.

*J. Reservoir Storages.

STOR(M,K) - Reservoir storage capacities in acre-feet (thousand cubic meters). Each value must be larger than the preceding one, up to 10 values corresponding to I,K,L & 5 cards.

* Items G through L repeated in sequence for each of NRES (B-5) reservoirs in any order, preferably in control point number sequence.

*K. Reservoir Areas.

AREA(M,K) - Areas in acres (thousand square meters) corresponding to storages on preceding card.

*L. Reservoir Outlet Capacities.

QCAP(M,K) - Outlet capacities in cfs (cms) corresponding to storages on card J.

**M. Inflows for Each of NFLOW (B-10) Stations, repeated each year.

1. M - Identification number of input inflows (columns 2-4).
2. Blank Field - (columns 5-8) can be used for identification of years.
3. QII (I,M) - Inflows in units corresponding to CNSTI (C-1), NPER (B-3) items per station each year for NYRS (B-1) years (6 columns each starting in columns 9-14 on all cards). If NMIN (B-22) is positive, values are flow lagged to downstream most control point.

**1. New Evaporation for Each Year, omit if IEVYR (B-31) is zero or negative.

EVAPO(I) - Net index evaporation in inches (mm) for each successive period, NPER items (B-3).

**2. New Evaporation for Each Year, omit if IEVYR (B-31) is zero or positive.

EVP(I,M) - Evaporation in inches (mm) for period I and Reservoir M, where IEV(M) is positive.

**3. New Diversion Requirement for Each Year, NDVYR (B-119) Sets.

QDIV - Diversion, in units corresponding to CNSTO (C-2), for each successive period, NPER (B-3) values.

**4. New Power Requirement for Each Power Plant Each Year. Plant order must be same as in item F7, NPWR (B-9) sets. Omit if IPWYR (B-32) is zero or negative.

POWR(I,IP) - Power requirement for each successive period in thousand kilowatt-hours or, if negative, plant factor ratio, NPER (B-3) values.

* Items G through L repeated in sequence for each of NRES (B-5) reservoirs in any order, preferably in control point number sequence.
** Items M through M7 repeated in sequence for each NYRS (B-1) years.

**5. New System Power Requirement for Each Year, NPWRS (B-17) Sets, omit if IPWYR (B-32) is zero or negative.

PWRS - System power requirement in thousand kilowatt-hours, NPER (B-3) items.

**6. New Storage Levels for Each Year, NLYR (B-18) Sets.

1. M - Control point number.
2. L - Level number.
3. STORL - Storage in acre-feet (thousand cubic meters), NPER (B-3) items.

**7. Desired Low-Flow Requirement for Each Year, NQYR (B-20) Sets.

1. M - Control point number.
2. QMIN - Minimum desired flow in units corresponding to CNSTO (C-2), NPER (B-3) items.

N. Benefit Function Names, omit if IECON (B-34) is not positive.

8 cards using columns 2-61 of each, must be in order of identification in the 8 fields of each E2 card.

1. *Table of Hydrologic Parameter, flow in cfs (cms), storage in acre-feet (thousand cubic meters), or power in thousand kilowatt-hours, omit if IECON (B-34) is not positive.

1. M - Station number.
2. MTH - Month sequence number (not necessarily calendar month number)
3. STORL - First table value of hydrologic element, etc., up to 8 table values (full card).

2. *Table of Benefit in Thousand Dollars (see example).

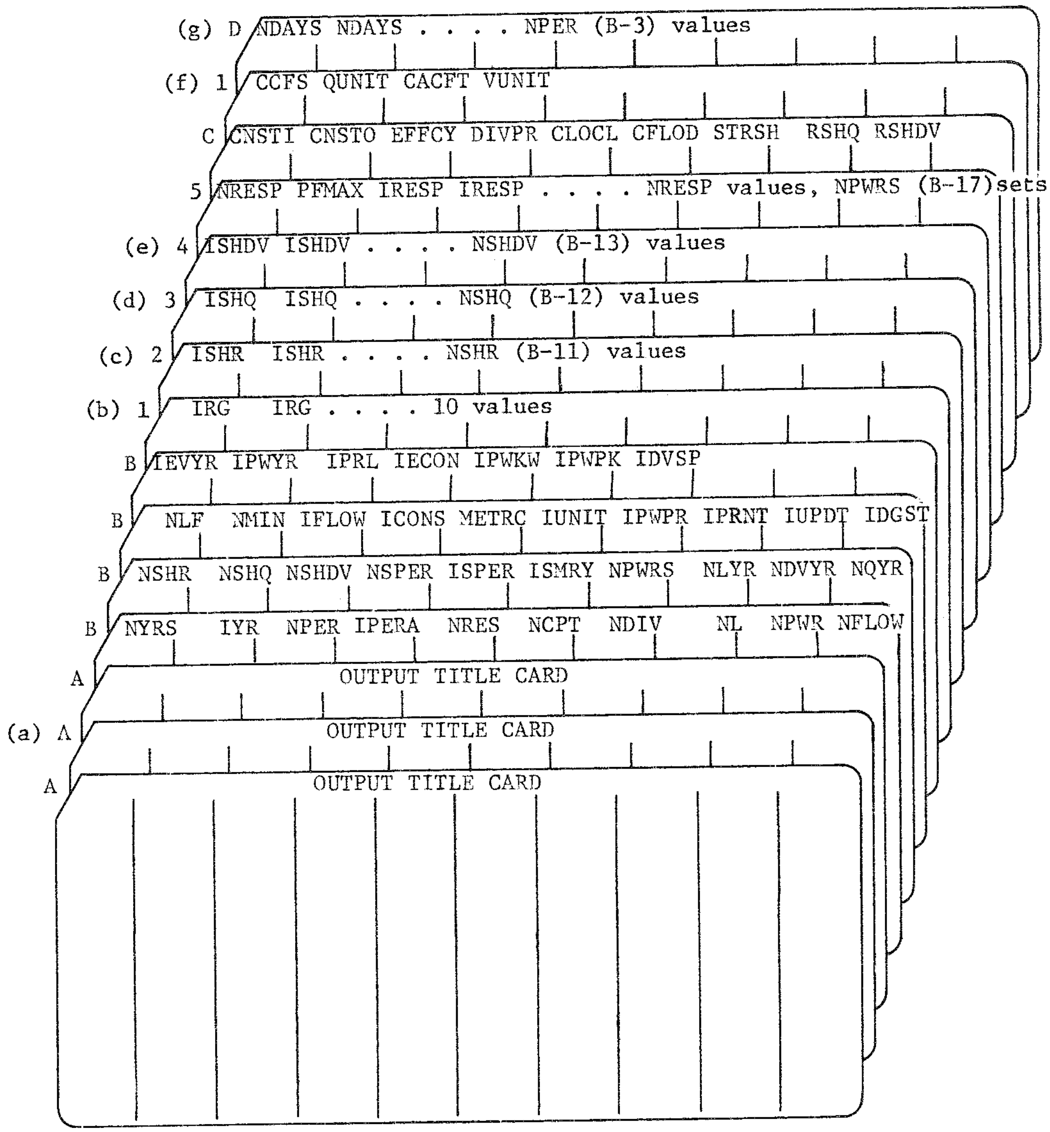
1. M - Station number, must be identical to preceding card.
2. MTH - Month number, must be identical to preceding card.
3. PSTOR - Economic value in thousand dollars for corresponding hydrologic value on preceding card, etc., up to 8 table values.

* Table cards must be supplied in pairs for each successive sequence month for all control points having positive indicator on E2 card for each economic function in turn (all points for first function, followed by all points for second function, etc.). Pairs should be omitted if the function for the following month is identical, except that the pair for the last month must be supplied.

Four blank cards should follow last job to cause computer to stop.

**Items M through M7 repeated in sequence for each of NYRS (B-1) years.

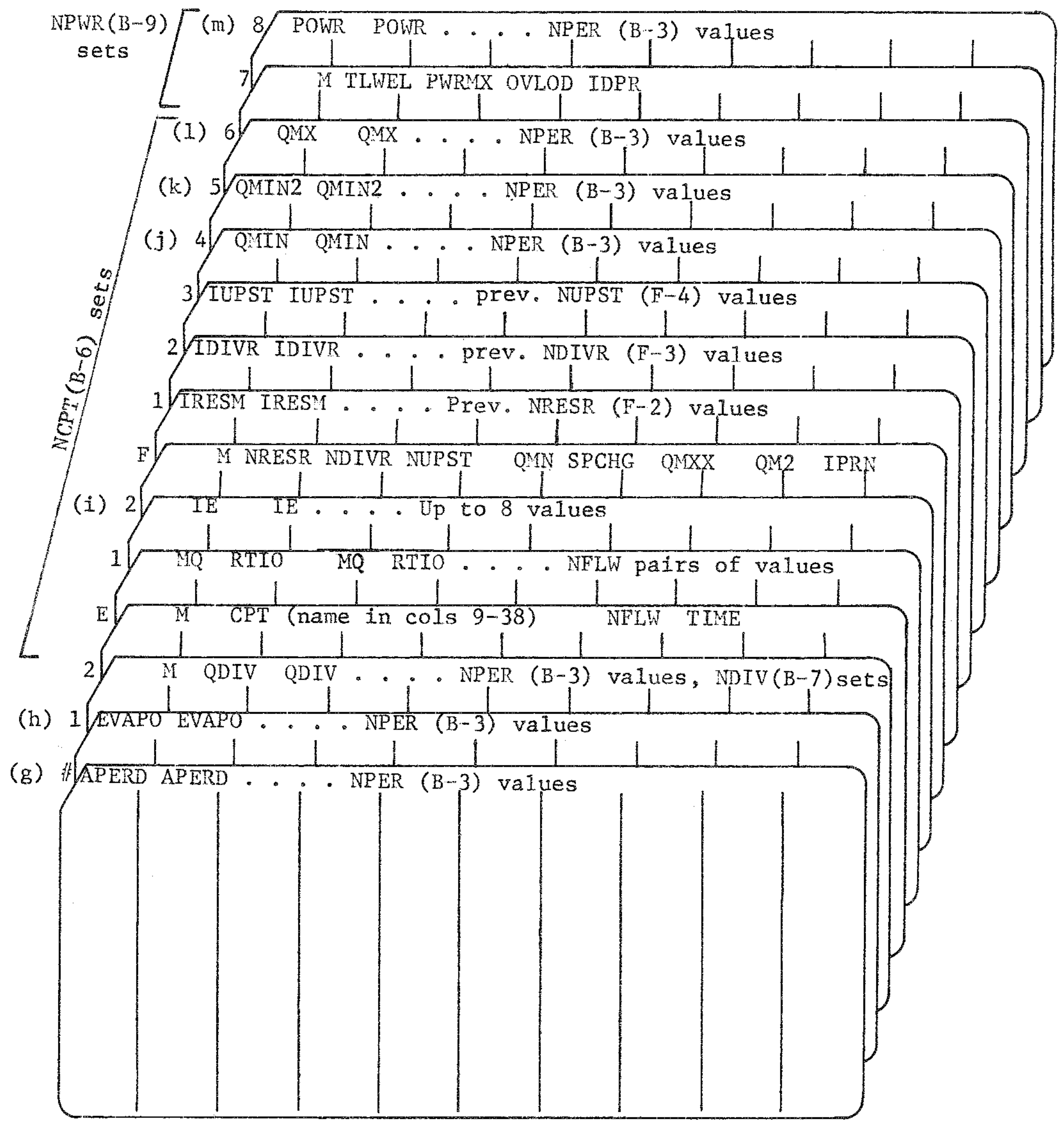
SUMMARY OF REQUIRED CARDS
PROGRAM 723-X6-L2030



NOTES:

(a) First 2 columns of the cards are ignored.
(b) Omit if ISMRY (B-16) is zero or negative.
(c) Omit if NSHR (B-11) is zero or negative.
(d) Omit if NSHR (B-11) or NSHQ (B-12) is zero or negative.
(e) Omit if NSHR (B-11) or NSHDV (B-13) is zero or negative.
(f) Omit if IUNIT (B-26) is zero or negative.
(g) Omit if NMIN (B-22) is positive.

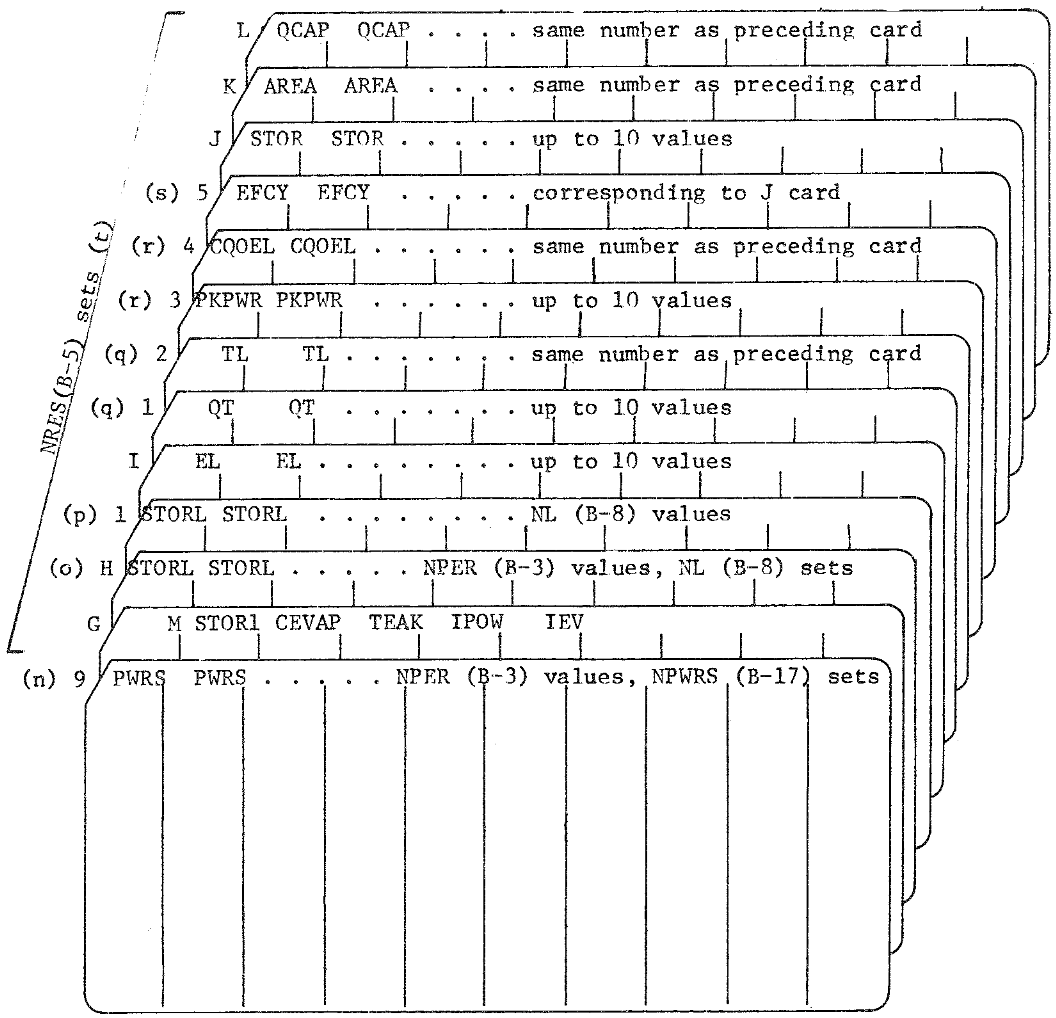
EXHIBIT 6



NOTES:

- (g) # Column 1 not reserved for identification.
- (h) Omit if NMIN (B-22) is positive or IEVYR (B-31) is not zero.
- (i) Omit if IECON (B-34) is zero or negative.
- (j) Omit if previous QMN (F-5) is zero or positive.
- (k) Omit if previous QM2 (F-8) is zero or positive.
- (l) Omit if previous QMXX (F-7) is zero or positive.
- (m) Omit if IPWYR (B-32) is positive.
- (n) Omit if NPWR (B-9) or NPWRS (B-17) is zero or negative or if IPWYR (B-32) is positive.

EXHIBIT 6



NOTES:

(n) Omit if NPWR (B-9) or NPWRS (B-17) is zero or negative or if IPWYR (B-32) is positive.

(o) Omit if NMIN (B-22) is positive.

(p) Omit if NMIN (B-22) is zero or negative.

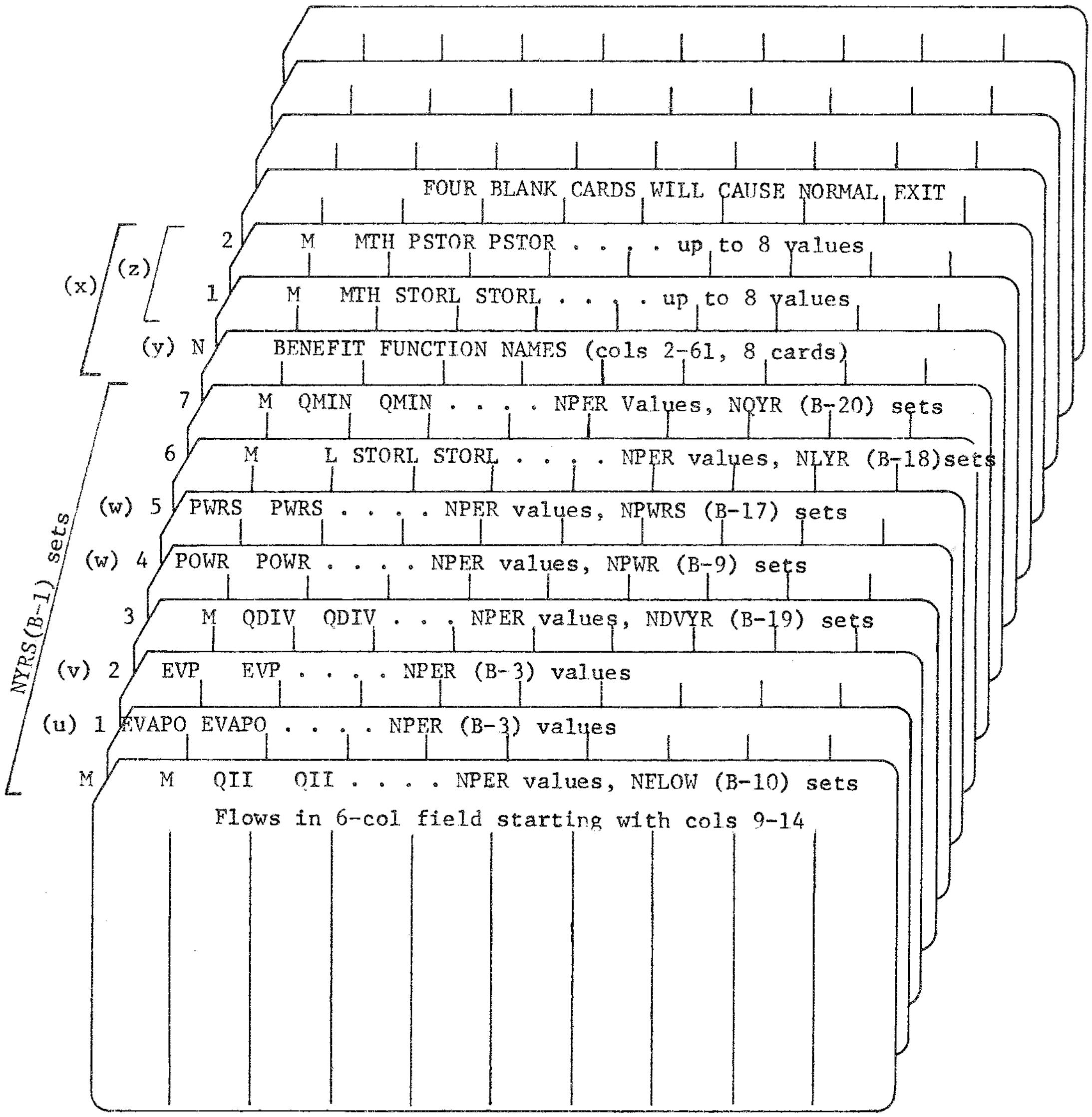
(q) Omit if no power plant at M (G-1) or if TLWEL (M) is not zero.

(r) Omit if no power plant at M (G-1) or IPWPK (B-36) or IPOW (M) is zero or negative.

(s) Omit if no power plant at M (G-1) or EFFCY (C-3) is zero or positive.

(t) These items in sequence for NRES (B-5) reservoirs in turn.

EXHIBIT 6



NOTES:

(u) Omit if IEVYR (B-31) is zero or negative.
(v) Furnish for each positive IEV (G-6) values if IEVYR is negative.
(w) Omit if IPWYR (B-32) is zero or negative.
(x) Omit if IECON (B-34) is zero or negative.
(y) Complete with blank cards if less than 8 benefits are used.
(z) Maximum of NPER (B-3) sets for each benefit function, see page 9, exhibit 5.

EXHIBIT 6

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