Chapter 4
Reservoir Systems

4-1. Introduction

Water resource systems should be designed and operated for the most effective and efficient accomplishment of overall objectives. The system usually consists of reservoirs, power plants, diversions, and canals that are each constructed for specific objectives and operated based on existing agreements and customs. Nevertheless, there is considerable latitude in developing an operational plan for any water resource system, but the problem is greatly complicated by the legal and social restrictions that ordinarily exist.

a. Mathematical modeling. Water resource system operation is usually modeled mathematically, rather than with physical models. The mathematical representation of a water resource system can be extremely complex. Operations research techniques such as linear programming and dynamic programming can be applied to a water resource system; however, they usually are not capable of incorporating all the details that affect 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. The simulation can be based on the results from the optimization of system outputs or repeated simulations. Successively refining the physical characteristics and operational rules can be applied to find the optimum output.

b. Inputs and requirements. 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 deficient. 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. Concepts for accomplishing this are discussed in paragraph 5-5.

4-2. System Description

a. Simulating system operation. 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. The system should include all components that affect the project operation and provide the required outputs for analysis.

(1) Reservoirs. For reservoirs, the relation of surface area and release capacity to storage content must be described. Characteristics of the control gates on the outlets and spillway must be known in order to determine constraints on operation. The top-of-dam elevation must be specified and the ability of the structure to withstand overtopping must be assessed.

(2) Downstream channels. The downstream channels must be defined. Maximum and minimum flow targets are required. For short-interval simulation, the translation of flow through the channel system is modeled by routing criteria. The travel time for flood flow is important in determining reservoir releases and potential limits for flood control operation to distant downstream locations.

(3) Power plants. For power plants at storage reservoirs, the relation of turbine and generation capacity to head must be determined. 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 are also important.

(4) Diversion structures. For diversion structures, maximum diversion and delivery capacity must be established. The demand schedule is required, and the consumptive use and potential return flow to the system may be important for the simulation.

b. Preparing data. While reservoir system data must be defined in sufficient detail to simulate the essence of the physical system, preparing the required hydrologic data may require far more time and effort. The essential flow data are required for the period of record, for major flood events, and in a consistent physical state of the system. Flow records are usually incomplete, new reservoirs in the system change the flow distribution, and water usage in the watershed alters the basin yield over time. Developing a consistent hydrologic data series, making maximum use of the available information, is discussed in Chapter 5.

4-3. Operating Objectives and Criteria

a. User services. Usually, there is a fixed objective for each function in a water resource system. Projects are constructed and 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. Some services, such as flood control and recreation, are not ordinarily covered by contracts. For these, service areas are developed to provide the degree of service for which the project was constructed.

b. Rules for services. Shortages in many of the services can be very costly, whereas surpluses are usually of minor value. Accordingly, the objectives of water resource system operational are usually fixed for any particular plan of development. These are expressed in terms of operational rules that specify quantities of water to be released and diverted, quantities of power to be generated, reservoir storage to be maintained, and flood releases to be made. These quantities will normally vary seasonally and with the amount of storage water 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 stream flows that would represent future runoff potential.

4-4. System Simulation

The evaluation of system operation under specified operation rules and a set of input quantities is complex and requires detailed simulation of the operation for long periods of time. This is accomplished by assuming that steady-state conditions prevail for successive intervals of time. The time interval must be short enough to capture the details that affect system outputs. For example, average monthly flows may be used for most conservation purposes; however, for small reservoirs, the flow variation within a month may be important. For hydropower reservoirs, the average monthly pool level or tailwater elevation may not give an accurate estimate of energy production.

To simulate the operation during each interval, the simulation solves the continuity equation with the reservoir release as the decision variable. The system is analyzed 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, and channel capacity, and reservoir storage capacity. As the computation procedure progresses to downstream locations, the tentative release decisions 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.

4-5. Flood-Control Simulation

Flood discharge can change rapidly with time. Therefore, steady-state conditions cannot be assumed to prevail for long periods of time (such as one month). Also, physical constraints such as outlet capacity and the ability to change gate settings are more important. The time translation for flow 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.

a. Computational interval. The computation interval necessary for satisfactory simulation of flood operations is usually on the order of a few hours to one day at the most. Sometimes intervals as short as 15 or 30 min 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. However, period-of-record may be unnecessary because 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.

b. Starting conditions. The starting conditions for simulating the flood-control operation for an historic flood period would depend on the operation of the system for conservation purposes prior to that time. Accordingly, the conservation operation could be simulated first to establish the state of the system at the beginning of the month during which the flood occurred as the initial conditions for the flood simulation. However, the starting storage for flood operation should be based on a realistic assessment of likely future conditions. If it is likely that the conservation pool is full when a flood occurs, then that would be a better starting condition to test the flood-pool capacity. It may be possible that the starting pool would be higher if there were several storms in sequence, or if the flood operation does not start the instant excessive inflows raise the pool level into flood-control space.

c. Historic sequences. While simulating historic sequences are important, future floods will be different and occur in different sequences. Therefore, the analysis of flood operations should utilize both historic and synthetic floods. The possibility of multiple storms, changes in the upstream catchment, and realistic flood operation should be included in the analysis. Chapter 7 presents flood-runoff analysis and Chapter 10 presents flood-control storage requirements.

d. Upstream-to-downstream solution. If the operation of each reservoir in a system can be based on conditions at or above that reservoir, an upstream-to-downstream solution approach 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, a simple simulation model is capable of simulating the system operation with a high degree of accuracy. However, as the number of reservoirs and downstream damage centers increase, the solution becomes far more complex. A priority criteria must be established among the reservoirs to establish which should release water, when there is a choice among them.

e. Combination releases. The HEC-5 *Simulation of Flood Control and Conservation Systems* (HEC 1982c) computer program can solve for the combination of releases at upstream reservoirs that will satisfy channel capacity constraints at a downstream control point, taking into account the time translation and channel storage effects, and that will provide continuity in successive time intervals. The time translation effects can be modeled with a choice of hydrologic routing methods. Reservoir releases are determined for all designated downstream locations, subject to operation constraints. The simulation is usually performed with a limited foresight of inflows and a contingency factor to reflect uncertainty in future flow values. The concept of pool levels is used to establish priorities among projects in multiple-reservoir systems. Standard output includes an indicator for the basis of reservoir release determination, along with standard simulation output of reservoir storage, releases, and downstream flows.

f. Period-of-record flows. Alternatively, a single time interval, such as daily, can be used to simulate period-of-record flows for all project purposes. This approach is routinely used in the Southwestern Division with the computer program "Super" (USACE 1972), and in the North Pacific Division with the SSARR program (USACE 1991). The SSARR program is capable of simulation on variable time intervals.

4-6. Conservation Simulation

While the flood-control operation of a reservoir system is sensitive to short time variations in system input, the operation of a system for most conservation purposes is usually sensitive only to long-period streamflow variations. Historically, simulation of the conservation operation of a water resource system has been based on a relatively long computation interval such as a month. With the ease of computer simulation and available data, shorter computational intervals (e.g., daily) can provide a more accurate accounting of flow and storage. Some aspects of the conservation operation, such as diurnal variations in power generation in a peaking project, might require even shorter computational intervals for selected typical or critical periods to define important short-term variations.

a. Hydropower simulation. Hydropower simulation requires a realistic estimate of power head, which depends on reservoir pool level, tailwater elevation, and hydraulic energy losses. Depending on the size and type of reservoir, there can be considerable variation in these variables. Generally, the shorter time intervals will provide a more accurate estimate of power capacity and energy productions.

b. Evaporation and channel losses. In simulating the operation of a reservoir system for conservation, the time of travel of water between points in the system is usually ignored, because it is small in relation to the typical computation interval (e.g., monthly or weekly). On the other hand, evaporation and channel losses might be quite important; and it is sometimes necessary to account for such losses in natural river channels and diversion canals.

c. Rule curves. 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.

4-7. System Power Simulation

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. Because 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 storage 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. EM 1110-2-1701 paragraph 5-14, describes hydropower system analysis.

4-8. Determination of Firm Yield

If the yield is defined as the supply that can be maintained throughout the simulation period without shortages, then the process of computing the maximum yield can be expedited. This is done by maintaining a record 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 basic procedure for computing firm yield is included in the HEC-5 computer program. Additionally, the program has a routine to make an initial estimate of the critical period and expected yield. After the yield is determined using the critical period, the program will evaluate the yield by performing a simulation with the entire input flow record. Chapter 12 describes storage-yield procedures.

4-9. Derivation of Operating 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.

a. Simulation. 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 requirement characteristics. For this reason, the development of a set of balancing levels is an iteration process, and a complete system simulation must be done for each iteration.

(1) When first establishing balancing levels in the reservoir system, 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 flood control storage 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.

(2) After a preliminary set of balancing levels is established, they should be defined approximately in terms of a minimum number of variables. The general shape and spacing of levels at a typical reservoir might be defined by the 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.

(3) Optimization of a set of balancing levels for operational rule curves can be accomplished by successive approximations using a complete system simulation computation for critical drought periods. However, the procedures are limited to the input specifications of demands and storage allocation. While one can compare simulation results and conclude one is better than another based on

performance criteria, there is no way of knowing that an optimum solution has been achieved.

b. Optimization. While water resource agencies have generally focused on simulation models for system analysis, the academic community and research literature have emphasized optimization and stochastic analysis techniques. Research performed at HEC (HEC 1991b) has found a proliferation of papers on optimization of reservoir system operations written during the past 25 years, primarily by university researchers. There still remains a considerable gap between the innovative applications reported in the literature and the practices followed by the agencies responsible for water resource development. One basic problem is that many of the reported applications are uniquely formulated to solve a specific problem for a given system. There is a general view that the models performance, or the methods assumptions, would not sufficiently evaluate a different problem and system.

c. Prescriptive reservoir model. HEC has developed a system analysis tool based on a network flow model (HEC 1991a). The Prescriptive Reservoir Model (HEC-PRM) will identify the water allocation that minimizes poor performance for all defined system purposes. Performance is measured with analyst-provided functions of flow or storage or both. The physical system is represented as a network, and the allocation problem is formulated as a minimum-cost network flow problem. The objective functions for this network problem are convex, piecewise-linear approximations of the summed penalty functions for each project purpose (HEC 1991d).

(1) Systems have been analyzed in studies on the Missouri River (HEC 1991d) and the Columbia River (HEC 1991f). A preliminary analysis of the Phase I Missouri River study has developed initial methodologies for developing operation plans based on PRM results (HEC 1992b). Continued application experience is required to define generalized procedures for these analyses.

(2) The primary advantages for the HEC-PRM approach are the open state of the system and the required penalty functions for each system purpose. There are no rule curves or details of storage allocation, only basic physical constraints are defined. The reservoir system information defines maximum and minimum storage in the reservoirs and the linking of the system through the network of channels and diversions. The other primary reservoir data is traditional period-of-record monthly flows for the system.

(3) The development of the penalty functions requires an economic evaluation of the values to be placed on flow and storage in the system. The process is difficult and there are disagreements on the values, due to the difficulty of defining values for some purposes. However, the process does provide a method for defining and reviewing the purposes and their relative values.

(4) The primary disadvantage of the HEC-PRM is that the monthly flow data and lack of channel routing limit its application for short interval simulation, such as flood control and peaking hydropower. Additionally, the optimized solution is provided in terms of period-of-record flows and storage; however, the basis for the system operation are not explicitly defined. The post-processing of the results requires interpretation of the results in order to develop an operation plan that could be used in basic simulation and applied operation. More experience with this analysis of results is still required to define these procedures.

4-10. System Formulation Strategies

a. Determining the best system. A system is best for the national income criteria if it results in a value for system net benefits that exceeds that of any other feasible system. Except where noted, the following discussion was developed in a paper presented at the International Commissions on Large Dams Congress (Eichert and Davis 1976). For a few components, analysis of the number of alternative systems that are feasible is generally manageable, and exhaustive evaluation provides the strategy for determining the best system. When the number of components is more than just a few, then the exhaustive evaluation of all feasible alternative systems cannot practically be accomplished. In this instance, a strategy is needed that reduces the number of system alternatives to be evaluated to a manageable number while providing a good chance of identifying the best system. System analysis does not permit (maximum net benefit system) for reasonably complex systems even with all hydrologic-economic data known. An acceptable strategy need not make the absolute guarantee of economic optimum because seldom will the optimum economic system be selected as best.

b. Incremental test. The incremental test of the value of an individual system component is definitive for the economic efficiency criteria and provides the basis for several alternative formulation strategies. If existing reservoir components are present in the system, then they define the base conditions. If no reservoirs exist, the base condition would be for natural conditions. The strategies described below are extensions of currently used techniques and are based upon the concept of examining in detail the performance of a selected few alternative systems. The performance is assumed to be evaluated generally by traditional simulation methods, like the use of HEC-5.

c. Reasoned thought strategy. This strategy is predicated upon the idea that it is possible to reason out using judgment and other criteria, reasonable alternative systems. The strategy consists of devising through rational thought, sampling, public opinion, literature search, and brainstorming, a manageable number of system alternatives that will be evaluated. No more than 15 to 20 alternative systems could be evaluated by detailed simulation in a practical sense.

(1) The total performance of each system in terms of economic (net benefit) and performance criteria is evaluated by a system simulation. A system (or systems if more than one have very similar performance) is selected that maximizes the contribution towards the formulation objectives (those that exhibit the highest value of net benefits while satisfying the minimum performance criteria). To confirm the incremental justification of each component, the contribution of each system component in the last added position is evaluated. The last added value is the difference between the value (net benefits) of the system with all components in operation and the value (net benefits) of the system with the last added component removed. If each component is incrementally justified, as indicated by the test, the system is economically justified, and formulation is complete. If any components are not incrementally justified, they should be dropped and the last added analysis repeated.

(2) The system selected by this strategy will be a feasible system that is economically justified. Assuming the method of devising the alternative systems is rational, the chances are good that the major worthwhile projects will have been identified. On the other hand, the chances that this system provides the absolute maximum net benefits is relatively small. This strategy would require between 30 and 60 system evaluations for a moderately complex (15 component) system.

d. First added strategy. This strategy is designed such that its successive application will yield the formulated system. The performance of the systems, including the base components (if any), are evaluated with each potential addition to the system in the "first added" position. The component that contributes the greatest value (net benefit) to the system is selected and added to the base system.

(1) The analysis is then repeated for the next stage by computing the first added value of each component to the system again, the base now including the first component added. The strategy is continued to completion by successive application of the first added analysis until no more component additions to the system are justified.

(2) The strategy does have a great deal of practical appeal and probably would accomplish the important task of identifying the components that are clearly good additions to the system and that should be implemented at an early stage. The strategy, however, ignores any system value that could be generated by the addition of more than one component to the system at a time, and this could omit potentially useful additions to the system. For example, the situation sometimes exists where reservoirs on, say, two tributaries above a damage center are justified, but either one analyzed separately is not, i.e., the system effect is great enough to justify both. The number of system analyses required to formulate a system based on this strategy could range upwards to 120 for a moderately complex (15 component) system, which is probably close to being an unmanageably large number of evaluations.

e. Last added strategy. This strategy, similar to first added strategy, is designed such that successive application yields the formulated system. Beginning with all proposed components to the system, the value of each component in the last added position is computed. The project whose deletion causes the value (net benefit) of the system to increase the most is dropped out. The net benefits would increase if the component is not incrementally justified. The strategy is continued through successive staged applications until the deletion of a component causes the total system value (net benefits) to decrease.

(1) The last added strategy will also yield a system in which all components are incrementally justified and in which the total system will be justified. This strategy would probably identify the obviously desirable projects, as would the others. However, its weakness is that it is slightly possible, though not too likely, that groups of projects that would not be justified are carried along because of their complex linkage with the total system. For example, the situation sometimes exists where reservoirs on two tributaries above a damage center are not justified together, but deletion of each from a system that includes both results in such a great loss in system value that individual analysis indicates neither should be dropped individually.

(2) The number of systems analyses required for this strategy would be similar to the first added strategy

requiring perhaps 10-20 percent more evaluations. Twenty-two last added analyses were made in the four stages required to select four new projects out of seven alternatives. This strategy is more efficient than the first added if the majority of the potential system additions are good ones.

f. Branch-and-bound enumeration. "Branch-and-bound enumeration is a general-purpose technique for identifying the optimal solution to an optimization problem without explicitly enumerating all solutions," (HEC 1985a). The technique provides a framework to evaluate independent alternatives by dividing the entire set into subsets for evaluation. The method has been applied in resource planning to problems of sizing, selecting, sequencing, and scheduling projects. HEC has developed a training document illustrating the application to flood-damage-mitigation plan selection (HEC 1985). Additionally, HEC Research Document No. 35 (Bowen 1987) illustrates an application for reservoir flood control plan selection using computer program HEC-5 for reservoir simulation. The procedure can use any criteria for evaluation and supports detailed simulation in the analysis process.

4-11. General Study Procedure

There is no single approach to developing an optimum plan of improvement for a complex reservoir system. Ordinarily many services are 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 been developed over a long period of time and that many services are in fact fixed, as are many system features. Nevertheless, an idealized general study procedure is presented below:

a. 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, evaporation, snowpack, hydrograph timing and runoff data pertinent to the project studies. Obtain physical and operational 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 nondamaging 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 10. 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 11, estimate the storage needed on each principle tributary for conservation services. Formulate a basic plan of development including detailed specification of all reservoir, canal, channel, and powerplant 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, engineering feasibility, and costs of various types of structures, and relocations.

d. Using the general procedures outlined in Part 2, develop flood frequencies, hypothetical flood hydrographs, and stage-discharge relations 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 paragraph 4-5 and Chapter 10, modify the plan, 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. 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. For system analysis to determine the best allocation of flow and storage for conservation purposes, consider optimization using a tool HEC-PRM (paragraph 4-9*c*). The program outputs would then be analyzed to infer an operation policy that could be defined for simulation and more detailed analysis. The alternative is to repeatedly simulate with critical low-flow periods to develop a policy to meet system goals and then perform a period-of-record simulation to evaluate total system performance.

f. Consider generating synthetic sequences of flow to evaluate the system's performance with different flow sequences (see paragraph 5-5). Future system flows replicate the period-of-record. Also, projected changes in the basin should be factored into the analysis. Typically, future conditions are estimated at several stages into the future. The system analysis should be performed for each stage. While these analyses will take additional time and effort, they will also provide some indication of how responsive the system results are to changing conditions.