APPENDIX C

COMPUTER MODELS FOR POWER STUDIES

C-1. Introduction.

a. This appendix briefly describes some of the computer models being generally used for power studies within the Corps of Engineers at the present time. While many models have been developed and used within the Corps over the years, not all are included here. Some are tailored to the specific needs of individual field offices. Others are almost identical to more commonly used models, and still others are now obsolete. However, examples of all of the major types of models have been included. The following models are described:

- Flow-duration models (Section C-2)
  - HYDUR
  - NAVOP

- Sequential streamflow routing models (Section C-3)
  - HEC-5
  - SUPER
  - HYSSR
  - RESOP
  - HLDPA (hourly)
  - HYSYS (hourly)

- Hybrid models (Section C-4)
  - DURAPLOT

b. The descriptions of the models and their capabilities are based on their status at the time of this manual's publication. Most of these models were designed with flexibility in mind, and they are being modified or expanded from time to time as needed to handle new types of problems. Hence, if special needs develop which appear to be beyond the capabilities of a given model, it is suggested that the office responsible for maintaining that model be contacted in order to determine the current state of the model and to determine whether the model could be adapted to meet those needs.

C-2. Flow-Duration Models.

a. General.

(1) The basic concepts of flow-duration energy analyses are relatively simple, and as a result, a number of models have been

developed at different Corps field offices. While all of these models are generally similar, each is tailored to the specific data base which is being utilized for streamflows, the degree of detail required, and the type of output desired. For example, while most models utilize USGS streamflow records, both Little Rock District and Southwestern Division have developed models which utilize daily flows generated by the SUPER Model (Section C-3(o)). Little Rock's model was designed to examine alternative turbine types, and thus reflects the variation of efficiency with discharge. Southwestern Division's model can automatically load alternative combinations of units to select the combination that produces maximum energy at each flow level, based on operating for peaking whenever conditions permit.

(2) Space does not permit a detailed discussion of each of the existing models. However, two models which have more general applicability will be briefly described: HEC's HYDUR model and Ohio River Division's NAVOP model.

(3) Another useful general model is North Pacific Division's DURAPLOT model. DURAPLOT can examine projects where head varies independently of streamflow. It is designed to compute power from sequential streamflow and reservoir elevation records prior to developing the duration curves, so it must be classified as a hybrid model rather than a true flow-duration model. DURAPLOT is described in Section C-4.

b. <u>HYDUR.</u>

(1) HYDUR is a standard flow-duration model with various options that permit it to address a variety of energy analyses. Some of the model's options are listed as follows:

- can derive annual, seasonal, or monthly data
- can input flow-duration curve or develop curve from user-specified data files
- can utilize GETUSGS technique for evaluating ungaged sites
- will account for upstream diversions or flow losses at dam
- can input tailwater curve or fixed average tailwater
- can input fixed average forebay elevation or forebay elevation vs. discharge curve
- can input fixed average efficiency or efficiency vs. discharge curve
- can specify maximum penstock discharge
- can adjust flow-duration curve to reflect effects of power storage (see Section 5-7m)
- can analyze either run-of-river or peaking (block load) operation (see Section 5-6g)

- will compute dependable capacity based on specified availability (Section 6-7f)
- will compute average annual energy or average energy by month or season
- will compute firm energy based on specified minimum plant factor or energy available at dependable capacity

(2) The model can also compute power benefits, estimate project costs, and select the plant size that provides maximum net benefits. The cost data and procedures used for doing these analyses were developed for the National Hydropower Study and as such should be considered applicable only to screening analyses.

(3) Documentation for the model is contained in HYDUR, Hydropower Analysis Using Streamflow Duration Procedures: Users Manual, (45). Copies of the manual and further information on using the model can be obtained from the Corps of Engineer's Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

c. NAVOP.

(1) NAVOP is a standard flow-duration model which evaluates the viability of low head hydro installations. The program is particularly applicable to for the analysis of addition of hydropower to existing low head dams. Two modes of operation may be specified: (a) run-of-river operation, where the inflow equals the turbine discharge plus the spill, leakage loss and navigation releases, or (b) limited peaking operation, where the pool is allowed to draw down during a specified length of time each day. The required data needed to run the model either in run-of-river or peaking mode are listed below:

- flow-duration curves for each month (based on either daily or mean monthly flows)
- turbine characteristics, including number of turbines
- maximum, minimum, and rated heads for the turbine
- efficiency of the turbine and generator
- minimum turbine discharge
- headwater and tailwater rating curves
- outage rate expressed as the fraction of time that the plant is shut down due to forced outages
- number of peaking hours per day
- maximum and minimum allowable pool elevations
- maximum allowable difference in tailwater fluctuation
- minimum required releases each month

(2) The model may be used to determine average monthly and annual energy available at a particular site. The program output consists of monthly duration curves of head, spill, turbine discharge, and plant capacity, for either run-of-river or peaking operation. A summary of monthly energy production, dependable capacity (based on a specified availability), intermittent capacity, and average capacity is also shown in the output. In addition, a summary of these parameters can also be provided to describe operation in the peaking mode.

(3) The model can also compute headwater elevations when only spillway discharge, crest elevation, and crest length are given. Several user-specified options are also included in the model. These options include controls for executing another simulation using the same data but varying the number and/or capacity of turbines during multiple runs.

(4) A user manual is available. For further information, contact the Plan Formulation Branch, Ohio River Division, PO Box 1159, Cincinnati, Ohio 45201.

C-3. Sequential Streamflow Routing Models.

a. General.

(1) Hand routing can sometimes be used for examination of single storage projects where non-power operation is well defined, but where non-power operating functions are complex, when storage operation is to be optimized, or where the project is to be operated as a part of a system, computerized SSR models must be used. A wide variety of seasonal SSR models have been developed over the years for estimating power potential in conjunction with other functions. Some of these models are generalized, and others have been developed to meet the needs and characteristics of a specific basin.

(2) Following are brief descriptiona of several of the most extensively used seasonal regulation models in the Corps: the Hydrologic Engineering Center's HEC-5, Southwestern Division's SUPER model, North Pacific Division's HYSSR model, and Ohio River Division's RESOP model. Other models have also been used in the Corps, including HEC-3 and models developed by the Alaska and Fort Worth Districts.

(3) Several models also address hourly problems, including, in addition to HEC-5, North Pacific Division's HLDPA model and the HYSYS model. These models are also described below.

(4) Sources of background information on the system aspects of reservoir modeling are references (19), (23), and (34). A number of modeling techniques and applications to different types of basins are described in these publications. Other information can be found in the proceedings of the American Society of Civil Engineers and the Institute of Electrical and Electronic Engineers.

b. HEC-5.

(1) General. HEC-5 is a general-purpose reservoir simulation model developed by the Hydrologic Engineering Center to evaluate a wide variety of flood control and conservation storage projects, including hydropower analysis. The program can be used efficiently for single reservoirs or for complete reservoir systems on either critical period or period of record studies.

(2) Driving Functions. The model is designed to simultaneously meet flood control criteria and conservation requirements within other operating constraints. Conservation requirements can be expressed in terms of seasonal flow requirements or seasonal generation requirements, at specific reservoirs or as seasonal flow requirements at downstream control points. Each demand may be served by one or more upstream reservoirs based upon input data. System operations are performed for flood control, water supply, and hydropower, where more than one reservoir is operated for a common location.

(3) Number of Projects. The model is presently designed to handle a total of 35 reservoirs and 55 control points, but arrays can easily be increased or decreased.

(4) Routing Interval. The model can use multi-hourly, daily, weekly, or monthly intervals. Continuous simulations can also be made using a combination of these intervals. For instance, weekly or monthly intervals can be used for non-flood periods and daily (or shorter) intervals can be used during flood periods.

(5) Channel Routing Methods. Six channel routing procedures are presently available: Muskingum, Modified Puls, Working R & D, Tatum, Straddle-Stagger, and Lag. For daily (or shorter) routing intervals, flows may be routed throughout the system in downstream sequence. Diversions may also be routed using a different routing network.

(6) Flood Control Operations. Flood control operation of projects having either gated or uncontrolled outlets is a fundamental part of the model. Reservoirs with gated outlets are operated for each time period to prevent downstream flooding and to evacuate flood control storage as quickly as possible without exceeding maximum flow levels at one or more downstream control points. Emergency gate

regulation criteria can be specified to override flood control releases for downstream locations, which are based upon seasonal balancing of input storage target levels.

(7) Power Operations. The model is designed to make power releases to meet user-specified firm energy requirements (often expressed as monthly plant factors) within non-power operating constraints. This criteria results in full use of power storage in critical water years, but in good water years, it generally maintains the reservoir as close to the top of the power pool as possible. Not specifying firm energy requirements provides an alternative strategy that will maximize the average annual energy output. Period-by-period (monthly, daily, and hourly) energy requirements can be specified, or the model can be run in an optimization mode, to automatically select the critical period and determine the maximum amount of firm energy that can be produced. Seasonal rule curve operation can be accomplished where energy requirements vary with elevation in the power pool. Pumped-storage projects can also be simulated.

(8) System Operation. Reservoirs are drafted proportionally to meet user-defined reservoir storage balancing levels to the extent possible within power and non-power operating constraints in order to meet user-specified system energy requirements for up to two different hydropower systems. Thermal loads are not simulated by the model, so they must be subtracted from the input hydropower system loads. Water supply and flood control system operation are also made based upon balancing reservoir storage levels.

(9) Documentation. A users manual, entitled HEC-5, Simulation of Flood Control and Conservation Systems, (40) is available. HEC Training Document No. 12, Application of the HEC-5 Hydropower Routines (included as Appendix K to this manual) provides additional details on the use of HEC-5 for hydropower analysis. Regularly scheduled training courses and video tapes are available from the HEC to provide instruction in the use of HEC-5. For additional information, contact the Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

(10) Applicability. HEC-5 is well-suited to examining the power potential of single storage projects or systems of reservoirs, where the projects are operated for hydropower alone or for flood control and other conservation purposes in addition to power. The model has been applied to many systems throughout the U.S. and overseas where hydropower is one of the project or system purposes.

c. SUPER.

(1) General. SUPER is a system of computer programs developed by Southwestern Division to simulate the daily sequential regulation of a multiple-purpose system of reservoirs and the corresponding hydrologic and economic impacts. The simulation is based on a specific plan of regulation, specific economic parameters, and a long period of daily hydrologic input. The model provides a way to compare alternative system regulation plans by providing hydrologic and economic results for each simulation.

(2) Driving Functions. The model is designed to simultaneously meet flood control objectives and conservation storage requirements within the specified operating constraints. Water supply requirements are expressed as seasonal pipeline system demands and seasonal streamflow requirements to be maintained at downstream control points. Eaoh demand may be served by one or more reservoirs as specified. Generation requirements are based on seasonal system load requirements and thermal purchase criteria as a function of system state. The daily generation schedule may be provided seasonally as a function of system or individual reservoir state.

(3) Number of Projects. The model is designed to handle any number of reservoir projects within the limitations of the computer system. Presently the maximum number of reservoirs included in a single model has been 40.

(4) Routing Interval. The model uses a one-day routing interval. However, the system power load filling routine is based on an hourly load requirement.

(5) Channel Routing Methods. The model uses the Muskingum Method to route reservoir releases downstream. The basic discharge hydrograph data input is total uncontrolled area flow at each stream control point and at each reservoir inflow point. These total uncontrolled area flows are developed by use of the Modified Puls streamflow routing procedure.

(6) Flood Control Operations. Reservoirs are regulated on a daily basis to stay within downstream maximum flow levels. These flow levels are expressed as a function of season and system or reservoir state. Priority of releases among reservoirs is based on seasonal balance levels which subdivide the flood control storage. On each day of the simulation, a tentative schedule of flood releases is developed for the next several days. This schedule takes into account downstream maximum flow levels, system balance and maximum allowable daily rate of release change.

(7) Power Operation. Power is produced for multiple system loads. Each particular reservoir, however, is assigned to a specific system. System loads are expressed seasonally, according to system state. Mandatory flood control and low flow releases are the first categories of flow used to generate power. Any excess energy above system local requirements is counted as dump energy. The necessity for thermal purchase as a function of system state and season is then determined. The remaindar of the load is then satisfied, if possible, taking into account available power storage, generating capacity and remaining available channel capacity. Any deficiencies are accounted for as additional thermal purchase. The daily operation factor may be expressed seasonally as a function of reservoir or system state as an option separate from the seasonal system load and thermal purchase option.

(8) System Operation. Reservoirs are operated within operating constraints as much as possible, in order to maintain seasonal reservoir balance in each system for both the flood control and the conservation storage zones.

(9) Documentation. Users manuals are available from the SWD for data base development, operation of the model, and display of the simulation and evaluation results. For further information, contact the Water Management Branch, Southwestern Division, 1114 Commerce St., Dallas, Texas, 75242.

(10) Applicability. The model is suited to the overall evaluation of multiple-purpose regulation objectives for large reservoir systems. The model's planning mode can also be used to evaluate various alternative power plants at a single reservoir by interfacing each reservoir model with the output from the total system model. The data required at the interface is the period of record daily inflows and flood pool balance levels for the reservoir being evaluated. The model thus provides an economical way to make period of record routings for the single reservoir with various power plants while maintaining flood control operations very close to those which would be obtained if the total system model had been utilized. The Tulsa District's Production Cost Avoidance (PCA) hydropower evaluation method (see Section 5-13d(3)) is incorporated in this model to develop both the hydrologic operation and the economic value of a specific hydropower alternative in a single computer run. This model requires extensive training and data base development. However, once a modeled system is established, it is relatively easy to make hydropower evaluations for various alternatives for any reservoir in the system.

d. HYSSR.

(1) General. HYSSR is a monthly sequential routing model that is designed to analyze the operation of a large reservoir system primarily for power and snowmelt flood control. The model was originally developed by North Pacific Division as a planning tool to examine alternative reservoir systems in the Columbia River Basin, and it is now being used in addition for operational planning. HYSSR has also been used in other basins as well, including the Mekong River Basin of Southeast Asia, where floods are of the monsoon type, and elsewhere.

(2) Driving Functions. This model is designed to meet a residual system power load (total system power load less expected thermal plant output) within the constraints of other project functions. These constraints include flood control, minimum in-stream flows for fish passage at downstream control points, minimum releases from individual projects for fish and wildlife and other purposes, and desired reservoir elevations for fish spawning, at-site recreation, and irrigation pumping.

(3) Number of Projects. The model currently handles a total of 150 projects, including 50 seasonal reservoirs.

(4) Routing Interval. The model normally uses a monthly interval. although half-month intervals can be used in months where reservoir operation changes in mid-month.

(5) Channel Routing Method. Because a monthly interval is used, detailed channel routing is not required.

(6) Flood Control Operation. Flood control operation is designed to simulate forecastable seasonal snowmelt floods. The actual day-by-day routing of each annual flood in the period of record is accomplished outside of HYSSR using the NPD's SSARR model (56). The results of the flood control regulation are translated into monthly guide curves and release schedules, which are provided as input to the HYSSR model. These curves and release schedules reflect the progressively decreasing uncertainty associated with a snowmelt type flood. Unless the flood control operating criteria are modified, it is not necessary to change the flood operation input from run to run.

(7) Power Operation. The objective of the power operation is to maximize firm energy load carrying capability. Rule curves are based on operation in a multi-year critical period. Because of the large size of the system and the large number of operating constraints,

optimization is done manually. The details of the Pacific Northwest power operation upon which the model is based are described more fully in Appendix L.

(8) System Operation. The major requirements which the Columbia River Basin projects must meet (power generation, flood control, navigation, fish flows, etc.) are for the most part system requirements, so the HYSSR model has been designed such that the reservoirs are operated to meet system requirements. The general objective is to proportionally draft headwater storage projects within non-power operating constraints in order to maintain head and thus maximize power production. Downstream storage projects are not usually drafted until required for flood control operation. The model is designed to handle operation of both annual and cyclical (multi-year) storage projects simultaneously.

(9) Documentation. The user's manual is entitled HYSSR (Hydro System Seasonal Regulation); Program User's Manual (46). For additional information, contact Power Section, North Pacific Division, PO Box 2870, Portland, Oregon, 97208.

(10) Applicability. HYSSR is best suited to the analysis of medium to large systems of projects where hydropower is a major function and flood control operation is well defined seasonally, such as with snowmelt and monsoon type floods. HYSSR is used in conjunction with SSARR to simulate flood control operation and with HLDPA (discussed below) to simulate hourly power operation.

e. RESOP.

(1) General. RESOP is a sequential routing model that was developed by Ohio River Division for examining the energy potential of an individual reservoir (either a storage project or a run-of-river project).

(2) Driving Function. The model is designed to operate a project to meet non-power requirements and operating constraints and, from the resulting regulation, determine the amount of power that could be produced. The simulation is based on rule curves, maximum reservoir elevation constraints defined by the flow regimes, and meeting any combination of the following operating parameters and constraints:

- reservoir surface evaporation
- minimum discharge requirements
- minimum power releases
- releases to meet non-power water requirements
- consumptive withdrawals from the reservoir
- powerplant characteristics

- tailwater constraints
- reservoir elevation constraints
- oil displacement parameters (for on-peak power)
- peaking time in hours per day

(3) Number of Projects. The model is designed to examine single projects.

(4) Routing Interval. Separate versions of the model use daily and monthly routing intervals.

(5) Channel Routing Method. Downstream effects are not considered.

(6) Flood Control Operation. For flood control projects the model follows the established (or specified) flood regulation procedures.

(7) Power Operation. The model is designed essentially to produce power while meeting non-power requirements and other operating constraints. There is no provision for seasonal regulation of conservation storage to maximize power production. However, one option evaluates the potential for peaking operation. This is done by specifying the number of on-peak hours per day in which generation is desired. The model then determines the amount of capacity that can be supported in each day given the daily average power discharge and the various operating constraints. When operating in the peaking mode, energy produced in the off-peak hours is classified as secondary energy. Dependable capacity is computed based on a specified availability (normally 90 percent) in the peak load months. Another option computes power benefits using specified regional power values.

(8) System Operation. Because the model is designed for examining single projects, system operation capability is unnecessary.

(9) Documentation. A user manual is available. For further information, contact the Plan Formulation Branch, Ohio River Division, PO Box 1159, Cincinnati, Ohio 45201.

f. HLDPA.

(1) General. North Pacific Division developed the Hourly Load Distribution and Pondage Analysis Program (HLDPA) as a planning tool to address such problems as optimum installed capacity, adequacy of pondage for peaking operation, and impact of hourly operation on non-power river uses.

(2) Driving Function. This model efficiently allocates a residual hourly power load to hydro projects in a system while meeting non-power operating constraints.

(3) Number of Projects. HLDPA is designed to handle a total of 50 projects, including both run-of-river and storage projects.

(4) Routing Interval. The model uses an hourly interval and examines one week at a time.

(5) Channel Routing Method. A simplified channel routing technique routes streamflow from project to projects. A more sophisticated model, such as SSARR (56) or SOCH (Simulation of Open Channel Hydraulics) should be used to examine water surface fluctuation at intermediate points on a reservoir or at downstream points. Hourly project discharges from HLDPA are used as input.

(6) Flood Control Operation. HLDPA uses monthly average project discharges and reservoir elevations from HYSSR (or another seasonal model) as input data, and these values reflect seasonal operation for flood control as well as seasonal storage regulation for power and other conservation functions.

(7) Power Operation. (See paragraph (2), Driving Function, above). The residual load to be met is the difference between total system hourly load and the expected load to be carried by thermal generation. This results in hydro normally being assigned to carry the peaking portion of the load. Pumped-storage can be included as a specific project.

(8) System Operation. Hourly loads are allocated among projects in accordance with plant generating capability, hydraulic capacity, operating constraints, and characteristics of adjacent plants.

(9) Documentation. A user's manual for the Hourly Load Distribution and Pondage Analysis Program, commonly known as the "Pondage Program," is available from NPD (42). For further information, contact Power Section, North Pacific Division, PO Box 2870, Portland, Oregon, 97208.

(10) Applicability. HLDPA is a planning tool and is best suited to examining hourly operation of peaking projects as a part of a system. It would normally be used in conjunction with a seasonal routing model such as HYSSR or HEC-5. The seasonal model would be used to develop the basic regulation using a weekly or monthly time interval, and HLDPA would be used to examine selected weeks in detail.

g. HYSYS.

(1) General. The Hydropower System Regulation Analysis (HYSYS) computer program was originally developed by the North Pacific Division, Corps of Engineers. The program is generalized so that it can be adapted for use on most hydropower systems where simulation of real-time conditions are desired. The program performs sequential river and reservoir routings that simulate reservoir regulation to meet a system power load. Emphasis is given to the evaluation of short-term projections, such as hourly generation determinations. While it was developed primarily as an operational tool, it can also be used in project planning in situations where detailed hourly simulations are required.

(2) Driving Functions. This program is designed to meet a residual system power load (total system power load less expected thermal plan output) within the constraints of non-power project functions. These constraints include flood control, minimum instream flows for fish passage and navigation, minimum releases from individual projects for fish and wildlife, and desired reservoir elevations for fish spawning, at-site recreation, and irrigation pumping. Given the projected system power load, fixed thermal generation schedule, and projected inflows, the program simulates the allocation of power to the individual projects Some projects may be constrained by specific schedules of releases or elevations, while others operate on power load control to meet the remaining system load. The program is also capable of simulating predetermined regulation schedules at all projects in order to provide the resultant system generation. The program does not contain optimization procedures, but optimal or desired regulation ranges are specified to the program and the program operates within the desired ranges to best meet the system load.

(3) Number of Projects. The program handles a total of 30 control points. A control point can be either a river station or a project.

(4) Routing Interval. The routing interval for projects can be as short as one hour or as long as 24 hours. Routing intervals for river reaches can be as short as one minute, but intervals of one hour or longer must be multiples of 60 minutes. This feature allows the program to more closely simulate the dynamic process in channel flow by placing emphasis on determining the tailwater elevations for detailed generation analysis. The program is capable of routing up to 168 periods. Therefore, the program can simulate a full week of hourly regulation. Using routing intervals of one day, a total of 168 days can be simulated.

(5) Channel Routing Method. The program uses the channel storage routing procedure to simulate river and flow/stage characteristics. Channel routing is accomplished as a series of incremental river reaches described in terms of storage/stage vs. discharge.

(6) Flood Control Operation. The model does not in itself perform flood control regulation, but uses as input data streamflows which already reflect flood regulation.

(7) Power Operation. The basic power operation procedure is described above, under paragraph (2), Driving Functions. Individual generating unit characteristics are described in the program, and units are loaded to take advantage of the best operating efficiency. By doing so, the program determines the optimum number of units required to meet various loads.

(8) System Operation. The program can operate in two different modes: (a) a system load is provided and generation is allocated to individual projects, or (b) a scheduled discharge, generation, or pool elevation pattern is provided and the resulting system generation is computed. The general objective of the system load mode is to proportionally draft or fill headwater storage projects to meet desired system generation targets. At the same time, pool fluctuations are minimized at pondage projects to maximize power production. The same general approach is followed in mode (b), except that pre-specified project operating data constrains the operation.

(9) Documentation. The user manual is entitled Hydropower System Regulation Analysis. For additional information, contact Chuck Abraham, Central Valley Operations Office, Bureau of Reclamation, 2800 Cottage Way, Sacramento, CA 95825.

(10) Applicability. For planning purposes, HYSYS is best suited for detailed hourly examination of individual power projects or groups of projects under varying operational assumptions. For example, the project or projects could be tested under different power loadings to determine adequacy of pondage, impact on tailwater elevation, etc. HYSYS requires more detailed input data than HLDPA, and is thus more cumbersome to use, but it has the advantage of being able to examine the impacts of specified project operations. HYSYS has also been used in planning day-to-day project operation.

C-4. Hybrid Method.

a. General. North Pacific Division's DURAPLOT is the only specifically designed hybrid model currently being used in the Corps.

It was developed primarily to examine the installation of power at existing non-power storage projects but has also been used for run-of-river projects. Similar routines could also be added to system regulation models such as HEC-5 and SUPER to access the output files from the system studies. These could be used in conjunction with output files for detailed examination of single projects, and thus it would not be necessary to rerun the entire system model for each alternate power installation.

b. DURAPLOT.

(1) Description. DURAPLOT is used to estimate the generation potential of a specific plant. Given the appropriate input data, the program uses the power equation,

$$P = \frac{QHe}{11.81} \qquad \text{(Eq. 5-2)}$$

to compute the average plant generation for each day in the period of record. The resulting daily generation data is then used to produce power-duration curve plots and tables, which summarize the plant capacity and energy potential. The program allows the user to place separate minimum and maximum head and flow constraints on each turbine-generator unit. Thus, the user is able to study, with minimal effort, any number of possible unit configurations using daily hydrologic data.

(2) Options. DURAPLOT normally accesses historical streamflow records, although any user-supplied streamflow and reservoir elevation data could be utilized. Options are listed below:

- can do analysis of total year, months, or a user-specified multiple-month peak demand season.
- will account for upstream diversions or losses at the dam.
- can input tailwater curve. fixed average tailwater elevation, or can input historical tailwater data if the elevation varies independently of flow.
- can input fixed average efficiency or efficiency as a function of head.
- will compute average annual energy or average energy by month or season.

- can define head loss either as a fixed value or as a function of flow.

- dependable capacity computed as average power output in peak demand season (average availability method, Section 6-7g).

- can use a fixed average forebay elevation or a seasonally varying forebay elevation (to reflect the seasonal use of flashboards at run-at-river projects).

- can specify the use of multiple units with varying head ranges.

- can examine projects where the reservoir fluctuation range exceeds the operating range of a single turbine.

(3) Input Data. Input data would be essentially the same as for the flow-duration curve method except that daily values of reservoir elevation must be provided in addition to daily streamflow values. This data could be obtained from USGS records, project operating records, or from system regulation models such as SUPER. As with the flow-duration method, daily data would be used in most cases.

(4) Output. Monthly, seasonal, and annual power-duration (Figure 5-60), flow-duration, and head-duration plots are available, as well as a bar chart showing monthly distribution of energy production (Figure C-1). The flow-duration and head-duration curves are useful in selecting turbines, and the monthly energy distribution chart is helpful in assessing marketability of the power.

(5) Sources of Information. Further information on DURAPLOT can be obtained from Power Section, North Pacific Division, PO Box 2870, Portland, Oregon, 97208.

(6) Applicability. The Corps of Engineers has used the DURAPLOT program primarily to study the feasibility of installing power at already existing non-power projects. These include both non-power storage projects and run-of-river projects. The power-duration feature of the program makes it particularly useful when studying a project that experiences a large range of head.

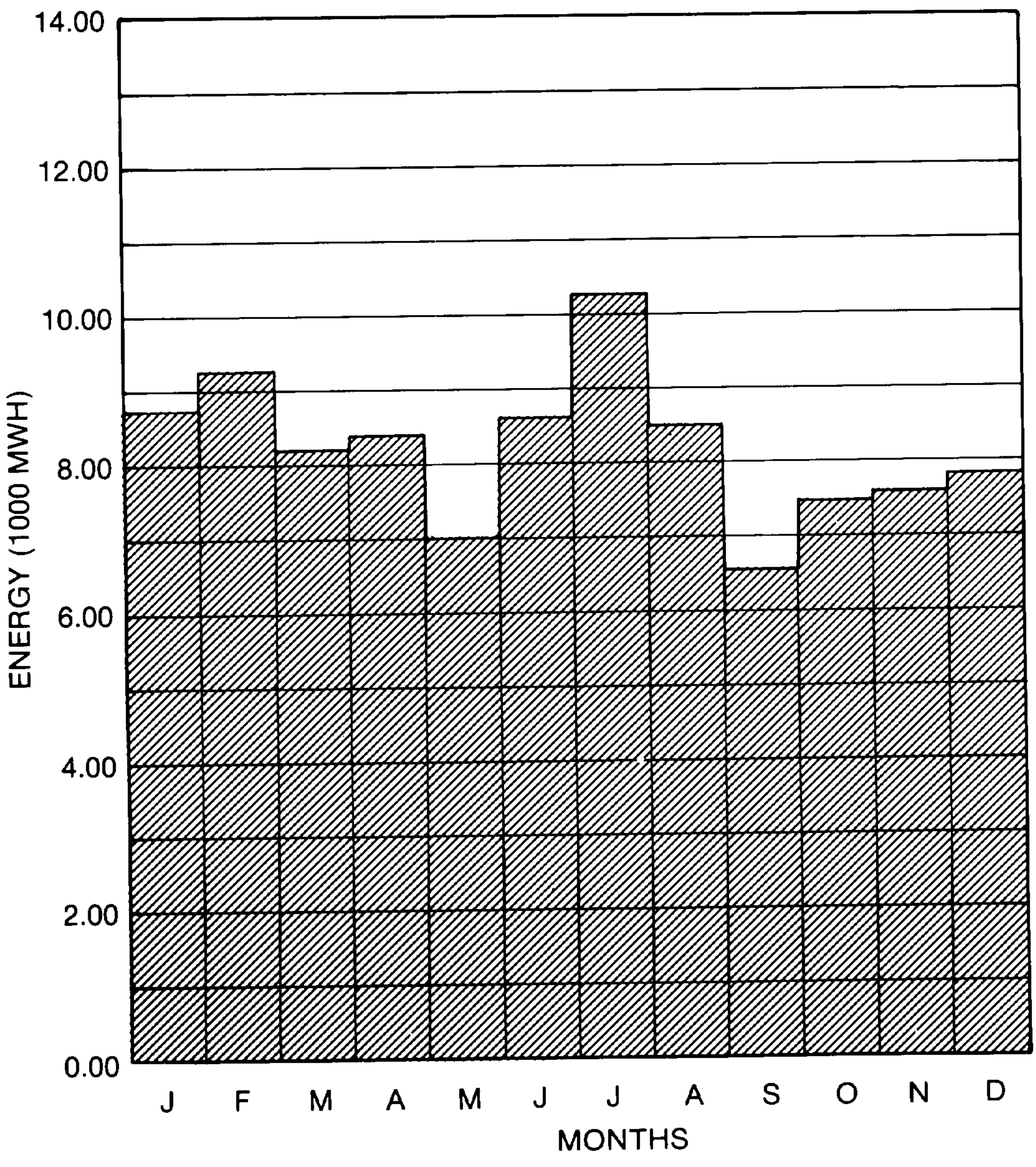

Figure C-1. Average monthly energy output from DURAPLOT model