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River System Modeling for Operational Forecasting

by

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The National Weather Service, National Oceanic and Atmospheric Administration, Department of Commerce, is responsible for issuing river and flood forecasts in the United States. The forecast service is under the direction of the Office of Hydrology, National Weather Service, with operational forecasting accomplished by twelve River Forecast Centers.

The establishment of the River Forecast Centers was begun in 1946. The forecast procedures used were based on graphically developed procedures, such as the Antecedent Precipitation Index and unit hydrograph approach as described by Linsley, et al. (1958). The first adaptation of high-speed computers in the river forecasting program was to computerize the original manual forecast procedures. Since the introduction of computers, the river forecast offices have initiated methods to automate data collection and processing, forecast preparation, and the distribution of warnings and forecasts. Sittner (1973) has discussed the updating of the river forecasting service in the United States.

The Hydrologic Research Laboratory of the Office of Hydrology is responsible for research and development support for the river forecasting program of the National Weather Service. Research efforts in the past have been primarily devoted to studies on the physical processes in the hydrologic cycle that could lead to improvement in forecast procedures. Recently, the Laboratory set a goal to develop forecast procedures which would maximize the usefulness of modern-day data acquisition and processing techniques and incorporate the use of a conceptual hydrologic model. The term "conceptual model" refers to a simulation model of the hydrologic cycle in which each significant physical component is represented. A few of the River Forecast Centers have developed or adapted conceptual models, but such models have not been in general use.

A recent publication, NOAA Technical Memorandum NWS Hydro-14 (NOAA 1972), describes the resulting procedures. The publication was prepared for use as a guide by the River Forecast Centers in developing and adapting the procedures throughout the United States. Since the information is of general interest to others working with hydrologic modeling, the publication has been given wide distribution.

The techniques and computer programs described in NWS Hydro-14 have been generalized for use on any river system, except for those portions of rivers subject to major backwater effects, and require a large computer. Some of the techniques have been adapted for limited use on smaller computers. The programs and techniques cover all phases of development, including the acquisition and processing of basic data, the calibration of model parameters, and operational forecasting procedures.

Acquisition and Processing of Basic Data

One of the primary reasons conceptual hydrologic models have been used only to a limited extent in operational river forecasting has been that continuous data are required for model calibration. It has been difficult to obtain continuous data for large areas in a form suitable for direct computer use. Efforts have been successful in arranging for hourly precipitation data and records, including daily precipitation, from the nearly 12,000 daily climatic stations in the United States to be available on magnetic tape in a format especially suitable for use in hydrologic modeling. These tapes are now available from the National Climatic Center (NCC), Environmental Data Service, NOAA, Asheville, North Carolina (NWS Office of Hydrology format).

At the present time, all hourly precipitation data since January 1948 and daily climatological data for the period since October 1963 can be obtained in the hydrology format. The remaining daily data back to 1948 are being placed on the NCC master tapes and should be ready for processing to the hydrology format by the end of 1974.

The U.S. Geological Survey can make available magnetic tapes of all daily streamflow records that have been published by that agency. A program for processing these tapes is also contained in the NWS Hydro-14.

Processing of basic data with the exception of those used in determining the channel response function are handled automatically. Techniques are described for computing average areal values of precipitation for six-hour intervals using the available basic data.

Methods are also presented for computing potential evapotranspiration for use in the soil-moisture accounting component of the conceptual catchment model.

A second factor which has somewhat inhibited the operational use of conceptual models has been the inadequacy of the data acquisition systems to provide and the inability of small computers to assimilate the large amount of data required on a real-time basis. General improvements have recently been initiated to increase the number of stations reporting automatically. One of the planned programs is to have hydrologic data collected via a Geostationary Operational Environmental Satellite (GOES) as discussed by Flanders and Schiesl (1972). The GOES spacecraft will have the capability of continuous collection and relay of data from 10,000 or more observing platforms within each six-hour period.

Catchment Model

The conceptual catchment model (for soil-moisture accounting) described in the forecast procedures was selected on the basis of results from a research project in which four models were evaluated. The models were tested on the following six river basins representing various climatic and hydrologic regimes of the contiguous United States:

Mad River at Springfield, Ohio (1,256 k^2);

Bird Creek near Sperry, Oklahoma (2,344 k^2);

French Broad River at Rosman, North Carolina (176 k^2);

Monocacy River above Jug Bridge near Frederick, Md. (2,116 k^2);

Meramec River near Steelville, Missouri (2,022 k^2);

South Yamhill River near Whiteson, Oregon (1,300 k^2).

Based on the results of the statistical analyses of the comparison tests, a modified version of the Stanford IV Model (Crawford and Linsley 1966) was selected for use in the present report and for the initial model to be used in field application.

Research on improvement of the catchment model and evaluation of other hydrologic models is a continuous effort. The forecast procedures are not dependent upon any specific model or type of catchment model. A revised or improved model will be incorporated into operational use as added value is demonstrated. All of the programs in the forecast procedures have been prepared in modular form so that individual sections may be modified or replaced with a minimum of effort.

Parameter Optimization

The parameter optimization technique used in the calibration of the moisture accounting and channel routing components of the model consist of both manual fitting and the application of a direct-search approach described by Monro (1971). Initial values for some of the parameters may be estimated from hydrograph analysis and typical ranges of parameter values are included for the guidance of those without experience with the catchment model. The channel routing technique used in the present model is Lag and K routing as described by Linsley, et al. (1958). Provisions are included for use of variable Lag and K and the future addition of other routing methods.

Future Additions

The modular form of the procedures permits the incorporation of additions and improvements with a minimum of effort. Two major additions are now being developed. The first will contain methods for adapting the procedures to areas with snow. The report will

also include techniques and computer programs to compute six-hourly mean areal air temperature from daily maximum and minimum temperature records.

A second supplemental report will contain programs for incorporating an implicit river routing technique for use on major rivers where serious backwater problems are encountered due to interconnected river systems or tidal effects.

Field Application

The usefulness of the procedures has been field tested. In late 1971, a new River Forecast Center was established at Slidell, Louisiana for the Lower Mississippi River Basin. Only a limited number of forecast procedures had previously been developed for this section of the United States. Procedures were developed using the techniques described in NWS Hydro-14 for a large section of the area. The major flooding which occurred over the Lower Mississippi Basin during the spring of 1973 provided a severe operational test of the utility of the procedures. The new procedures accurately predicted record high discharges for four headwater basins to within a few tenths of a foot. For the area as a whole, the model responded exceptionally well to the unusual moisture conditions and the predicted hydrographs closely followed the observed, as well as providing very satisfactory forecasts of peak streamflow.

Program Availability

All programs for the development and operational use of the forecast procedures described in NWS Hydro-14 are available on magnetic tape from the Acquisition Office, National Technical Information Service, U.S. Department of Commerce, Springfield,

Virginia, 22151. The magnetic tape containing the computer programs and test data may be ordered for $97.50 using the order number COM-73-10298.

References

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