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Computer Programs in Water Resources

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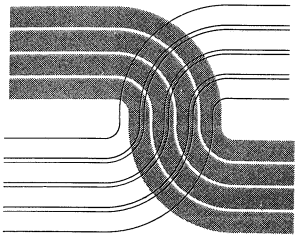

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Computer Programs in Water Resources: Scope and Availability

by

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I. Introduction

The objective of this research study was the review of selected computer programs in the field of water resources with the aim of assisting in the application of these programs by potential users. Research and design efforts in this field have resulted in the development of many computer programs. Some of these are of primary interest to those in the research phase of water resources. Others may be initially of interest to research people but will be used for design purposes as information on and confidence in the programs develop. Other programs are based on well known procedures and as a result have immediate application to design problems. The second and third types of programs are of primary interest in this report, but some programs of all three groups have been included.

Concern is frequently expressed by design-oriented engineers over the problem of communication between research and design hydrologists. The designers are actively interested in mathematical modeling of hydrologic processes but are faced with a difficult choice as to which models to use. A solution to this problem may not be available at this time because new models are continuously being developed and these will require considerable testing and evaluation before they find general acceptance.

Relative to initial applications of computer programs in Water Resources, the late 1950's and early 1960's are associated with significant developments in this field. In 1958 the U.S. Army Corps of Engineers embarked on a study to utilize computer techniques in the water resources field. Working in cooperation with the National Weather Service, this led to the development of the SSARR (Streamflow Synthesis and Reservoir Regulation) Model. In 1959 the Stanford University Research Program in digital simulation techniques was initiated by Crawford and Linsley resulting in the development of the Stanford Watershed Model series (Appendix 1).

While many organizations, both governmental and private, were developing computer programs in the 1960's, the development of the Corps of Engineers Hydrologic Engineering Center (HEC) is worthy of noting. This organization produced about 28 programs of interest in the field and also initiated a training program for Corps of Engineers personnel, but also available to others, concerning computer applications and hydrologic engineering.

The passing of the Water Resources Research Act in 1964 and the development of the Office of Water Research and Technology and of Water Resources Research Centers in each of the States resulted in a very active research program in the Water Resources field and the development of many computer programs and simulation models.

Other federal agencies active in this field include the Agricultural Research Service, the Soil Conservation Service, the Bureau of Reclamation, the Environmental Protection Agency, and the U.S. Forest Service. The Tennessee Valley Authority and many state agencies have also made significant contributions.

The initial objective of some of these agencies was the adaption of existing methods to digital computer solution techniques. In the process, it was sometimes possible to introduce much more sophisticated procedures than were possible with desk top calculators while still retaining the basic principles associated with accepted design procedures.

Some of the programs prepared by the Corps of Engineers Hydrologic Engineering Center were based on Corps of Engineers methods, such as unit hydrograph theory and various "hydrologic routing" procedures. However, in some instances HEC has incorporated features that were not feasible prior to the advent of the digital computer. For example, a loss-rate routine using four variables has been used in several programs for hydrograph analysis, in place of the $\emptyset$ index. Another very valuable feature of some of these programs is an optimization process based on fitting of observed events to assist in an evaluation of variables or parameters in the program.

Two of the HEC programs receiving considerable use by both governmental and private organizations are HEC1 - Flood Hydrograph Package and HEC2 - Water Surface Profiles.

The HEC programs are well documented relative to the purpose of the program, identification of variables, and explanation of input and output procedures. However, they often presume a knowledge of Corps of Engineers design procedures and this can cause difficulty in the use of some programs.

The Soil Conservation Service has also prepared a series of programs that are well documented and of considerable interest to the applied hydrologist. One of these, the TR-20 PROGRAM concerns the computation, combining, and routing of hydrographs for a series of the sub-watersheds of a larger watershed. This has been widely used for both rural and urban studies. A second program, DAMS2, is for the study of the effect of variations in the number and characteristics of proposed flood retarding structures in the watershed upon flows; a third is a water surface profile program (WSP2). The SCS programs use some basic procedures associated with that agency while utilizing the computer to the best advantage.

The Bureau of Reclamation has in excess of 50 programs covering a variety of hydrologies and hydraulic topics. These were originally listed in "Abstracts

of Computer Programs Developed by the Bureau of Reclamation", Electronic Computer Programs Abstract Issue No. 4, May 1966 and Abstract Issue No. 5, February 1969. The latest information received on them consists of loose-leaf tabulations listing the name, language, CM size and the availability of documentation. Some of these programs are described in the annotated bibliography of Appendix 2. Several programs concerning water quality appear of special interest.

The National Weather Service has developed a number of computer programs of interest to the river hydrologist. These include the National Weather Service River Forecast System (NWSRFS3,4,5)[97] and a "Generalized River Forecast Program", RIVALL, described by R.H. Dickson of the Kansas City offic. This is based in part on the API Model. As noted above, the National Weather Service collaborated with the Corps of Engineers on the SSARR Model. R.J.C. Bernash and R.L. Ferrol of the National Weather Service and R.A. McGuire of the California Department of Natural Resources collaborated on "A Generalized Streamflow Simulation System" (sometimes referred to as the Sacramento Model). Of these, the SSARR Model appears to have received the most attention outside of the Weather Service. At the University of Minnesota, St. Anthony Falls Hydraulic Laboratory the SSARR and NWSRFS have been implemented and the Kansas City version of the API Model is currently being implemented.

Several programs developed or sponsored by the Environmental Protection Agency (or its predecessors FWPCA or FWQA) have been reviewed. One of these is for optimization of water quality in streams and others relate to urban runoff. The EPA Storm Water Management Model (SWMM) developed in cooperation with the University of Florida, the consulting engineering firm of Metcalf and Eddy, and Water Resources Engineers, Inc. is receiving considerable attention. A quality model QUAL-2 (Appendix 1) is widely used.

As noted above, the development of the Office of Water Research and Technology (formerly Office of Water Resources Research) and the creation of Water Resources Research Centers in each of the states has resulted in extensive research funded by the Federal and state governments. Other state and University research has been funded in part by the National Science Foundation, the Federal Highway Administration, and the Corps of Engineers. The well-known Stanford Model [E-5] sponsored in part by NSF and Stanford University and developed by N.H. Crawford and R.K. Linsley is a particularly noteworthy development involving University and Federal cooperation. The computer program associated with this model was initially written in a form of Algol. It has since been rewritten in Fortran by L.D. James, formerly at the University of Kentucky and referred to as the Kentucky Model or as the Kentucky-Stanford Model. It has also been rewritten in Fortran by the National Weather Service, W.L. Moore and associates at the University of Texas, and V.T. Ricca at the University of Ohio. The second edition of the book, Hydrology for Engineers, by R.K. Linsley, M.A. Kohler, and J.L.H. Paulhus contains a chapter on "Computer Simulation of Streamflow" which includes a discussion of modeling procedures. The Solutions Manual for this book announced the availability of a Fortran version of SWM through the firm of Hydrocomp. A copy of this translation was obtained and

successfully operated. A new model has been developed by B.J. Claborn and W.L. Moore as a result of their work on the Stanford Model.

A number of reports or papers have been published in which comparisons have been made of various computer programs on the same subject. Of special interest are the following:

1. "Survey of Programs for Water Surface Profiles", by Bill S. Eickert, [31].
2. "A Critical Review of Currently Available Hydrologic Models for Analysis of Urban Stormwater Runoff", by R.K. Linsley, [81].
3. "Models and Methods Applicable to Corps of Engineers Urban Studies", by J.W. Brown, M.R. Walsh, R.M. McCarley, A.J. Green, Jr., and H.W. West, [17]. An outstanding report.
4. "Comparative Analysis of Urban Stormwater Models", by Albin Brandstetter, [14].
5. "Urban Hydrological Modeling and Catchment Research in the U.S.A.", by M.B. McPherson, [91].
6. "Comparative Evaluation of Three Urban Runoff Models", by J. Marsalek, T.M. Dick, P.E. Wisner, and W.G. Clark, [88].
7. "An Independent Evaluation of Three Urban Stormwater Models", by D.P. Heeps and R.G. Mein, [61].
8. "Comparison of the Georgia Tech, Kansas, Kentucky, Stanford, and T.V.A. Watershed Models in Georgia", by Alan M. Lumb, [86].
9. "Critical Review of Currently Available Water Quality Models", by P.S. Lombardo, [168].

Textbooks and reference books containing comparisons of various programs and the principles associated with mathematical simulation models include the following:

1. "Computer Simulation Techniques in Hydrology", by George Fleming, American Elsevier Publishing Co., 1975 (Appendix 2).
2. "Computer Simulation of Water Resources Systems", Edited by G.S. VansteenRiste, North Holland Publishing Co., 1975.
3. "Treatise on Urban Water Systems", Edited by M.L. Albertson, L.S. Tucker, and D.C. Taylor, Colorado State University, July 1971.
4. "Systems Analysis and Water Quality Management", by R.V. Thomann, McGraw-Hill, Inc.
5. "Stormwater Modeling", by Donald E. Overton and Michael E. Meadows, Academic Press, 1976, 358 pp.

The "Handbook of Applied Hydrology" edited by Ven Te Chow, McGraw-Hill, 1964, contains a chapter on "Application of Electronic Computers in Hydrology". While

extensive developments have occurred since the book was published, the chapter on computers is still of interest. However, of primary interest is the excellent overall summary of information on Hydrology and Water Resources contained in the 29 chapters by various authors, including 6 chapters by the Editor-in-Chief.

Currently, numerous short courses, seminars, and symposiums are conducted each year. Proceedings of one such symposium of special interest is "Mathematical Models in Hydrology Symposium, Vols. I, II, III", Proceedings of the Warsaw Symposium, International Association of Hydrological Sciences, July 1971.

II. Evaluation of Programs and Models

The evaluation of computer programs and models is a very difficult task. The results and value of such evaluations depend on the experience and ability of the person making the evaluation as well as on the quality of the model and the data used for comparison. The more complex models require many runs over a period ranging from 2 to 12 months for a person to become familiar with the performance and limitations of the model.

One method of evaluation, for a runoff model, involves the input of data for a past storm and the comparison of computed and observed runoff rates. Frequently, several models are compared for the same area and storm. If the model does not have a self-optimizing routine, it is necessary for the user to make sufficient runs to insure an optimum solution. If sufficient runs have not been made, the comparative results may be misleading.

In the present study information was assembled on several hundred programs. As it was not possible to compile and use all of these programs, it was decided to use the following procedure:

1. Select about 28 programs of special interest for actual use in the study. (Appendix 1)
2. Provide an annotated bibliography of a much larger (about 390) list of programs. (Appendix 2)

As a result of initial work with some of the urban runoff models, it became apparent that measured urban runoff data were not in a form readily usable in some models. It was then proposed that some data be assembled and put in a form such that potential users could easily use it in selected models. This developed into a difficult task. While data were assembled on four selected catchments and prepared in a form for use in several models, it was decided to omit this information from the report due to space limitations.

There is a serious need for data, particularly in urban areas, in a form that will permit its use in a variety of models. Many consulting engineers continue to place full reliance on the Rational equation because it is difficult to use and compare simulation models.

The American Society of Civil Engineers Urban Water Resources Research Program was developed to coordinate long-range research in urban water resources. Program Director for this program was M.B. McPherson. Sponsorship of portions of the program has been by the Office of Water Research and Technology. These studies have resulted in a very significant contribution to urban runoff analysis in the form of 24 excellent technical memorandums; some of these provide information on simulation models and urban runoff data. The reports are available through the National Technical Information Service.

Summary

1. Information on computer applications in Water Resources has been assembled.
2. Twenty-eight were selected for study and in some cases operation. Detailed abstracts have been provided in Appendix 1.
3. An annotated bibliography on 390 computer programs in Water Resources has been provided as Appendix 2.
4. Brief descriptions on eight books of special interest has been provided as Appendix 3.
5. A list of 177 references supplements the Annotated Bibliography.

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