

The assistance of digital computers in hydrologic research and its consequences¹

D.L. Chery, Jr.²

ABSTRACT: The digital computer is now an indispensable tool in the processing of hydrologic data. Further, it has become an indispensable assistance in the analysis of collected data and information. The ultimate consequence of this assistance will be the direct interfacing of computers with the experiment. Immediate consequences of the presence of computers are the need to reduce to digital form great masses of accumulated records; the reconsideration of experimental designs; the development of improved instrumentation and data acquisition systems; and the adjustment in thinking to realize the potential of computer assistance.

RÉSUMÉ : Actuellement l'ordinateur digital est un instrument indispensable pour le traitement des données hydrologique. De plus, il est devenu une aide indispensable dans l'analyse de l'information et de données recueillies. La conséquence finale de cette aide sera la confrontation direct des ordinateurs et de l'expérience. Parmi les conséquences immédiates de l'existence des ordinateurs figurent: — le besoin de réduire sous forme digitale de grandes masses d'archives accumulées; — la reconsidération des dispositifs expérimentaux; le développement d'une instrumentation et de systèmes d'acquisition des données; et le changement de mentalité de façon à ce que soit réalisé toute la puissance de l'aide que peuvent fournir les ordinateurs.

INTRODUCTION

Mesthene (1968) in a discussion of the interaction between the social structure and scientific research refers to the influence of fashions in science and illustrates his point with our "present-day passion for computers and computer science" (Mesthene, 1968, p. 138). Indeed the passion for computers is pervasive, and it has gained more than a foothold in hydrologic research. Now even symposiums (such as this one) are being held to help researchers understand this passion and to adjust their scientific thinking to better accommodate it.

The digital computer has become an extremely helpful tool in hydrologic research; in fact, it is becoming indispensable. It processes and analyzes the data from which the researcher gains knowledge. More and more the computer becomes an integral part of the experiment and eventually, it will likely be controlling the design and operation of extensive experimental projects.

PROCESSING DATA

The processing of data is a major present use of digital computers in hydrologic research. This processing may be structured as data checking, data tabulation, and data storage and retrieval. It is evident that many agencies and organizations are using, to one degree or another, computers to process the data collected in conjunction with their hydrologic research. In the past few years, articles have appeared in the literature describing the

1. Contribution of the Southwest Watershed Research Center, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Arizona Agricultural Experiment Station, Tucson, Arizona.

2. Research Hydraulic Engineer, Southwest Watershed Research Center, USDA, Agricultural Research Service. Soil and Water Conservation Research Division, Tucson, Arizona.

computer programs and procedures of various groups to process groundwater, rainfall, runoff, sediment, vegetation, soil, meteorological, and other hydrologic data. As an illustration of these programs and procedures, I shall describe those of the Southwest Watershed Research Center, Agricultural Research Service, with which I am familiar. However, they will, in general, be representative of what is developing everywhere.

Data are collected in the field or in the laboratory and conveyed to the data processing group. The data can be collected in either analog or digital form on any recording form—recorder charts, magnetic tape, punched tape, tabulation sheets, etc. and then transcribed. The operation I am using as an illustration processes primarily rainfall and runoff data gathered at five field locations operated by the Research Center.

Analog rain gage charts are received from the field, cursorily checked and receipts returned to the field with comments about the quality of record. The charts are then coded and the record digitized by either keypunching or using a chart reading device. The punched card record is transferred to magnetic tape by a small "Pre-Check Program." From this point on, only the record on the magnetic tape is used. The process of getting the record to its place on a magnetic tape requires much manual handling. Naturally, errors have accumulated (in our case about 5 errors per 100 cards) which can be detected by a logical check of the record. This is a formidable manual task but a natural one for a computer. Thus, a checking program has been prepared which makes over thirty logical checks on the data and provides a listing of the data with the errors or possible errors noted. The staff then checks the errors and prepares correction cards which are read by another small program and used to correct and update the data filed on the magnetic tape.

The data are now ready for tabulating—applying any necessary correction factors, making the calculations of basic quantities as well as any summaries that will be used in analysis. The tabulation of our Center's rainfall data is rather extensive and requires a lengthy and elaborate computer program to perform the task. The rainfall data tabulation program calculates the military time, elapsed time, rainfall intensity, total storm depth, daily, monthly and yearly rainfall totals, maximum depths for selected time intervals, centroid of the histogram, and the metric equivalent for all the depth values. In addition it makes corrections, adds notes, and prints comments in the output when instructed by special cards in the data.

The processed data are placed on two separate output magnetic tapes (one containing primary data, rainfall times and depths, and the other the secondary information such as the maximum depths, and centroid calculations). An index of the tapes is kept in a data library; thus the information is available to the staff for any particular use they desire.

The discharge records are processed in a similar way and any other data or information could also be processed similarly. For example, Schreiber (1967) has prepared a computer program to calculate particle size distribution and make the textural classification of soil samples collected in his research work.

ANALYSIS OF DATA

With the data in digital format and stored on magnetic tape, punched tape or punched cards, it is ready for any amount of "massaging" on the computer by the researcher. Any of the common statistical analyses can be made of the data. For instance the University of Arizona Computer Center has a computer system library with a standard analysis of variance program which has been used by our staff. Such computer library programs are a standard part of any computer center, and anyone having access to a computer should have such standard programs at his disposal. But when necessary, we have prepared our own statistical programs, such as a multivariate analysis and a Duncan multiple range test (Sutter and Schreiber, 1968). Anyone who has attempted the laborious

sums of products and cross products, square roots and nearly impossible matrix inversions of statistical calculations appreciates the assistance of a computer. It will calculate in seconds what used to take hours, days, and even months.

Models or hypotheses can readily be tested when the data are in digital format and the programs are available to make the analysis. Again, many computer centers have library solution programs such as a multiple linear regression program available to our staff in the computer library at the University of Arizona. But any hypothesis or idea can readily be tested with all the data at one's disposal—that is if it has been prepared and is stored in forms ready to be digested by a computer.

Further, the computer can easily summarize, reformat, and prepare graphical displays of data and information. All of these can be used by the scientist for making decisions, interpreting, and formulating new ideas.

EXPERIMENT AND COMPUTER INTERFACED

Eventually researchers in hydrology will have computers directly connected with their research in the laboratory and the field; that is, provided that society is willing to make the investment in hydrologic research that they are now making in some other fields. Presently neurological and psychological research is being done in some university centers in which the output from sensors placed in the nervous systems of animals or insects are connected directly with a computer where they are analyzed in "real time". Cathode ray scope displays are made of the results, and the experiment continues along a programmed course or adjusts itself with instructions from the researcher. All along the way a conceptual or mathematical model of some aspect of life is being developed and refined at an extremely rapid pace.

CONSEQUENCES

Mesthene (1968, p. 138) in his article "How Technology Will Shape the Future" proclaims that "...once a new technology is created, it is the impetus for the social and institutional changes that follow it." An immediate ramification of the computer technology is a problem of the availability and suitability of data. Often researchers in hydrology found they had useless data or, more commonly, insufficient data for the numerous analyses possible with the aid of a computer. As usual with our short sightedness, "we got caught with our pants down." In some cases there existed an abundance of data, but to great dismay, it was unacceptable to the new tools. So some investigators began vigorous programs to place the data in a useable format (punched cards, magnetic tapes, etc). Still, they continued collecting data in an archaic and cumbersome fashion.

But if this is the immediate consequence, what possible things does this recent innovation in technology portend for future hydrologic research. First consideration must be in the realm of experimental design. And possibly the objectives themselves need to be reoriented. It is obvious that a greater amount of data and a greater number of variables or parameters can be scrutinized with the aid of the computers. This fact reflects on the instrumentation and methods used to gain the data. Instruments that record in a format that can be fed directly to the computer must be obtained and used, and arrangements that facilitate these procedures must be instigated. Further, more experiments must be designed with other technologies in mind. For instance, voluminous amounts of data can now be quickly collected using the entire spectrum of electro-magnetic imagery from airplanes and satellites. With the assistance of the computer, this type of information can be easily processed and analyzed. But rather than just being able to manipulate greater and different amounts of data, thought must be given to how the society will gather its

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information in the future. Shouldn't the researchers be developing some models which will be relevant to the data collection systems of the future?

The nearly unlimited capability of the computer to consume data means that the cost of data acquisition can increase many times over what it is now. If the potential assistance of the computer is to be realized, this investment in data acquisition will have to be made. I have no estimates of budget proportions, but I can speculate that for a given computer assistance, every unit of investment in complementary data acquisition will have a return of several times in increased research production. In fact, if a research organization is to survive in a modern industrialized society it will be forced to make this investment. As Mesthene (1968, p. 137) states: "...economic pressures argue for the greater efficiency implicit in a new technology."

The impact of the technology is not only on the objectives and methodologies of the research but also on the entire organization. Nowadays, for effective research to be done the organization must provide the researcher with computer assistance. This means more than just arranging time on a computer somewhere. The researcher must be able to instruct the computer to do his bidding. The time will soon pass when every researcher has only to learn a little Fortran to have the computer at his beck and call. Thus the research organization must provide programming support service for its scientists; just as it should provide administrative, secretarial, library and other support services.

These innovations in technology require a readjustment, a reorientation, in the attitudes and perspectives of the persons leading, guiding and supervising the research organization. They must divine the potential of the new technology, readjust their organization to make maximum benefit of the new tools and employ those researchers conversant with the new methodologies.

SUMMARY

It is now obvious that computer technology is irrevocably influencing the affairs and course of our society. Hydrologic research has already experienced the impact of this new technology, but considerable readjustment is yet necessary to realize the full assistance of this tool. Existing records and data need to be prepared so that they can be processed and analyzed by computers.

Hydrologic research objectives and designs need to be prepared with an awareness and understanding of the new technologies—both in computers and the complementary field of data acquisition. Further research must be relevant to how management and operations organizations will employ the new technologies in the future. And finally the research organization itself must be adjusted and reoriented where necessary so that greatest use of the new technology will materialize.

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