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COMPUTER APPLICATIONS IN CONTINUING EDUCATION⁽¹⁾

By

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INTRODUCTION

The need for continuing education of engineers and other technical specialists in newly-developed theories and new techniques for application of the theories has been evident for a relatively long time. A number of continuing education programs have been developed at many colleges and universities to help satisfy this need. Also, some large engineering organizations have developed in-house training courses to educate engineering staffs in techniques and methodology relevant to their particular technical requirements.

Because access to computers for engineering work is available in most engineering organizations and because many of the recently developed theories and techniques are computer-dependent for effective application, a substantial portion of many continuing education programs is primarily concerned with computer applications. Some programs focus on training engineers in computer programming, employing various typical routine engineering problems as vehicles that serve to familiarize the engineer with the capability of the computer

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for engineering problem solving. Other programs focus on theories or techniques, employing computers as vehicles for obtaining results that demonstrate the validity and utility of the techniques and theories, but not necessarily emphasizing applications of the techniques to particular problems.

Although most continuing education programs involving computer applications would fall into one of these two categories, neither approach is completely satisfactory when evaluated with respect to the impact of the training on the productive work of the trainee when he returns to his regular working environment. In either case the trainee must spend a substantial amount of time after the formal training session extending his newly acquired knowledge to produce implementable engineering solution techniques. In many engineering organizations it is frequently difficult to allocate this additional time to efforts that do not directly impact on current production requirements. Consequently, some of the potential value of the training is lost. If a relatively long period of time elapses before the engineer has an opportunity to attempt to implement the knowledge, most of the value of the training will probably be lost.

One way of avoiding the problems that arise in conjunction with either of the aforementioned approaches to training in computer applications is to orient the training program toward providing the trainees with training in actual application of a computer-oriented technique rather than concentrating primarily on the technique itself. If the training emphasizes the use of a technique under a variety of realistic problem conditions along with the fundamentals of the technique, and if--during the course of the training--the trainee is given the opportunity to actually use various techniques in

a problem-solving situation that closely approximates his normal working environment, the time and effort required to implement the techniques into productive work will be minimized.

In order that engineers become aware that computers do not simply relieve them of computation tasks but rather provide them with enhanced capability, it is important that trainees have the opportunity not only to learn the techniques themselves and their application to one or two standard problems, but also to observe the effects of alternative assumptions in formulation of problems, the adequacy of solutions under varying conditions of data availability, and the problems of developing data and criteria for use with the techniques. In the relatively short time usually allotted to continuing education courses, these latter objectives can only be satisfied if the trainees are given the opportunity for some type of relatively frequent "hands-on" interaction with the computer.

Colleges and universities have recognized the value of the additional insight into problems and solutions that can be obtained from this type of interaction with computers, and a number of schools are using interactive time-sharing terminals and rapid turn-around remote batch terminals in undergraduate and graduate courses. However, the extension of this concept into continuing education programs has been much less rapid. As an illustration of what might be accomplished in this regard, an in-house training program in hydrologic engineering for the Corps of Engineers is described in this paper, and the integration of computer use into the technical training is discussed.

USE OF COMPUTERS IN HYDROLOGIC ENGINEERING

In the Corps of Engineers, hydrologic engineering has traditionally been one of the areas which required management and analysis of massive amounts of data. Also, many of the basic hydrologic engineering studies such as backwater computations, flood routing, sequential reservoir routing and flood hydrograph analysis frequently required laborious, repetitive calculations. Consequently, hydrologists and hydraulic engineers were among the first users of electronic computers in the Corps. Initially, most computer applications consisted of computerization of traditional manual methods. These first applications were gradually extended to accommodate problems and studies that were too large or too complex to be handled by manual calculations. During this time, engineers also began to look beyond computerization of manual techniques, and new techniques were developed to utilize the computation advantages of the computer more fully and to incorporate advances in hydrologic engineering technology (2).

These developments have resulted in tremendous extensions of the analytical capability associated with hydrologic engineering. A knowledgeable engineer working with an appropriate computer program can effectively analyze problems that are extremely difficult because of either scope or complexity; his analysis can be comprehensive without sacrificing detail; and he can study and evaluate the sensitivity of his solutions to variations in data, assumptions and criteria for the problem. These capabilities are realized by relegating to the computer, through intelligent use of a program, most of the repetitive and time-consuming computations and the many straightforward determinations and choices that do not require judgment and

experience, while reserving for the engineer the decisions and conclusions that are dependent on judgment and experience. This frees the engineer from tasks that have traditionally absorbed a disproportionate amount of effort and provides him with the opportunity to focus his experience, judgment and analyses on elements of the problem where they can produce the greatest impact.

The increasing importance of integrated system operation for existing multiple purpose projects and the requirements for hydrologic investigations associated with comprehensive land and water resource planning and development have greatly increased the scope and complexity of hydrologic engineering analyses during the past decade. Also, the requirements for explicit consideration of water quality, recreation, and environmental factors have added several new dimensions to hydrologic problems. Without the analytical capability provided by the use of computers, hydrologic engineers cannot continue to respond to the ever-increasing demands for more comprehensive and more complex hydrologic studies.

TRAINING IN HYDROLOGIC ENGINEERING

There was a time when training in hydrologic engineering in the Corps of Engineers consisted only of on-the-job training designed to teach newly employed engineers the practical application of principles and techniques they had encountered in their academic studies and to familiarize them with procedures and techniques that were not included in engineering curricula. For a time this approach was satisfactory; but as the pace of technological advances in hydrologic engineering increased and as the gap between hydrologic

engineering in the undergraduate curricula and the requirements for hydrologic engineering studies in the Corps widened, it became evident that on-the-job training alone could no longer satisfy the continuing education needs in hydrologic engineering. The advent of the computer, with the attendant necessity for training in computer use and training in application of computer-oriented techniques, accentuated the need for continuing education in hydrologic engineering.

In 1964 the Corps of Engineers established The Hydrologic Engineering Center (HEC) and assigned it the missions of (a) research and development of hydrologic engineering techniques for use in the Corps' day-to-day work, (b) training Corps' employees in traditional and newly developed hydrologic engineering techniques, and (c) assistance to Corps' field offices in hydrologic engineering studies. From the very first, HEC concentrated on computer applications and utilization in carrying out these missions. The training program described in the following paragraphs has concentrated on training engineers not only in how to use computers or in how to solve hydrologic engineering problems, but also in how to use computers effectively in solving hydrologic engineering problems.

HEC TRAINING PROGRAM

The basic purpose of the training activities conducted or sponsored by the Center is to improve the hydrologic engineering capabilities of the Corps of Engineers in accomplishing its civil works mission. This specialized training contributes to more efficient performance of technical studies associated with planning, design and operation of civil works projects.

The training program of the Center includes the following types of activities:

(1) About six to ten training courses per year, generally 2 weeks in duration, each with classroom-type instruction covering one major specialty of hydrologic engineering such as Hydrologic Probabilities, Flood Hydrograph Analysis, River Hydraulics, Flood Plain Hydrology, Water Quality Management and Reservoir System Analysis.

(2) One or two short conferences or seminars per year, normally 3 to 5 days in length, following planned agendas for guidance of open discussions and professional-paper type presentations related to various phases of hydrologic engineering such as Sediment Transport in Rivers and Reservoirs, Urban Hydrology and Computer Applications in Hydrology.

(3) Individual or small group training assignments, involving instruction and supervision of trainees assigned to the Center for various periods of time, usually 1 or 2 weeks. Where urgent training needs cannot be met by the formal training courses, individual training assignments can be scheduled with emphasis placed on subject areas of special importance to each trainee.

The typical trainee in the HEC courses has a degree in engineering, about 3 years of experience in hydrologic engineering, has been with one or more of the 52 Corps of Engineers offices, and has specialized in one or more areas of hydrologic engineering. However, trainees in a particular course range in experience from less than 1 year to more than 20 years. Approximately 15 to 20 percent of the trainees are from other Federal agencies, state water resources agencies and local flood control agencies.

Normally about 20 percent of the trainees in a given course have had little or no experience in the particular specialty of hydrologic engineering being taught.

The daily format of the training courses consists of a 1-hour review and quiz related to the previous day's work, two or three 1-hour lectures and a workshop period of 3 or 4 hours. This format allows the trainees to thoroughly review the preceding day's subject matter, apply the lecture material to actual problems in the workshops, clarify areas of uncertainty (assisted by workshop instructors), and compare their solutions to workshop problems with solutions prepared by the instructors.

A substantial portion of the individual training assignments to HEC is for the specific purpose of acquiring an understanding of and proficiency in the use of one or more computer programs. Generally it takes about a week for a trainee to become fairly proficient in using the more complex programs. During these training assignments the trainee reads the program documentation, discusses the use of the program with experienced users, prepares input data and runs the program for several problems and analyzes the results with the assistance of experienced users.

The Special Assistance mission of the HEC serves to point up the needs for training as well as for research and provides realistic examples of application for use in the training program. More important, it assures that the methods and techniques taught are of real and practical value in application.

The seminars conducted are intended to define the state of the art as practiced by Corps' field offices in a particular specialty area, to define

the principal problems that exist in that specialty area, and to suggest the manner in which the technology might best be advanced.

It is considered that any successful training program must be dynamic. Although many courses with the same title are "repeated" each year, they are substantially modified to reflect new problems and techniques and to relate better to the changing water resources development needs. The seminars and special assistance programs are invaluable in this regard.

GENERALIZED COMPUTER PROGRAMS

In order for training in computer applications to be of maximum value to the trainee and his organization, the trainee should be able to implement his newly acquired knowledge in his normal working environment with a relatively small expenditure of time and effort. When the training is primarily concerned with computer applications, the time and effort required for implementation can be minimized by providing the trainee with computer programs that can be used in his normal working environment with little or no modification and by orienting the training so that the trainee understands the programs and becomes relatively proficient in their use during the formal training period.

The HEC has developed, tested, documented and made available to all Corps offices about 30 generalized computer programs in hydrologic engineering. The programs are generalized in that they can be applied without modification to almost any problem in their specific area of application regardless of the scope of the problem, the geographic location of the problem, or the degree of detail required in a particular solution. Four of the programs

are large package programs, each of which combines the functions of several smaller programs (1). The four package programs are in the areas of flood hydrograph analysis, water surface profile determination, reservoir system analysis and monthly streamflow simulation.

All of the generalized programs are characterized by three attributes: portability, flexibility and adaptability. Portability (the transferability of the programs among the various types of computers) is achieved by developing the program logic and code in a manner which minimizes machine dependence for compilation and execution of the program. Flexibility (the utility of the programs on a wide variety of problems, under a wide variety of assumptions and criteria, and with a large variation in data requirements) is achieved by developing the input logic and structure in a manner which permits the engineer-user to specify by input alone which data will be required, what criteria and assumptions will be specified, what physical dimensions of the problem are to be considered, which computation techniques will be used and what output data will be produced. Adaptability (the utility of the program for applications that differ somewhat from those envisioned by the program authors) is achieved by developing the input and computation logic in a manner which will permit addition to or modification of the program code without extensive revision of the input structure or the portions of the solution technique which are adaptable to the particular problem.

To achieve portability, flexibility and adaptability without a loss in generality, the input structure for a generalized program must be more complex than the input structure for a single-purpose or special-purpose program. Consequently, the instructions for input preparation will be more complex

and a relatively high degree of documentation must be provided so that the engineer-user can evaluate alternative computation techniques and data requirements to select the program options that are most suitable for a particular application. Although this requires that the engineer spend a relatively long period of time familiarizing himself with the program's capabilities and the input requirements, it gives him a tool which can be used effectively on a variety of problems once the initial familiarization is achieved. If the familiarization with the program is accomplished during a training course which also provides the engineer with an understanding of the technical procedure used in the program, the implementation of the program should require very little additional time or effort.

Although the generalized computer programs developed by HEC are usually documented to a relatively high degree, it is still difficult to fully understand and effectively use the programs without a considerable effort on the part of the engineer-user. This learning process can be greatly facilitated by providing the potential user with the opportunity to use the programs on a variety of problems under the guidance of experienced users. This is the objective of the types of training discussed in the remainder of this paper.

COMPUTER USE IN HEC TRAINING COURSES

The degree to which computer applications can be integrated into training courses depends upon the goals of the training institution and the availability of a computer. The goal of The Hydrologic Engineering Center in this area is to promote efficient and effective computer utilization in the solution of

engineering problems. Specific objectives include developing proficiency in data input preparation for generalized programs, and developing problem solution capability using the generalized computer programs.

The objectives of HEC have been pursued through three categories of classroom workshops: (1) computer-oriented exercises for which no computer run is made, (2) computer-oriented exercises in which only one successful run is necessary and, (3) computer-oriented exercises requiring a number of submittals because of the interactive nature of the appropriate solution technique.

The recent experience of the HEC in pursuing its objectives through use of the above categories of classroom workshops is described herein not only to document some successes but also to identify possible pitfalls in integrating computer applications into continuing education programs. A few introductory comments are offered here to provide a background for evaluating the classroom workshops to be discussed. Most training courses of the type conducted by HEC are of necessity short and intensive--seldom exceeding 2 weeks in duration--and generally require full daily attendance. The complexity of the workshop problem that can be presented for solution is limited not only by the background of the students but also by the time available for problem orientation. The problems must be stripped to the bare essentials to avoid cluttering trivia. The techniques and program applications are the important elements, but real-world situations are mandatory. The amount of data that must be prepared and processed is another major consideration. Key-punching and card-handling problems can become bottlenecks. Finally, perhaps the most important consideration is the proximity

and availability of the computer facilities. Assuming that computer capability exists, availability is determined by the "turn-around time" or the time that elapses between submittal of data and receipt of computer output. It will become apparent that turn-around time greatly influences both the efficiency and effectiveness of training in computer applications.

Workshops requiring no computer operations can only be designed to acquaint the trainee with computer program capabilities and provide an introductory experience in detailed data preparation. Prior to the workshop, lectures present the general capabilities of the computer program(s) to be used and briefly review data input requirements. A program document containing detailed instructions for data preparation is provided. Each trainee is required to prepare detailed input to solve a given problem such as: derivation of unit hydrograph, computation of a water surface profile, or performing a reservoir operation study. The workshop time allotted is generally about 2 hours.

This approach was used by HEC until 1970 when a computer terminal facility was installed at HEC, but it is now limited to situations where computer facilities are not available, such as when training courses are conducted away from HEC's training center. At the end of the workshop session, solution sheets that contain the correct input data and a sample of the corresponding output are distributed.

Exercises of this type can be useful where a specific objective of the exercise is instruction in detailed data preparation and trainees are attending on that basis. Comments received from trainees indicate, however, that detailed data preparation exercises as a means of teaching program application do not

achieve the desired goal. In these instances exercises that have data preparation without computer processing as the end product may result in the alienation of some trainees. In the absence of computer processing facilities, workshop exercises will generally be more productive and effective if they are designed to demonstrate program applications for a problem solution rather than data preparation.

The second type of workshop used in the HEC training program requires that the trainee prepare data and process a single computer run. Workshops of this nature are also designed to acquaint the student with program capabilities and provide experience in detailed data preparation. Problems may be the same as in the preceding case--the major difference being that the computer becomes the authority on what is correct and what is not. The distinction seems to be significant in that the trainees seem to be more receptive to this approach and the objectives are more fully realized. The drawbacks are apparent. The opportunity to correct computer-detected errors is severely limited, and the possibility of interacting with the computer to derive a solution requiring intermediate judgments is nonexistent.

The number of errors which occur can be limited by having the instructor review the input data before actual submission to the computer; however, it has become apparent that errors detected by the computer are repeated far less frequently than those pointed out by the instructors. Apparently the computer's "no" makes a significant impression.

The HEC presently resorts to this approach only when teaching a course in another office or when the computer terminal facility is not available for use during a scheduled workshop session. Prior to September 1970, when the

high-speed terminal was installed at HEC, only daily turn-around was available and this approach was the best option available and was used where possible for several years.

The third type of workshop requires several submittals to the computer during a single workshop period and is dependent upon the availability of rapid turn-around for remote batch operation. This provides an opportunity for interacting with the computer a number of times during a workshop period and enables HEC to use workshop problems that require judgments to be made at intermediate steps in the solution process. It also permits effective utilization of problems designed to provide experience in detailed data preparation.

The present facilities at HEC permit virtually instantaneous turn-around (generally within 5 to 15 minutes). The terminal facility consists of a communications unit that has the capability of reading and transmitting 300 card images per minute and simultaneously receiving and printing 300 lines of output per minute. An on-line card punch that is capable of punching an average of 140 cards per minute is also available. Two key punch machines are located within the facility. For processing workshop problems, jobs are run in the batch mode under a priority that generally provides output from the computer within 10 minutes.

The programs to be used during the workshop are stored on a magnetic drum at the central processing facility and are accessed by reading a few control cards. During the workshop, only input data must be read and transmitted to the computer, thereby minimizing card handling and data transmission problems.

Workshop exercises in two recent HEC training courses serve to illustrate the manner in which computer applications have been integrated into the training program. The first course, entitled Hydrologic Systems Analysis, emphasized techniques for evaluating the natural hydrologic characteristics of stream systems and the change in hydrologic characteristics associated with alterations in physical characteristics. The course included a number of workshops designed to acquaint trainees with the capabilities of specific routines in one of the generalized computer programs and to provide experience in input data preparation for the program. A typical exercise required selection of appropriate program options for a given problem and preparation of input data necessary to obtain a solution for the problem. The class of 30 trainees was divided into 15 teams. Each team prepared input forms and submitted them for key punching. On the average, about 20 minutes elapsed between submittal of the data for punching and receipt of the computer output. This problem required that the trainees derive a unit hydrograph and associated loss rates from given rainfall and runoff observations. About 30 data cards were required. An average of three submittals per team were needed to complete the exercise. All but two teams successfully completed the exercise within the 2-hour period allotted.

The second course, entitled Hydrologic Evaluation of Projects, was directed toward training in concepts involved in project analysis. The workshop exercises in this course concentrated on the use of computer analyses to evaluate hydrologic effects of various types of water resource developments. In general, the exercises did not require extensive data preparation, since the objective of the workshops was to familiarize the trainees with the interpretation and use of computer output in evaluating projects. A typical problem

for this course required a short familiarization session in which the trainees were briefed on the objectives of a particular hydrologic evaluation, and familiarized with the physical and hydrologic data associated with the problem. The problem required the trainees to develop a preliminary estimate of the size of a flood control reservoir to maximize net economic benefits. The class of 30 students was divided into 10 teams, and each team was furnished an identical data deck and the computer output from an initial run based on that deck. The information furnished each team included cost, demand and value functions; reservoir site features; and watershed characteristics. The data deck modeled the hydrologic-economic response of a watershed consisting of four subbasins and two damage centers. To complete the exercise each team had to study the output provided, estimate the size reservoir needed to maximize net benefits and develop operating criteria for the proposed reservoir. Based on these analyses a few input cards were prepared and inserted into the data deck. The completed decks were then submitted for computer processing. When the output was received the review and analysis was repeated, new estimates were made, new data cards were punched and inserted into the data deck, and the job was resubmitted to the computer. The process was repeated until each team of trainees was satisfied that the reservoir which maximized net economic benefits had been determined. An average of 3.4 runs per team were performed during the 2-hour workshop period. A total of 7 minutes of UNIVAC 1108 computer time was used.

In this course the computer was used extensively by the trainees on 8 of the 10 working days. A total of 216 submittals were made during the course, an average of 2.7 submittals per team per day. Enthusiasm of the trainees

for this type of training reflected the value of demonstrating good computer service as well as the technical advantages of computer applications.

SUMMARY AND CONCLUSIONS

The key to increasing the integration of computer applications into the training program at HEC has been the availability of a high-speed terminal for obtaining rapid turn-around on a large computer. The proximity of a complete batch-processing terminal to the training facility and the capability for essentially immediate turn-around permit the trainees to concentrate continuously on the principles and techniques being applied to the problems at hand. The fact that the thought process is not significantly interrupted is an intangible factor that contributes immeasurably to the effectiveness of the training. It may be that there are lessons to be learned from this that would apply to the use of computers in general productive engineering work. In particular, it is probable that rapid turn-around would greatly increase the effectiveness of production work in engineering and that the increased effectiveness would more than offset the incremental cost of obtaining the rapid turn-around service.

Most of the emphasis on computer applications at HEC has focused on remote batch processing. Because of the large amounts of basic data required in hydrologic engineering problems and because of the voluminous output resulting from the most frequently used hydrologic analyses, this processing mode seems to be most advantageous. However, in other technical disciplines and even in some types of hydrologic analysis it might be advantageous to consider the use of the teletype terminals, cathode ray tube terminals and

other devices that are most frequently associated with processing in the time-sharing mode. It appears that there is no reason why the procedures used in the batch processing mode would not work equally well in the time-sharing mode.

Regardless of the type of computer equipment available for use in a training or continuing education program, two significant considerations insofar as the effectiveness of the training is concerned are the availability of adequate computer equipment and service at the trainees' regular place of employment, and the attitude of the trainees' supervisors toward the use of computers in productive engineering work. In order for the training to be of maximum value, the supervisors and executives in the trainees' organizations must be willing to permit the trainees to use the computer in accomplishing engineering studies and must assist engineers at the working level in securing access to and priority for computer service that is commensurate with the analyses required for the engineering problems at hand. In some engineering organizations, supervisors and executives have not acquired the background necessary to evaluate requests by their subordinates for computer services, to support and defend the requirements for computer services in discussions with other elements of the organization, or to review for technical adequacy engineering studies in which computer analyses have been a major factor. Providing personnel at these levels with the necessary background may be as important as the training in computer applications. A 1-week course on computer applications and utilization for engineering executives has been organized and conducted by HEC. The course is designed to familiarize personnel at supervisory and executive levels with the potential of the

computer for engineering applications and to provide them with an understanding of the capabilities of various types of computer systems and various modes of operation.

The experience of HEC in integrating computer applications into its continuing education program for hydrologic engineers has indicated that it is possible to provide experienced engineers with a good working knowledge of computer-oriented problem-solving techniques in a continuing education environment. However, it appears that the effectiveness of integrating computer applications into continuing education programs--as measured by the ability of the engineers to use the techniques in their normal working environment--is dependent upon three factors: the availability of broadly applicable, well-documented computer programs in the technical subject; the development of workshop problems for use in the training program to illustrate the capability of the programs for solving both routine and unusual problems; and the availability of rapid turn-around computer capability that enables the trainees to obtain "hands-on" experience in using the programs.

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