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EXPERIENCES OF THE HYDROLOGIC ENGINEERING CENTER IN MAINTAINING WIDELY USED HYDROLOGIC AND WATER RESOURCE COMPUTER MODELS

by

BILL S. EICHERT

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The experiences of the Hydrologic Engineering Center in maintaining a library of computer models for use by a large number of offices are presented. The type of support provided by HEC is described in terms of research, documentation training, user support and program distribution. Ways to encourage usage of models are covered along with the cost and manpower of providing the computer program support.

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EXPERIENCES OF THE HYDROLOGIC ENGINEERING CENTER IN MAINTAINING WIDELY USED HYDROLOGIC AND WATER RESOURCE COMPUTER MODELS

By Bill S. Eichert[1]

INTRODUCTION TO HEC

The Hydrologic Engineering Center (HEC) of the United States Army Corps of Engineers, located in Davis, California, was established in 1964 to serve all 52 offices of the Corps of Engineers (Corps) in the area of hydrologic engineering. Its mission was later expanded to include development and implementation of analytical planning techniques. The Center's basic purpose is to assist practicing engineers throughout the Corps in applying state-of-the-art technology to current planning, design and operation problems. This basic purpose is accomplished by locating, evaluating and/or developing new procedures and techniques (primarily mathematical models), by teaching these and other state-of-the-art techniques in approximately 24 weeks of formal training courses each year, by developing and maintaining a library of some 12 major state-of-the-art computer programs, and by assisting Corps offices in applying these techniques in current studies. The above missions are presently accomplished through a staff of approximately 40 employees, including 25 engineers, 5 computer system analysts and 10 technicians and clerical support personnel. An annual budget of about $1,850,000 includes about $500,000 reimbursable work for assisting in project studies, $250,000 for training, $150,000 for program maintenance and $950,000 for research and development (including developing and/or improving computer models).

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MAJOR HEC PROGRAMS

All major HEC programs (see Table 1) are written to be useful on a fairly wide range of problems in a specific area of hydrologic engineering or water resource planning. They are also generalized so that they can be used in about 95% of the studies without any code changes. Input data is used to describe site specific data. The programs are written using FORTRAN statements which are acceptable on most computers so that the programs are transportable to many different computer systems with little or no modification. Specific rules (which will be discussed later) followed in producing this code were derived by experience gained from converting the programs to many other systems over several years. The major HEC programs which are being supported by HEC in the production mode are shown in Table 2. Many other smaller production programs are available and several other major programs are still in the research stage, such as our work in two-dimensional hydrodynamics.

HEC CYCLE OF PROGRAM SUPPORT

The HEC cycle for computer support includes the important steps of:

a. Research. Program development and improvement.

b. Documentation. User manuals, programmers manuals, training documents, special application reports.

c. Training. Formal courses (1-2 weeks each), video tapes, individual training.

d. User Support. Consulting, answering telephone calls, reviewing jobs mailed to HEC, correcting errors in program.

e. Distribution. Mailing publications, source decks, test data and computer solutions.

TABLE 1

MAJOR HEC COMPUTER PROGRAMS

Program	Program Size		No. of Offices on List of Source Deck Holders as of 15 November 1976			
	No. of Statements	Core[1] Storage (Words)	Corps	Other Govt., Universities, Foreign	Private	Total
HEC-1, Flood Hydrograph Package	4,150	68K	28	141	231	400
HEC-2, Water Surface Profiles	8,000	44K	42	228	362	632
HEC-3, Reservoir System Analysis for Conservation	4,030	66K	20	64	41	125
HEC-4, Monthly Streamflow Simulation	1,985	60K	15	76	45	136
HEC-5C, Simulation of Flood Control and Conservation Systems	12,000	122K	11	42	17	70
HEC-6, Scour and Deposition in Rivers and Reservoirs	6,000	53K	18	33	15	66
Urban Runoff: Storage, Treatment and Overflow (STORM)	5,200	66K	19	109	113	241
Regional Frequency Computation	1,330	43K	19	44	34	97
Gradually Varied Unsteady Flow Profiles	4,300	55K	25	37	26	88
Water Quality for River-Reservoir Systems	7,800	71K	5	43	23	71
All Others	--	--	122	423	269	814
Total			324	1,240	1,176	2,740

[1] Core storage requirements are based on a CDC CYBER 175 located at Boeing Computer Company in Seattle, Washington and are shown in words (base no.)

f. Feedback. From user to HEC on input problems, program errors, desired program improvements.

The methods used by HEC in each of the steps above are described as follows:

a. Research. Most HEC supported programs were developed by HEC, but a few of the programs such as the STORM AND WQRRS programs were initially developed by others and have been adapted and improved by HEC or by contractors to HEC over the years. Improvements to the programs are important, for unless the programs are kept up-to-date, they will no longer be used and the results of the research will be terminated.

b. Documentation. Computer program documentation is generally accomplished with separate users and programmers manuals. The programmers manual provides useful information for implementing the program on the user's computer. The users manual explains what technical procedures are used in the program, how it operates, how to code input for the program, and how to interpret output. Notification of program error corrections and improvements is made periodically to all current source deck holders. Other HEC publications include training course notebooks, newsletters, professional papers, and computer program abstracts.

c. Training. Each year approximately 24 weeks of training are provided by HEC for Corps personnel in 1 to 2 week courses. Approximately 10 percent of the spaces in these courses is reserved for personnel from other U.S. Federal, state and university offices. Two special 4-week courses were given to foreign representatives in 1972 and 1974 as a U.S. contribution to the International Hydrological Decade. A number of U.S. and Canadian universities are using HEC developed courses and/or are using HEC computer models in their courses.

Individual training is performed by HEC to meet specific needs not met by the formal courses. Arrangements have been made by the U.S. State Department for foreign training by HEC. Fifteen of the HEC courses have been videotaped, and the 223 tapes are available for loan along with instructional material (lecture notes, visual aids and references). These tapes are particularly useful when someone who has taken the course is available to answer questions after the tapes are viewed. Visitors to HEC desiring individual training on a certain computer model often use these video tapes before getting individual help on solving a particular problem. Eleven visitors from Brazil recently received 4 weeks of training at HEC using this approach. In spite of the above, insufficient training is currently available to the non-Corps user.

d. User Support. The HEC provides support to the HEC programs by assigning each program to an engineer who answers calls on the program concerning program capabilities and limitations, input problems and program aborts. Sometimes program executions are reviewed to help the user find input errors or to correct program errors.

e. Source Deck Distribution. As shown in Table 1, the HEC has distributed source decks to a variety of different offices. Based on our survey in November 1976, over 2,700 source decks are still considered active by the using offices. Each year approximately 700 new source decks are requested. Assistance to program users is provided, to the extent possible, in implementing the models in their equipment, answering questions on use of models and eliminating program malfunctions. These services are provided without charge except that private firms are charged a $60 reproduction and handling fee for each source deck and set of documentation provided.

f. Feedback. Users of HEC programs have provided valuable feedback to HEC in terms of needed improvements in program capabilities, documentation deficiencies, program malfunctions, etc.

Each of the steps in the program support cycle is an important link. If one or more of these steps is missing or neglected it will eventually stop the cycle and prevent the generalized code from being used effectively. The program support cycle cannot get started until the models are in demand by various users.

WAYS TO ENCOURAGE USAGE OF THE MODELS

Technology can be transferred very effectively through computer models. However, many very good computer models have been developed which will never be effectively used because of model limitations, poor model documentation or lack of support for the model. The HEC has tried to observe the following principles in order to make the models more attractive and useful to the user.

a. Use Commonly Accepted Techniques. In HEC models we have tried to provide several of the best available methods so that a user's personal preference can be satisfied. For instance, some 6 different flood routing methods and 4 different loss rate functions are incorporated into our HEC-1 Flood Hydrograph Package.

b. Make Models Generalized and Flexible. A complex computer model that is designed for a specific project may be very valuable for that project, but probably is not useful for the same type of project at another site. At HEC we try to write major models so that a large proportion of similar types of problems at other locations can be solved without any program modification. The programs are written in large packages so that most problems in that general field of interest can be solved with the same model. All programs are written in FORTRAN IV in such a way that they are easily transported to a wide range of different computers.

c. Make Input Simple. Most models in use today are difficult to use because not enough attention was given to making the input user-oriented. The amount of use the program will receive by others is heavily influenced by how easy the the program is to use.

d. Make Documentation Simple and Readable. Models that have extensive computational capabilities in solving complex programs are easy to find. Models with good documentation are very hard to find. Too much documentation will scare away a potential user, and too little will leave a potential user frustrated and angry. The documentation should be written so that the beginner can easily use the model on a simple problem and the experienced user can use the model on a complex problem.

e. Support the Finished Model. In very few cases are knowledgeable personnel available to help users effectively use the models. All major HEC models are supported by one or more persons who help users by answering questions on the telephone and by tracing down user problems. A lack of model support by the developing office is perhaps the most important reason why some models are not effective in transferring technology. A good model sitting on the shelf without any support is worthless. Model support can require a substantial amount of manpower and funds. Good documentation and simple input can greatly help in reducing the required support. While the increased use of the model increases the success of the technology transfer, the requirements for support of the model are also increased, sometimes beyond the office's capability to provide that support. The support required on the HEC-2 model with over 600 offices currently using it has reached the point where 2-3 people are spending almost half-time on the support activity.

The amount of support that is provided for a model should be dependent upon how much the model is being used. If a program has few users, then perhaps the support effort (mainly improvements) should be transferred to more successful models. Determining the extent of use of the models is very difficult when many different computers are being used. Results from surveys such as that shown in Table 2 are quite useful when based on questionnaires of known program users. Table 2 shows that much more use is being made of our HEC program in the private sector than in our own Corps offices. Other results show what additional program capabilities need to be added and where difficult input coding problems occur. Where programs are used by many offices on the same computers, routines like our SNOOPY program can be added to provide periodic information on program usage, options called, etc., as shown in Table 3.

TABLE 2

RELEASE OF NOVEMBER 1976 VERSION OF HEC-2

SOURCE DECK DISTRIBUTION

Type of User	Number
Private (U.S.)	98
Corps	18
Other Federal	11
State or Local Government	54
University (U.S.)	29
Private (Foreign)	7
Foreign Government	11
University (Foreign)	3
Total	231

USAGE SURVEY

Type of User	Number of Offices Responding	Program Has Been Used During Last 3 Mos.	Number of People Using HEC-2	Approx. No. of Program Executions Per Year
Private	137	101	921	84,161
Corps	24	21	243	34,010
Other Federal	12	7	57	1,045
State or Local Government	52	35	284	12,665
University (U.S.)	25	13	216	2,488
Others	3	3	10	1,000
Totals	253	180	1,731	135,369

TABLE 3

NUMBER OF EXECUTIONS OF HEC COMPUTER PROGRAMS
AT THE LAWRENCE BERKELEY LABORATORY
DURING A 10-MONTH PERIOD

	Number of Executions				
Month	HEC-1	HEC-2	HEC-5C	Freq Anal.	Unsteady Flow
October 1976	374	1,307	82	80	86
November 1976	295	1,363	64	129	89
December 1976	270	1,462	100	164	79
January 1977	*	1,661	357	162	35
February 1977	*	1,712	954	176	123
March 1977	*	2,243	420	195	32
April 1977	*	899	363	199	28
May 1977	*	1,764	187	218	91
June 1977	*	2,807	284	176	66
July 1977	*	2,412	306	104	103
Total	939	17,630	3,117	1,603	732
Projected Annual Total**	3,756	21,156	3,740	1,924	878

* SNOOPY routine not in operation.

** Projected annual total obtained by dividing "total" figures by number of months figures were available, and multiplying by 12.

COST AND MANPOWER FOR PROGRAM SUPPORT

The estimated costs and manpower requirements for supporting the generalized computer programs in the HEC library are shown in Table 4. The support efforts are a function of many factors, including the number of users, the extent of use by each user, the technical background of the user, the amount of training the user has in the subject area and subject program, and the amount of experience the user has in using a particular program. Two or three of our programs require about half of our total support efforts, while several programs require very little support. Our development and improvement costs vary considerably from year to year and from program to program. Initial development costs of a typical large HEC program are $100,000. While the program is still in a production mode, additional improvements over a 5 to 10 year period may increase that total cost to about $500,000.

Total support costs (which exclude the development/improvement costs) of the 12 major programs in the HEC have not changed greatly in the last 2 years since the number of users has gradually leveled off.

COMPATABILITY WITH OTHER COMPUTER SYSTEMS

Even though FORTRAN is a common computer language available in most scientific computing systems, care must be exercised to prepare programs that will execute on all systems. This is because most FORTRAN compilers made available by vendors contain variations or enhancements to the standard FORTRAN language that may not be available or at least implemented in the same way on other systems.

To produce the most usable code for all FORTRAN installations:

a. Isolate file initialization statements at the beginning of the main program for easy adaptation to other systems.

TABLE 4

COST AND MANPOWER FOR PROGRAM SUPPORT

Item	Approx. No. Products Per Year	Annual Cost HEC Programs	Equivalent Full Time Employee
Training Courses - Development & Presentation	22 Weeks	250,000	4.0
Program - Development/Improvement	12	200,000*	3.5
User Support	12 Major Programs	85,000	2.0
Documentation - Development/Improvement	15	30,000	.5
Maintain Programs on Two 3-Computer Systems	3	20,000	.5
Video Tapes and Support Documents - Distribute	500	5,000	.5
Source Decks - Reproduce & Distribute	700	40,000	.3
Documentation - Reproduce & Distribute	4,000	15,000	.2
Video Tapes - Development	100	15,000	.1
Totals		$660,000	11.6

*Estimated part of $950,000 annual research program used for 12 major programs currently supported by HEC.

b. Avoid BACKSPACE statements.

c. Use standard READ and WRITE statements for I/O operations.

d. Restrict alphanumeric input/output to four characters per word (A4).

e. Use no more than 3 subscripts for arrays.

f. Prepare code in logical subroutine units that can be debugged independent of other routines, and overlayed in smaller machines as necessary.

g. Avoid multiple entry points in a subprogram.

h. If variable dimensions are required, pass the dimension limit in the call statement, not in common areas.

i. Place DATA statements that preset labeled common areas in BLOCK DATA subprograms.

j. Use care where loss of precision may affect computer results, such as in differences of numbers of nearly equal magnitudes. It may require DOUBLE PRECISION in some machines to give the same result as single precision gives in others.

k. Where special features of a system are germane to the operation of a program, such as direct access I/O, character manipulation, etc., isolate them in a single subroutine that may be easily adapted to other systems.

IMPLEMENTING PROGRAMS ON OTHER SYSTEMS

The costs and manpower requirements to transport computer programs to other systems are difficult to estimate. If programs are transported frequently and feedback on the difficulties encountered are corrected, then eventually the programs become quite portable. This is the case with most HEC programs. Recent HEC benchmark programs were converted to several different United States Computers in a few days' time. Typical conversion times for a single HEC program should require less than one man-day of work, given that the computer system is large enough and that the programmer is skilled on his system. Most difficulties for HEC programs have been encountered by users who had IBM equipment, because of lack of core memory, symbol table storage deficiencies in the compiler, or problems with double precision (not knowing what variables have to have double words). The most common problem for non-IBM users has been a lack of core storage, but that problem is very rare now except for one or two HEC programs.

The main problems in sending HEC source decks to foreign countries is that many offices have the smaller IBM systems and that the feedback from those countries to HEC is less than adequate because of lengthy communication times and security problems on both ends. In spite of a few problems, good success has been experienced in transporting HEC programs to over 700 different offices per year including many foreign countries.

CONCLUSIONS

The use of generalized models can be an effective tool in accomplishing water resource studies if sufficient funds and manpower are provided to support the necessary functions described in this paper. Information on manpower and costs provided in this report may be useful in estimating the necessary logistic support required for similar support centers in other offices.

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