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WATER AND SANITATION
FOR HEALTH PROJECT



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**ECUADOR:
ASSISTANCE TO NATIONAL WATER
AND SEWERAGE AUTHORITY (IEOS)
IN ENGINEERING ASPECTS OF
MICROCOMPUTER APPLICATION**

WASH FIELD REPORT NO. 136

OCTOBER 1984

The WASH Project is managed
by Camp Dresser & McKee
Incorporated. Principal
Cooperating Institutions and
subcontractors are: Interna-
tional Science and Technology
Institute, Research Triangle
Institute, University of North
Carolina at Chapel Hill,
Georgia Institute of Tech-
nology—Engineering Experi-
ment Station.

**Prepared for:
USAID Mission to the Republic of Ecuador
Order of Technical Direction No. 193**

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November 8, 1984

Mr. Orlando Llenza
USAID/Ecuador
Quito, Ecuador

Attention: Dr. Kenneth Farr

Dear Mr. Llenza:

On behalf of the WASH project I am pleased to provide you with 10 copies of a report on Assistance to National Water and Sewerage Authority (TEOS) in Engineering Aspects of Microcomputer Application.

This is the final report by Daniel Gallagher and is based on his trip to Ecuador in October of 1984.

This assistance is the result of a request by the Mission in September 1984. The work was undertaken by means of Order of Technical Direction No. 193, authorized by the USAID Office of Health in Washington.

If you have any questions or comments regarding the findings or recommendations contained in this report we will be happy to discuss them.

Sincerely,

Dennis B. Warner
Director
WASH Project

cc: John H. Austin
S&T/H/WS

DBW:kk

The WASH Project is managed by Camp Dresser & McKee Incorporated. Principal Cooperating Institutions and Subcontractors are: International Science and Technology Institute; Research Triangle Institute; University of North Carolina at Chapel Hill; Georgia Institute of Technology—Engineering Experiment Station.

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Prepared by:

Daniel Gallagher

October 1984

**Water and Sanitation for Health Project
Contract No. AID/DSPE-C-0080, Project No. 931-1176
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EXECUTIVE SUMMARY

The National Water and Sewerage Authority of Ecuador (IEOS) requested assistance in developing the capability of their engineers to use its Alpha Micro computer for evaluating engineering alternatives during the design of drinking water and basic sanitation projects.

This process was started in early 1983 by having Dr. Donald Lauria and Mr. Keith Little of the University of North Carolina (UNC) make a presentation to the Guayas Engineering Society. At this time, they demonstrated how computers could be used to make engineering alternative decisions during the design process. As a result of this presentation, the country asked for WASH assistance to incorporate such concepts in the day-to-day working of IEOS.

This report covers the efforts of a consultant to (1) adapt the UNC programs to an Alpha Micro computer that had been purchased by IEOS; (2) load these programs into the computer; and (3) train 10 to 15 IEOS engineers in how to use the programs.

The report then recommends a series of steps that should be taken to improve the availability of the computer to the engineers for whom it was bought.

In addition, the report recommends a course of action for (1) reinforcing the knowledge presented during this mission; and (2) expanding the number and type of programs in the IEOS library.

Chapter 1

SCOPE OF WORK

This mission had two specific objectives. The first was to transfer computer programs for the design of water distribution networks to an Alpha Micro 1003 computer at IEOS. These programs had been developed at the University of North Carolina under World Bank sponsorship. The second objective was to teach a small group of IEOS engineers how to use these programs and introduce concepts for low cost network design.

Chapter 2

SUMMARY OF ACTIVITIES

2.1 Modification and Transfer of Programs

The modification and transfer of the computer programs was much more involved than anticipated. The major reasons for this were the limited data communications software available for the Alpha Micro and the proprietary nature of the BASIC computer language used by the Alpha Micro. Data communications software is not yet available from Alpha Computers. Additionally, AlphaBASIC did not support the communications ports located on the machine. This prevented writing a small BASIC program to allow the transfer. Program transfer was possible only for the BASIC programs by configuring the small NEC computer as a terminal to the Alpha Micro. The NEC is a lap sized computer with an eight line screen and 32K memory. Since the Alpha Micro uses a compiled version of BASIC rather than the more common interpretive versions, only BASIC statements that were correct for the Alpha Micro were accepted during transfer. All other lines were automatically deleted. Because of this limitation, all modifications to the programs had to be made on the NEC prior to the program transfer. The small size and memory limitations of the NEC slowed the modifications somewhat. The other option of manually typing the programs into the Alpha Micro was ruled out because of their lengths. The process of learning AlphaBASIC, modifying the existing programs, transferring them, and debugging them was ongoing during the entire two week period. A summary sheet for programs that were entered in the Alpha is appended to this report (see Appendix A). Jaime Davalos and Ing. Daniel Polo assisted during the operation.

2.2 Problems with Sewer Design Program

All of the available BASIC programs were eventually transferred. To date, all but one of the programs have been debugged and are operational on the Alpha Micro. The consultant was unable to debug the program for sewer design during this visit. The one FORTRAN program, FLOW, could not be transferred at this time because of incompatibilities between the Alpha Micro and the NEC. Microsystemas, the local Alpha Computer dealer, expects to have a software package for communication between Alpha Micros and IBM PC compatibles within the next month. IBM diskettes with the FORTRAN program were left with both Microsystemas and IEOS. Microsystemas has agreed to transfer the program when the software becomes available. The program likely will require modifications before it can be run successfully on the Alpha Micro, since it was written in a different version of FORTRAN than is available on the Alpha Micro.

2.3 Technology Transfer Workshops

Three days of workshops were conducted with local engineers from IEOS, starting on October 4 and ending on October 9 (October 8 was a national holiday in Ecuador and no class was held). Ing. Gonzalo Ordonez assisted as a teacher and translator for these workshops. The engineers were divided into two groups of five to six people each. This class size was excellent for the

purpose of the workshop. Classes of about four hours each were held in the morning and afternoon for each group. Each of the programs were introduced, the data requirements were discussed, and the sample programs were run. For the engineers, the classes provided hands-on experience in the use of both the programs and the computer. Because of the small size of the groups, the engineers could use the two available terminals to enter the data, and to examine various alternative designs. With the exception of the sewer design program and FLOW, all of the available programs were discussed and used.

Chapter 3

CONCLUSIONS

3.1 Assessment of Existing Situation

The Alpha Micro itself appears to be a more than adequate piece of hardware for IEOS's needs, although an eventual expansion of the memory and number of terminals may be needed. The computer has 2 terminals, 256K of memory, a hard disk, and a floppy disk. Up to 7 terminals eventually can be supported. A major drawback of the computer is the lack of available software. With the small size of Alpha Computers and the relatively small users' base, this situation will not change appreciably in the near future. An example of the problem is seen with the communication software discussed earlier. Although the Alpha Micro has been available for a number of years, such software is still not available. Some software that is available would definitely suit IEOS's needs, particularly a data based management system. Current practice at IEOS is to write each piece of software as the need arises. This is both time-consuming and expensive in the long run. Some of these programs can easily take months to write and debug, and then are useful only for the specific problem for which they were written.

3.2 Need for Program "Backups"

Currently, the video cassette recorder that should be used to back up the hard disk is not working. This equipment must be repaired as soon as possible. Backups of existing programs are a necessity, not a luxury, particularly when power outages and line surges are common. During this visit, for example, the Alpha Micro was in the repair shop for almost three days because of an apparent power surge. Months of work will be lost if the programs and data on the hard disk are affected and backups are not available.

3.3 Computer Availability to Engineers

At present, the Alpha Micro is not used for design purposes and the engineers do not have general access to it. The computer is used during regular business hours for data based management, inventory, and payroll. Network design is performed on hand-held calculators such as the HP-41. This situation must change. The computer was purchased to aid in the design and analysis of water supply systems. The computer must be made more available to the engineers for this purpose.

3.4 Follow-up Efforts

The course and the programs were generally well received. It is apparent, however, that at least one more such course will be necessary, particularly after the engineers have gained some experience with both the computer and the programs. A more in-depth study of how to use these programs to find the least-cost design, including more of a theoretical background and more work with local examples, is strongly needed.

Chapter 4

RECOMMENDATIONS

4.1 Computer Availability to Engineering Staff

The Alpha Micro computer must be made available to the engineers if it is to fulfill the function for which it was purchased. The computer should be moved back to the main IEOS building, and at least one terminal should be placed at the full time disposal of the engineers. Sufficient capacity exists for the other terminal to be used for the administrative purposes IEOS requires.

4.2 Use of Commercially Available Software

The staff of IEOS should purchase commercially available software when it is appropriate, rather than to try and write the software themselves. Commercially available software is generally more flexible and powerful, and in the long run it is less expensive. Of particular importance right now is a data based management system.

4.3 Greater Use of Existing Computer Capability

IEOS should move to expand its hours of operation for the computer to include early morning and evening hours as well as some weekend hours. The current practice of using the computer only during regular business hours allows a good deal of the computer capacity to go unused. The situation will become more difficult as more people begin to use the machine.

4.4 VCR Backup of Programs and Data

The VCR backup system should be made operational as soon as possible. Backups of all programs and data routinely be made routinely on tape. Until the VCR is working, important programs and data should be backed up on floppy disks. This procedure is too expensive to be used routinely.

4.5 Need for an Uninterruptable Power Supply

IEOS may wish to consider buying an uninterruptable power supply in addition to the line filter that is currently in use. This would prevent loss of data during the relatively frequent power losses in Quito. The cost of uninterruptable power supplies generally increases with the length of time power must be supplied. But as only a few minutes are required to save the current program or data to disk and to shut off the computer, such a unit would not have to be very large.

4.6 Evaluation of Efforts to Date

Sometime around January or February, IEOS should be contacted by AID to determine if the design engineers are making use of the computer. If they are not, then the reasons should be determined and appropriate steps taken to improve the situation.

4.7 Recommendations for Future Action

Sometime around April or May of 1985, another course should be taught to a larger group of engineers. This course would focus more on the comparison of various low cost network design alternatives using the computer programs that have been installed. This topic was introduced during this workshop, but time did not permit a full discussion. The course should be taught by someone like Dr. Donald Lauria of the University of North Carolina. Dr. Lauria has an excellent background in both the theoretical and practical aspects of low cost water supply planning. A second person would work with the Alpha Micro, continue debugging the two programs that are not yet running, and make any modifications in the existing programs that IEOS may need. The section of the course dealing with the current programs could be taught by the currently trained engineers, since they should have had sufficient experience in their use by this time. Although a larger class is recommended, the class size should be kept small enough so that all participants have some access to the computer.

APPENDIX A

**Summary Sheets for Computer Programs
Entered into the Alpha Computer**

MINIMUM SPANNING TREE

Program: MINTREE.BAS

Description: Allows user to find the branched network that connects all the nodes of a looped network and has the minimum total length of all such branched networks.

Purpose: Obtain the minimum spanning tree from a looped network.

Language: BASIC

Input:

Data Requirements: The length and two endpoint nodes of each pipe in the looped network.

Input Method: Data are entered through BASIC DATA statements.

Data Editing Facilities: DATA statements may be edited through the BASIC line editing features.

Results: The pipes that comprise the minimum spanning tree.

Output: The minimum spanning tree may be output to a lineprinter. No disk file output is supported. The input DATA statements may be stored as a BASIC program and merged to the original program to rerun.

Limitations: Depending on the size of the network, the uncompiled program may take some time to run. Some minor programming ability is helpful to enter the DATA statements. Multiple minimum spanning trees may exist for a given looped network. Only one will be found with this program. The minimum spanning tree is based on length only and does not consider flow. Therefore the minimum spanning tree network may not be optimal for a primary water distribution network.

LEAST COST DESIGN OF BRANCHED WATER DISTRIBUTION NETWORK

Program: BRANCH.BAS

Description: Formulates and solves the linear programming problem for the least cost design of a branched water distribution network.

Purpose: Obtain the lengths and diameters of pipe that minimize cost subject to maintaining a minimum residual pressure at each node.

Language: BASIC

Input:

Data Required: The number of links, the hydraulic grade line of the reference node, the minimum residual pressure, the maximum residual pressure, and the flow peaking factor. For each pipe the required data are the link number, the Hazen-Williams coefficient, the link length, the upstream node number, the demand at that node, the elevation of that node, the downstream node number, the demand at that node, the elevation at that node, and the type of constraint that must be satisfied. For each link the number of candidate diameters, the diameters and their unit cost are required.

Input Method: Data are entered through BASIC DATA statements.

Data Editing Facilities: DATA statements may be edited through the BASIC line editing features.

Results: The lengths and diameters of the least cost combination of pipes for each link and the total construction costs are calculated. Also determined are the hydraulic grade line at each of the nodes. The user may optionally request the hydraulic grade line at any interior point in the network.

Output: The results may be output to a line printer. No facilities for disk output are provided. The BASIC DATA statements may be stored as a BASIC program and merged with the original program to rerun. Some minor programming ability is helpful to enter the DATA statements.

Limitations: Available memory may limit the size of the network that can be solved. The program is capable of incorporating existing and parallel pipe.

LOOPED DISTRIBUTION NETWORK SIMULATION

Program: LOOP.BAS

Description: The program simulates the hydraulic characteristics of a looped water distribution network using the Hardy-Cross method.

Purpose: Obtain the hydraulic grade line at each node in the network and the flows through the pipes in the network.

Language: BASIC

Input:

Data Required: The number of loops, links and nodes in the network along with the flow peaking factor. Also required are the stopping criterion and the maximum number of iterations. For each node, the ground elevation and the inputs or demands are required. The network geometry in terms of the loops, nodes, and links is required, as is the length, diameter, and friction coefficient of each link. Finally, the hydraulic grade line of the reference node must be entered.

Input Method: The data are entered through BASIC DATA statements.

Data Editing Facilities: DATA statements may be edited through the BASIC line editing features.

Results: The flow and velocities at each link are calculated. The hydraulic grade line at each node is calculated.

Output: The results may be output to a line printer. No facilities for disk output are provided. The DATA statements may be stored as a BASIC program and later merged to the original program to rerun.

Limitations: Minor programming ability helpful to enter DATA statements. The program is designed to network with a single source input at known hydraulic grade line. Multiple inputs require a trial and error solution by the user to insure the proper heads are obtained at the additional sources. Inline hydraulic features such as pumps and valves are not supported. Convergence is not guaranteed with the Hardy-Cross method.

MULTIPLE LINEAR REGRESSION

Program: REGRESS.BAS

Description: Menu driven program to provide the parameter estimates from multiple linear regression.

Purpose: Obtain the linear regression coefficients and estimates of the goodness of fit.

Language: BASIC

Input:

Data Required: Full set of dependent and independent variable observations, number of independent variables in the model, variable names (optional).

Input method: User is prompted for each required entry by the program and the data are entered through the keyboard. Data previously entered and saved to disk may be recalled directly.

Data Editing Features: Facilities exist from the menu to change or edit data points, add or delete data points, add or delete independent variables, and transform variables.

Results: The user may optionally select the following calculations from the menu: correlation matrix, parameter estimates and goodness of fit statistics, residuals, and partial F statistics.

Output: Input data and each portion of the results may be output to line printer as desired. Input data may be stored to disk.

Limitations: Regression is limited to linear models or models that are transformed to linear. All data is held in memory when running which may limit the size of the data set. Current defaults allow for 100 data points with 6 independent variables each.

NONLINEAR FUNCTION MINIMIZATION

Program: SIMPLEX.BAS

Description: Multidimensional nonlinear function minimization using the direct search method of Nelder and Mead.

Purpose: Obtain the values of the function variables that minimize an input function.

Language: BASIC

Input:

Data Required: The function to be minimized must be input as a BASIC subroutine. The number of variables, an initial guess for each variable, and the stopping criteria are required.

Input Method: The function must be written and entered into the program as a BASIC subroutine. Other values are entered through BASIC DATA statements.

Data Editing Facilities: The function and the DATA statements may be edited through BASIC line editing features.

Results: The value of the function at its minimum and the values of the function variables at this point.

Output: No facilities are provided for printer or disk output. The function subroutine and the DATA statements may be stored as a BASIC program and merged with the original program to rerun.

Limitations: All standard precautions concerning nonlinear optimizations apply. Ability to program in BASIC is required to enter the function. As written, the program will minimize the function. If maximization is required, enter the function to be minimized as $-1 * \text{the function to be maximized}$.

LOOPED DISTRIBUTION NETWORK SIMULATION

Program: FLOWMAIN.FOR with 8 subroutines FLOWSUB1.FOR through FLOWSUB8.FOR

Description: The program simulates the hydraulic characteristics of a looped water distribution network by directly solving the system of nonlinear equations.

Purpose: Obtain the hydraulic grade line at each node in the network and the flows through the pipes in the network.

Language: FORTRAN

Input:

Data Required: The units desired, the stopping criteria, the peaking factor, the number of pipes, the number of nodes, the number of nodes that are reservoirs, the number of in-line booster pumps, the number of pressure valves, and the number of check valves are needed. For each pipe, the length, diameter, roughness coefficient, and nodes at either end are required. For each node, the input/demand and the elevations are needed. For the reservoirs, the head and pump curve coefficients are needed. The pump curve coefficients are also needed for each booster pump. For each pressure reducing valve, the operating head and the resistance coefficient are required.

Input Method: Data must be entered and stored on a disk file. Data elements must conform to the respective FORTRAN FORMAT statements. A line editor or word processor with standard ASCII output is required to create the data file.

Data Editing Facilities: The data must be edited directly using a line editor or word processor.

Results: The velocity, head, and gradient at each pipe are calculated. The hydraulic grade line of each node is also determined.

Output: The input data and the results are stored on a disk file which may be printed or read into a word processor as desired. No direct facilities for use of a lineprinter exist within the program.

Limitations: Multiple sources and inline hydraulic features such as pumps and valves are supported. Program requires a FORTRAN compiler and 256K of memory. Velocity and flow only valid if specific units have been chosen. A line editor or word processor with standard ASCII output is required to create and edit the data file.

APPENDIX B

**Summary Sheet for Computer Program Delivered to
IEOS but not Programmed into Computer**

DESIGN OF SANITARY SEWER NETWORK

Program: SSD.BAS

Description: SSD.BAS is a menu driven program to aid in the design of sanitary/ sewer networks.

Purpose: Obtain an approximate least cost design of a sanitary sewer by minimizing excavation depth subject to various velocity and design constraints.

Language: BASIC

Input:

Data Required: Roughness coefficient, minimum and maximum velocity, minimum and maximum cover depth, number of pipes, crown elevation of sewer outfall, and cost coefficients (optional) are needed. For each pipe, the ground elevation of the downstream manhole, the pipe length, average flow, proposed diameter, and network geometry information are required.

Input Method: The user is prompted for the required data by the program as needed. Data are entered through the keyboard. Data previously saved to disk may be recalled directly.

Data Editing Facilities: From the menu the user may edit or change the design criteria and constraints and all the input data for a specific pipe.

Results: For each pipe, the peak flow, velocity at peak flow, water depth, depth to diameter ratio, design slope, minimum feasible slope, ground slope, crown elevations, invert elevations, and average excavation depth are calculated. A cost estimate of the network may also be provided.

Output: The input data and the results may be output to a line printer and/or a disk file. Input data may be stored to a disk file for later reuse or revision.

Limitations: Design is heuristic and may not be strictly optimal.