A GRAPHIC DIGITIZER PROGRAM
TO INTERPOLATE MATRIX GRID VALUES:
USERS MANUAL

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by

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Water and Land Resources Department

June 1973

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SUMMARY

A quick and efficient method is required for conversion of data from contour form into matrix nodal values. A new computer program, described in this paper, was developed which uses a PDP-9 digital computer and a graphic digitizer. Through use of this program a contour map may quickly be converted to matrix form with virtually no errors.

This work was performed by the Water and Land Resources Department of Battelle-Northwest for application to the Radionuclides in Soils Program sponsored by the Atlantic Richfield Hanford Company.

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SYMBOLS AND DIMENSIONS

n		total number contour points	
j		index number of a singular point along contour ($j=1,n$)	
k		total number of contours surrounding a node	
i		index number of a given contour ($i=1,k$)	
$X_{\text{node}}, Y_{\text{node}}$		coordinate position of a node within a region	
X_j, Y_j		coordinate position of a digitized point along a contour	
X_i, Y_i		coordinate position of i^{th} point along river boundary	
X_{i+1}, Y_{i+1}		coordinate position of $i+1^{\text{st}}$ point along river boundary	
P_i		contour value at i^{th} point on river boundary	
d_i		distance between i^{th} point and intersection of perpendicular from node	
d_{i+1}		distance between intersection of perpendicular from node and $i+1^{\text{st}}$ point	
P		contour value at intersection	

USE OF A GRAPHIC DIGITIZER PROGRAM
TO INTERPOLATE MATRIX
GRID VALUES

INTRODUCTION

The Radionuclides in Soils Program being conducted by Battelle-Northwest for the Atlantic Richfield Hanford Company has as its major objective the development of a groundwater management system for the Hanford Reservation. The primary segments of this management system are mathematical models which can predict transient groundwater and contaminant movement.

These models require various types of input information, much of which can be represented by a surface, i.e., groundwater potential contour maps. In applications this data must be efficiently converted from maps and charts to a form which can be input to computer programs by techniques such as a three-dimensional equation or a two-dimensional array containing surface elevations.

Complex surfaces are usually difficult to describe by a three-dimensional equation and even if such an equation can be developed the computer calculations required during use can be lengthy. The second method (a two-dimensional array) is sufficient to describe most surfaces and computer application is normally easier than for the three-dimensional equation. This report describes a new interpolation scheme to accomplish efficient computer input of data with a graphic digitizer utilizing the two-dimensional array method.

USE OF THE GRAPHIC DIGITIZER

The system utilized to produce an even grid matrix of surface values has two principal segments, a small process computer and a graphic digitizer. The digitizer has an adjustable table with a width of 46 inches and a length of 72 inches, of which the usable digitizing area is 36 inches wide by 48 inches long. There are two input devices. The first is an electronic cross-hair cursor which, when positioned on the table surface, magnetically forces a servo-mechanism to move a sensor under the table top to a position directly beneath the cursor. The x-y coordinates of the cursor are then available for input to the computer upon depressing a button on the side of the cursor. There also is a 16-key keyboard which is used to input contour values or control data to the computer.

Prior to digitizing a contour map, the map is placed on the digitizer table so that the y lines are horizontal to the table, as shown by the digitizer x-y indicator lights at the computer. The cursor is simply placed at the far left on any y line on the map and the y indicator lights noted. The cursor is then moved to the far right on the same y line and the map is adjusted until the y indicator lights read as they did in the first position. The map is then secured firmly to the table to prevent further shifting. This assures that the matrix to be generated corresponds in nodal positions to the map. A more detailed description of the computer system and graphic digitizer is presented in Appendix F.

Original methods of calculating an even grid matrix of surface values require the straight line interpolation of digitized data in a raster pattern along the y matrix lines. This is done along each y matrix line from left to right as shown in Figure 1. Each intersection of a contour and a y matrix line is input to the computer from the digitizer (Appendix F) with the proper contour value and x distance. The matrix values are then calculated by straight line interpolation for each node along the y matrix line.

This is done for each y matrix line from bottom to top until all nodes are calculated within the matrix. Two obvious disadvantages come to light with this method: the value of the contour must be input at each intersection of a y matrix line; and, inaccuracies occur where contours are not orthogonal to a y matrix line as shown in Figure 2. It can be seen that the nodes indicated by +'s (when straight line-interpolated between digitized points 1 and 2) would all have the same value as points 1 and 2 (200).

FIGURE 1. STRAIGHT LINE DIGITIZING AND INTERPOLATION SCHEME

FIGURE 2. INACCURACIES OF STRAIGHT LINE INTERPOLATION

Because of these shortcomings, new interpolation schemes have been investigated and an improved scheme called the Closest-Point Interpolation (CPI) program developed.

THE CPI PROGRAM

The CPI program allows the operator to digitize along contours instead of across them, thereby eliminating the need to input a new contour value with each digitized point. With the CPI program contour maps are digitized in a piecewise fashion by moving the cursor in a series of loops forming closed regions bounded by contours, Figure 3.

FIGURE 3: DETERMINATION OF A REGION

The digitizing sequence is begun at some convenient starting point (such as Point A in Figure 4) on one of the contours. Successive points are digitized along the length of the contour at random spacing determined by the program operator. When a length of the contour is reasonably straight, the digitized points can be spaced further apart; however, as a contour begins to bend, the digitized points should be closer together in order to more accurately describe the

contour curvature. Various options for contouring and their complete descriptions are presented later in this document.

FIGURE 4. CLOSED LOOP REDIGITIZING PATTERN USING THE CPI PROGRAM

To calculate the matrix nodal values within a region the following interpolation formula is used:

$$P_{\text{node}} = \frac{\sum_{i=1}^k \frac{P_i}{D_i}}{\sum_{i=1}^k \frac{1}{D_i}}$$

where:

P_{node} = the value at the node

P_i = the value of the i^{th} adjacent contour

D_i = the distance between the node and the
closest point on the i^{th} contour

k = the number of contours surrounding the
node (normally $k=2$, in stagnation regions
 $k>3$)

The distance (D_i) is the relative distance between the interpolated node and the closest point on each of the adjacent contours. In most cases there are only two contours; however, when the interpolated node lies in a stagnation area there can be several contours.

After a region has been closed each node which lies within that region is calculated using the interpolation formula. First, however, it must be determined whether or not a node lies within the region. In order to do this a rectangular area surrounding the region is set apart from the system and only the nodes within this area are checked, as demonstrated in Figure C-1, Appendix C. This substantially decreases the number of nodes to be checked. The next step is to determine which nodes within the rectangular area lie within the digitized region. To do this a simple algorithm is used and the identified nodes are interpolated onto an evenly spaced grid. This algorithm is described in Appendix C.

Figure 5 shows a contoured surface which has been divided into several regions. These regions have been selected by their specific configurations and are therefore governed by certain option numbers. Several options are available to the user, including an option that covers any groundwater surface configuration. The proper option number for each region is shown in parentheses in Figure 5. These options are explained in full detail on the following pages.

FIGURE 5. SELECTION OF PROPER CONTROL OPTIONS FOR REGIONS

The CPI program is designed for versatility. With it the operator will be able to accurately digitize and interpolate parallel contours, concentric circular contours, and stagnation regions. In addition, redigitizing of small portions of the contour maps is facilitated by the closed-loop design. Because of these features, the Closest-Point Interpolation Program has significantly reduced the time and effort previously spent in converting contour maps to evenly spaced digital data.

The following two sections describe user operation of the CPI program. The first section describes the initial program setup (PROGRAM INITIALIZATION) required for each first use, including two options, one of which is selected by the operator according to the particular mode he wishes to utilize after program initialization. The second section (PROGRAM OPTIONS) describes in detail these two options and the other options to be used once the program has been initialized.

PROGRAM INITIALIZATION

Immediately after loading (see Appendix A), the program interrogates the user for information required by the disc to set up a new data matrix or initialize the one already stored (Appendix B-2).

Once this has been done, the digitizer must be initialized to the proper map scale by digitizing the bottom left point (0,0) and the bottom right point (maximum x) on the map. This information is requested on the teletype.

The program now types the following message:

CONTOUR OPTION, KK =

The user now types a 1 or a 4 depending on the option he wishes to begin with.

KK = 1 Initializes all pointers and counters prior to entering adjacent or circular contour modes.

KK = 4 Initializes all pointers and counters required prior to entering river mode.

Appendix G shows the digitizing sequence for all of the following control options.

PROGRAM OPTIONS

Only after the initialization procedure has been completed is the user free to utilize the options described below:

Table 1. PROGRAM OPTION NUMBERS

<u>Option Number</u>	<u>Action</u>
1	Start new region
2	Adjacent contours, saddle points
3	Circular contours
4	River boundary
5	Finished-return to DDT
Any other number	Error in option number input; get new number

OPTION 1 (Start New Region)

This option is used whenever a new region is to be defined prior to entering either an adjacent or circular contour mode. It resets all counters, pointers and tables to the initial condition whenever the operator wishes to change from one region to another. Regardless of the new region configuration, he simply types the following message, then 1 and a carriage return (CR). (This message is typed after a region has been closed; see Options 2 and 3).

CONTOUR OPTION, KK = 1
└──────────┘ └┘
└──────────┘ └──────────┘
(Typed by program upon) (Typed by user to)
(closing a region) (start new region)

When this has been done the program types:

ENTER VALUE OF CONTOUR

At this point the user enters a contour value in a lPE 9.4 format (i.e., x.xxxx+xx) and continues as in options 2,3, and 4.

With a 1 option no lines are saved from the last region; therefore, common boundary lines between regions must be redigitized. Also, when marking off the individual regions care must be taken that the contours within each region intersect the straight line boundaries at the proper scaled intervals. This insures continuity between regions (see straight line boundaries 1 and 2 in Figure 6).

OPTION 2 (Adjacent Contours)

Option 2 is used when adjacent contours are to be digitized, as exemplified by Figure 6. Contours 200, 205 are digitized and the area closed. Using option 2 to save the digitized 205 contour, the operator then digitizes the 210 contour and the area between 205 and 210 is calculated. Additional contours adjacent to the 210 contour can be digitized in the same manner, as the program always saves the last stored contour, eliminating the need to redigitize many of the contours within a region. This method also eliminates holes which might arise between new areas.

Three examples of this option are shown on the following pages. Once the technique is acquired, the flow of digitizing becomes smooth and natural. In the first example shown in Figures 7A, B, and C, the digitizing flow progresses from right to left.

The following steps are used in all cases; it is just a matter of keeping the sequence in order.

Example 1

- 1) Initialize the program or call a new region (KK=1)
- 2) Enter value of contour on digitizer keyboard using the format: x.xxxx+xx
- 3) Digitize starting point (A)
- 4) Continue digitizing contour
- 5) When finished with a contour and ready to go to next one, digitize last point twice (B)
- 6) Digitize the starting point on the adjacent contour (C)

FIGURE 6. CALCULATING PROPER SCALING AT ENDS OF REGION

- 7) Enter value of contour (see step 2)
- 8) Redigitize point C
- 9) Continue digitizing contour
- 10) When finished with contour digitize last point twice (D)
- 11) Close region by redigitizing point (A)
- 12) After the computer calculates values of all nodes within this region and outputs this data to the disc, the following message is typed:

CONTOUR OPTION, KK =

- 13) To continue digitizing adjacent contours type a 2 (see Table 1) after KK and a carriage return (CR). This saves the points of the last digitized contour, placing point C as point A and point D as point B in the digitizing sequence (see Figure 7B). A new point C is now selected as a point on contour 3 close to point B
- 14) Continue as in steps 7 through 12
- 15) If region 2 is to be calculated perform step 13 (see Figure 7C). A new point C is now selected as a point in contour 4 close to point B
- 16) Continue as in steps 6 through 13 until all adjacent contours have been digitized and a new region is desired.

Example 2

A digitizing pattern from right to left is described above, but the same sequence may be used when the operator wishes the digitizing pattern to progress from left to right (See Figures 8A, B, and C).

Example 3

A saddle region (see Figure 9) may also be described by OPTION 2 for adjacent contours. Such a region may have several bounding contours and the procedure is the same for all cases.

FIGURE 7A

FIGURE 7B

FIGURE 7C

ADJACENT CONTOURS

FIGURE 8A

FIGURE 8B

FIGURE 8C

ADJACENT CONTOURS

Once the straight line boundaries of the chosen region have been defined, select a starting point (A) at the intersection of a contour and a straight line boundary (see Figure 9); then

- 1) do steps 1 through 10 (Example 1)
- 2) digitize point E
- 3) do steps 2 through 10 (Example 1) using E,F,G, and H for A,B,C, and D
- 4) close region by redigitizing point A.

Figure 9 shows the digitizing pattern.

FIGURE 9. SADDLE REGION (ADJACENT CONTOUR OPTION)

OPTION 3 (Circular Contours)

Figure 10A illustrates a configuration for which the circular contour option would be used. In this case there are two circular regions enclosed by the 300 contour.

The digitizing of a region with circular contours always starts from the center point and radiates outward. Use the following procedure (see Figure 10B):

- 1) Initialize the program or call a new region (KK=1)
- 2) Enter value of center point (A) on digitizer keyboard using the format:

 x.xxxx+xx
- 3) Digitize point A twice
- 4) Enter value of next contour on digitizer keyboard
- 5) Select a starting point (B) on this contour and digitize
- 6) Continue digitizing contour
- 7) Close region by redigitizing point B
- 8) After computer calculates values of all nodes within this region and outputs this data to the disc, the following message is typed:

CONTOUR OPTION, KK =

to continue digitizing circular contours type a 3 (see Table 1) after KK and a carriage return (CR). This saves the points of the last digitized line

- 9) Select a new point B on the next contour (see Figure 10C)
- 10) Continue with steps 4 through 8, digitizing in the OPPOSITE DIRECTION (note difference in direction of digitizing in Figures 10B and 10C)
- 11) Continue with steps 4 through 8 until all nodes have been interpolated within the circular region.

CIRCULAR CONTOURS

FIGURE 10A

FIGURE 10B

FIGURE 10C

OPTION 4 (River Boundary)

This option is unique in that the values vary at each point along the river boundary (Figure 11) and must be input separately and digitized to indicate coordinate positions. This method is slower than the other options but equally accurate.

- 1) This option can be exercised at program initialization or after another region has been closed and the following message has been typed:

CONTOUR OPTION, KK =

To begin a river region, type a 4 (see Table 1) and a carriage return (CR) after KK =

- 2) Enter value of contour closest to river boundary on digitizer keyboard using the format:

x.xxxx+xx

- 3) Digitize starting point A
- 4) Continue to digitize contour
- 5) Terminate line by digitizing point B twice
- 6) Digitize first point C on river boundary
- 7) Enter value of point C on digitizer keyboard
- 8) Digitize next point on river boundary
- 9) Enter value of point on digitizer keyboard
- 10) Repeat steps 8 and 9 until all desired points are entered in consecutive order
- 11) Close region by redigitizing the last point on the river and entering its value on the keyboard (the intersection of the 400.0 foot contour and the river boundary), then redigitize point A on the starting contour. The program now calculates all nodal values within the region defined by the 410.0 foot contour and the river boundary (shaded area of Figure 11).

FIGURE 11. RIVER BOUNDARY

OPTION 5 (All Lines Completed)

When Option 5 is used the computer types the following message on the teletype:

ALL LINES COMPLETED

The program then returns control to DDT.

OPTION 6-999 (Error Condition)

When a number greater than 5 (6 through 999) is typed as the option number an error condition exists and the program simply requests a new option number. This allows the user to make a correction in options if he notices a typing error prior to typing the carriage return (CR). EXAMPLE: The user is digitizing adjacent contours and inadvertently types a 3 instead of a 2 for the option number. If the (CR) has not been typed he may enter an additional number, such as 0, in this example:

CONTOUR OPTION, KK = 30

The computer retypes the message after (CR) has been entered

CONTOUR OPTION, KK =

The user then enters the correct code (2) after KK = and continues.

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APPENDIX A

PROGRAM LOADING PROCEDURE

APPENDIX A

INTERP PROGRAM LOADING PROCEDURE

1. Get Disc Operating System (DOS) Monitor.

- A) Type Control C (↑C) on the teletype keyboard. When the DOS Monitor initially gets control, it outputs

\$

to the teleprinter to indicate readiness to accept a keyboard command. Subsequently, it outputs "\$" to indicate readiness. In both cases, the keyboard command should be typed on the same line as the dollar sign (\$). If this procedure fails to get the DOS Monitor, go to B.

- B) i) Set 37720 in the Address Switches on the PDP-9 console.
- ii) Depress I/O RESET.
- iii) Depress START.

The Monitor should output \$ if it is activated. If not, go to C.

- C) Unless there is a hardware malfunction, or the system software has been destroyed on the disc, this method will always get the DOS Monitor.
- i) Load DOS BOOTSTRAP into paper tape reader and clear reader flag.
- ii) Set address switches to 37720 on the PDP-9 Console.
- iii) Depress I/O RESET switch.
- iiii) Depress READIN switch.

This procedure reloads the system Bootstrap back into core and automatically sends control to the DOS Monitor.

2. If a matrix has not previously been set up, the INTERP program will set it up so go to Step 3. If the matrix

has been set up and is available, transfer it from DEC tape to disc in the following manner.

- A) Set to WRITE LOCK and REMOTE on DEC tape unit 1 and mount tape.
- B) Get PIP by typing PIP (CR) after \$.

\$ PIP

- C) Once in core memory, PIP informs the user of its readiness to accept keyboard commands by outputting the following to the teleprinter:

PIP V9A

>

The user now types the following message after the angle bracket (>).

>T DK2 ← DT1 fname ext(B)

where fname is the array name (i.e., HANFRD) and ext is the extension (i.e., POT).

- 3. The interpolation program is also transferred to disc from DEC tape. If the program is in the form of a Q file (this is denoted by INTERP DMP on the DEC tape listing) go to step ii.

- i) Assembly language form. Indicated by INTERP BIN on the DEC tape listing, this form must be loaded using DDT and is slower to set up than the Q file form.

The user types the following command string on the same line as the angle bracket (>).

>T DK2 ← DT1 INTERP BIN

This transfers to disc 2 from DEC tape 1 the program INTERP binary.

The user recalls the DOS Monitor by typing Control C (↑C).

\$

The user now makes a DAT slot assignment for the user library stored on DEC tape 1.

```
$ A DT1 -5
```

The Monitor returns a \$ and the user calls DDT.

```
$ DDT
```

Once in core memory, DDT informs the user of its readiness to accept keyboard commands.

```
LOADER V4A
```

```
>
```

The user then types the following after the angle bracket (>).

```
> INTERP [ALT MODE]
```

The program is now loaded into core (see Appendix B) and when finished types:

```
DDT V4A
```

```
>
```

The user then can type a control Q (↑Q) after the angle bracket to set up a Q file. (This eliminates reloading the program in case of a serious error.)

```
> ↑Q
```

The monitor types:

```
DKAD
```

The user then types a disc address (6400,7000, etc.) on the teletype and a carriage return. The Q file is now stored on disc and may be recalled at any time by the DOS Monitor by typing the following after \$.

```
$ G      Disc  
        Address
```

Now go to step 4.

- ii) Q File form. This is the fastest method of loading the program and also entails the use of PIP.

The user types the following command string on the same line as the angle bracket (>).

```
>T DK2      DT1      INTERP      DMP(B)
```

As this Q File is file-oriented, it is transferred directly to disc 2 and entered into the directory. To use the program, get the Monitor and type the following after \$.

```
$ GET 2 INTERP
```

- 4. The following message is now output to the teleprinter:

```
DDT  V4A  
  
X   XXXX   XXXXXX   X  
  
>
```

The user initiates the program by typing an apostrophe (') after the angle bracket (>).

```
>'
```

The program now starts and if a data matrix is not on a disc unit (see step 2) interrogates the user to get the proper matrix specifications (see Appendix B).

APPENDIX B

LOAD MAP AND MATRIX SETUP

APPENDIX B

LOAD MAP AND MATRIX SETUP

↑C

\$ A DT1 -4,-5

* DDT

LOADER V4A

>INTERP

INTERP 31664

D7IN. 31377

INTXV7 31372

HFPXV7 31364

MX.SU 30464

REFLP. 30242

MX.IFL 30101

MX.RW 27757

MX.OPT 27574

MX.AD2 27425

WDEC. 27345

WSRIT. 27314

WMSG. 27256

IWDAT. 27217

P57. 27027

BNUM. 26771

POUP. 26734

IRDAT. 26706

UP57. 26631

MUL. 26617

DIV. 26604

GARG. 26575

HSCP. 26556

HSOPT. 26424

CMP. 26402

IFLT. 26351

SFIX. 26313

IFIX. 26254

FSUB. 26225

FADD. 26102

FNEG. 26055

FMUL. 26004

FDIV. 25876

FPSL. 25501

FGARG. 25471

FPER. 25402

DKD. 23677

DDT V4A

>↑C

DKAD 17500

DDT V4A

>↑C

\$ ENTER 17500 2 INTERP

*

↑C

\$ G 2 INTERP

DDT V4A

>'

DIGITIZER INTERPOLATION ROUTINE

MATRIX SET-UP

DISC UNIT NO. 2
FILE NAME EXT HANFRD POT
HORIZONTAL DIMENSION 131
VERTICAL DIMENSION 145
SECTORS PER SECTION 6
OVERLAP 5

MATRIX CONFIGURATION
FILE HANFRD POT
HORIZONTAL DIMENSION = 131
VERTICAL DIMENSION = 145
SECTORS PER SECTION = 6
OVERLAP = 5
HORIZ. NODES PER SECTION = 26
VERT. NODES PER SECTION = 25
NO. HORIZONTAL SECTIONS = 6
NO. VERTICAL SECTIONS = 7
TOTAL NO. SECTIONS = 42
NO. DATA DISC SECTORS = 252
WORDS PER SECTION = 650

DIGITIZE (0,0) POINT
DIGITIZE MAXIMUM X
CONTOUR OPTION, KK= 1
ENTER VALUE OF CONTOUR
DIGITIZE LINE

APPENDIX C

FINDING A NODE WITHIN A REGION

APPENDIX C

FINDING A NODE WITHIN A REGION

Prior to interpolating nodal values, the program reduces the number of nodes that need to be tested (to see if they lie within the region) by internally defining a rectangular area around the region to be calculated (Figure C-1). Once this has been accomplished, only the nodes within this rectangle are tested, thereby speeding up computer calculations considerably.

The following algorithm is then used to determine whether a node lies inside or outside the region defined by the closed loop.

Position an axis with the node in question as the center. This was done with NODE 1 in Figure C-2. Starting at the first point X_1, Y_1 , calculate X_o, Y_o .

$$X_o = X_1 - X_{\text{node}}$$

$$Y_o = Y_1 - Y_{\text{node}}$$

If the next point steps into an adjacent quadrant in a counter-clockwise direction around the axis, add one to a counter (initialized to zero). If the next point steps into an adjacent quadrant in a clockwise direction, subtract one from the counter.

The counter will be zero if the node lies outside the region and non-zero if it lies within the region.

Picking (X_1, Y_1) as the starting point, this algorithm may be demonstrated in a step by step fashion.

<u>Step</u>	<u>Accumulative Value of Counter</u>
Start	0
A	+1
B	+1
C	+2
D	+2
E	+3
F	+3
G	+3
H	+3
I	+4
J	+4

The counter is non-zero, therefore node 1 lies within the contour region. Now position node 2 as the center of the axis (Figure 3C).

Once again picking (X_1, Y_1) as the starting point, the algorithm may be again demonstrated.

<u>Step</u>	<u>Accumulative Value of Counter</u>
Start at (X_1, Y_1)	0
A	+1
B	+1
C	+1
D	+2
E	+1
F	0
G	-1
H	0
I	0
J	0

The counter is zero, therefore, node 2 does not lie within the contour region.

In this fashion, each node within the rectangular area is checked to determine whether it lies within the contour region. If it does, the proper value is calculated using the interpolation formula.

Appendix D shows nodal calculations using T. Because transmissivity values usually vary with such great magnitude as compared to potential values, a slight modification must be made to the program by the user. This is necessary because the calculated values must be stored in the matrix in the form of logs rather than fixed points as are potentials. This is described in full detail in Appendix E.

FIGURE C-1. DETECTION OF A NODE WITHIN A REGION

FIGURE C-2.

DETECTION OF A NODE

FIGURE C-3.

APPENDIX D

PROCEDURE TO CALCULATE CLOSEST DISTANCES

APPENDIX D

FINDING SHORTEST DISTANCE BETWEEN NODE AND CONTOUR (D_i)

Figure D-1 shows a typical situation between digitized points and a node within the region.

FIGURE D-1. CALCULATING SHORTEST DISTANCE BETWEEN A NODE AND CONTOUR

Values are known for d , L_1 and L_2 . A value is required for D_i .

First calculate d_1 and d_2

$$d_1^2 + D_i^2 = L_1^2$$

$$D_i^2 = L_1^2 - d_1^2 \quad (1)$$

$$d_2^2 + D_i^2 = L_2^2$$

$$D_i^2 = L_2^2 - d_2^2 \quad (2)$$

equating Eq. 1 and 2

$$\begin{aligned} L_1^2 - d_1^2 &= L_2^2 - d_2^2 \\ \text{solve for } d_2^2 \\ d_2^2 &= L_2^2 - L_1^2 + d_1^2 \end{aligned} \tag{3}$$

The following relationship is also known

$$\begin{aligned} d &= d_1 + d_2 \\ \text{solve for } d_2^2 \\ d_2 &= d - d_1 \\ d_2^2 &= (d - d_1)^2 \end{aligned} \tag{4}$$

equating Eq. 3 and 4

$$\begin{aligned} L_2^2 - L_1^2 + d_1^2 &= (d - d_1)^2 \\ \text{solve for } d_1 \\ d_1^2 &= d^2 - 2dd_1 + d_1^2 - L_2^2 + L_1^2 \\ 2dd_1 &= d^2 + L_1^2 - L_2^2 \\ d_1 &= \frac{d^2 + L_1^2 - L_2^2}{2d} = \frac{d}{2} + \left(\frac{L_1^2 - L_2^2}{2d} \right) \\ d_1 &= \frac{d}{2} + (L_1 + L_2) \left(\frac{L_1 - L_2}{2d} \right) \end{aligned} \tag{5}$$

The perpendicular distance D_i can now be calculated.

$$D_i^2 + d_1^2 = L_1^2$$

$$D_i^2 = L_1^2 - d_1^2 \quad (6)$$

This is done for each countour and the resulting D_i 's used in the interpolation formula.

This is a very accurate and rapid method of determining nodal values from a contour map and has proven very successful in groundwater applications.

METHODS USED TO CALCULATE SHORTEST DISTANCE BETWEEN NODE AND CONTOUR

CASE 1: First point on contour is closest point to node.

- i) Normal. Shortest distance to contour lies between first and second points on the contour

- ii) Shortest distance = distance between node and first point

iii) Perpendicular distance does not lie between points

In this case the distance between the first point and the node is selected as the shortest distance.

CASE 2: Closest point is last point on line

i) Normal

ii) Perpendicular distance and distance between node and last point are the same

iii) Perpendicular distance does not lie between points

In this case the distance between the last point (X_n, Y_n) and the node is selected as the shortest distance.

CASE 3: Closest point is not first or last point

i) Shortest distance lies between previous point and closest point

ii) Shortest distance and distance between node and closest point are the same

iii) Shortest distance lies between closest point and next point

Method used to calculate intermediate contour values for river boundary type calculations:

$$P = P_i + \frac{(P_{i+1} - P_i) * d_i}{(d_i + d_{i+1})}$$

APPENDIX E

CALCULATING TRANSMISSIVITIES

APPENDIX E

CHANGING THE PROGRAM TO CALCULATE TRANSMISSIVITIES

In order to calculate transmissivities instead of potential, one change must be made to the interpolation. The user initializes the program as described in Appendix A; however, prior to initiating step 4 the following must be performed.

Step 4 shows that the following message is output to the teleprinter:

```
DDT      U4A
X      XXXX      XXXXXX      X
>
```

The user now types the following after the angle bracket (>)

```
>CHANGE/
```

This opens up the location labeled CHANGE and the following message is typed:

```
>CHANGE/      SKP
```

(NOP) and a carriage return (CR) after the (SKP) is typed as follows:

```
>CHANGE/      SKP      NOP
```

This replaces the SKP command in core to an NOP and the printer types another angle bracket

```
>
```

The user initiates the program by typing an apostrophe (') after the angle bracket

```
>'
```

The program now starts as described in step 4 of Appendix A.

APPENDIX F

SYSTEM CONFIGURATION AND DESCRIPTION

APPENDIX F

SYSTEM CONFIGURATION AND DESCRIPTION

To expedite solutions to problems involving mathematical or pure data induced models, it became necessary to improve man-machine interactions and input of field data. The improved equipment and interactive method reduce the tedious and time-consuming chores involved in program manipulation with large off-line computer systems.¹ The use of the CPI program in conjunction with the graphic digitizer greatly reduces the time required to convert analog data to digital form.

The system presently includes:

- 1) PDP-9 Computer (16K, DMA, API, EAE)
- 2) EDWIN graphic digitizer (36" X 48")
- 3) DDC disc memory (500K)
- 4) UNIVAC 1558 graphic display with light pen
- 5) INFOMAX printer/plotter
- 6) DEC tape (2 transports)
- 7) Remote connection to UNIVAC 1108 computer.

Future plans may include an analog computer system. Further technical data which describe the various components in the system hardware configuration (Figure F-1) and explain their operation may be obtained from Reference 2.

Figure F-2 shows the graphic digitizer. The cross-hair cursor and 16 key keyboard can be seen on the table top.

The digitizer keyboard is pictured in Figure F-3. The delete key may be used anytime prior to striking the carriage return (CR) key to delete the entire sequence which has just been entered on the keyboard. The number (i.e., 2.4 + 04) is accepted by the program only after the CR key has been struck.

The entire computer system is pictured in Figure F-4.

F-2

FIGURE F-1. HARDWARE SYSTEM CONFIGURATION

FIGURE F-2. THE COORDINATE DIGITIZER

FIGURE F-3. THE DIGITIZER KEYBOARD

FIGURE F-4. COMPUTER SYSTEM LAYOUT

APPENDIX G

FLOW CHART FOR DIGITIZING SEQUENCE

FIGURE G-1. FLOW CHART FOR DIGITIZING SEQUENCE

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