NUREG/CR-2845
PNL-4345

DIGRD: An Interactive Grid Generating Program

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Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
**U.S. Nuclear Regulatory
Commission**

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Manuscript Completed: October 1982
Date Published: November 1982

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Prepared for
Division of Health, Siting and Waste Management
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B2292

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U.S. Department of Health, Education and Welfare
Office of Research, Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20545
NRC File 82-82

SUMMARY AND RECOMMENDATIONS

Pacific Northwest Laboratory has completed the development and documentation of an interactive grid generating program (DIGRD, digitize grid). This program is designed to rapidly generate or modify grids and their attendant description necessary to the variably saturated flow code TRUST. In addition to the code, a user's manual was prepared. Unfortunately, the computer hardware that comprises an interactive graphics capability is often unique. Therefore, actual technology transfer could not occur. Rather, this report is intended to convey the utility of interactive graphics in supplying a grid generating capability.

This program, DIGRD, has already been effectively used in the preparation of grids for the analysis of leachate movement from uranium mill tailings. The principal conclusion is that the interactive graphics employed in DIGRD are very useful and economical in the development of complex grids. Grid generation activities that originally took between a half and a full manmonth have recently been completed in less than a week.

A recommendation from those using DIGRD has been for the development of a uniform grid, either rectangles or equilateral triangles, which could be superimposed on any domain and then adjusted through the DIGRD program to match the domain boundaries and material zones of a uranium mill tailings disposal facility. This improvement to the DIGRD package would further reduce the effort in grid generation while providing more optimal grids.

SUMMARY AND RECOMMENDATIONS

Pacific Northwest Laboratory has completed the development and documentation of an interactive grid generating program (GIGP, digital grid). This program is designed to rapidly generate or modify grids and their associated description necessary to the variously formatted flow code TRUST. In addition to the code, a user's manual was prepared. Unfortunately, the computer hardware that controls an interactive graphics capability is often unique. Therefore, actual technology transfer cannot occur. Rather, this report is intended to convey the utility of interactive graphics in supplying a grid generating capability.

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A recommendation from those using GIGP has been for the development of a uniform grid, either rectangular or circular, which could be superimposed on any domain and then adjusted through the GIGP program to match the domain boundaries and internal lines of a domain with a fixed disposal facility. This improvement to the GIGP package would further reduce the effort in grid generation while providing more optimal grids.

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INTRODUCTION

As part of the U.S. Nuclear Regulatory Commission's (NRC) efforts to formulate technically based criteria for disposal of uranium mill tailings, Pacific Northwest Laboratory (PNL) is conducting research to develop experimental and computer modeling tools to assess the long-term environmental impact of leachate movement from uranium mill tailings. Under this project, Assessment of Leachate Movement From Uranium Mill Tailings, computer codes are being developed to model uranium mill tailings drainage and contaminant transport by describing variably saturated flow and mass transport in multidimensions with deformable geologic media; that is, media which can consolidate under an effective stress. One such code, TRUST, has been used to analyze disposal sites situated above the water table. TRUST, developed by T. N. Narasimhan (1975) Narasimhan and Witherspoon (1977, 1978) Narasimhan, Witherspoon and Edwards (1978), is based largely on TRUMP, a code developed by Edwards (1968).

TRUST analysis is founded upon the integrated finite difference method which focuses attention upon the flux entering or leaving a subdomain rather than the infinite detail of the continuum within the subdomain (Narasimhan and Witherspoon 1976). When applied properly, the method has strong local guarantees of conservation; however, accuracy of the method depends upon the orthogonality of the different grid components.

The need for an interactive grid generation capability became apparent during an analysis of a uranium mill tailings site in Wyoming.^(a) Subsequent grid generation exercises have borne this out. The capability to rapidly generate, and later modify, a grid for input to TRUST is essential to the cost effective use of this code. Basically, the grid generation program dramatically reduces the time necessary to generate the necessary input files for TRUST. As a result, an interactive grid generation capability was developed and is herein documented to compliment the TRUST code applications. This grid generation tool (DIGRD) can be used in conjunction with any code based upon the integrated finite difference method [e.g., TRUMP (Edwards 1968), PT (Mangold, Lippmann and Bodvarsson 1980) and SHAFT 79 (Pruess and Schroeder 1980)]. However, the special hardware facilities (i.e., refresher scopes, digitizing tables, graphic display systems) used by DIGRD in an interactive graphics made technology transfer per se impractical unless such hardware is available or purchased to duplicate the system outlined in this report. Therefore, this report's objective is to convey the general utility and cost savings of interactive graphics in supplying a grid generation capability in support of integrated finite difference codes. In addition, this document will serve as a user's guide for the execution of the DIGRD interactive graphics package.

(a) Two codes FED (Schauer 1973) and OGRE (Weres and Schrueder 1978) were considered, but FED uses a unique compiler language and OGRE was inefficient because of core space requirements and manipulations necessary to reduce three-dimensional output into a two-dimensional format for use in TRUST.

INTRODUCTION

As part of the U.S. Nuclear Regulatory Commission's (NRC) efforts to formulate technically based criteria for disposal of uranium mill tailings, Pacific Northwest Laboratory (PNL) is conducting research to develop experimental and computer modeling tools to assess the long-term environmental impact of leachate movement from uranium mill tailings. Under this project, Assessment of Leachate Movement from Uranium Mill Tailings, computer codes are being developed to model uranium mill tailings drainage and contaminant transport by describing various saturated flow and mass transport in multidimensional systems. The geologic media, that is, media which can consolidate under an effective stress. One such code, TRUST, has been used to analyze disposal sites situated above the water table. TRUST, developed by T. W. Harshbarger (1975) Harshbarger and Witherspoon (1977, 1978) Harshbarger, Witherspoon and Edwards (1978), is based largely on TRUP, a code developed by Edwards (1968).

TRUST analysis is founded upon the integrated finite difference method which focuses attention upon the flux entering or leaving a subdomain rather than the infinite detail of the continuum within the subdomain (Harshbarger and Witherspoon 1976). When applied properly, the method has strong local guarantees of conservation; however, accuracy of the method depends upon the orthogonality of the different grid components.

The need for an interactive grid generation capability became apparent during an analysis of a uranium mill tailings site in Wyoming. (a) Subsequent grid generation exercises have borne this out. The capability to rapidly generate, and later modify, a grid for input to TRUST is essential to the cost effective use of this code. Basically, the grid generation program described here reduces the time necessary to generate the necessary input files for TRUST. As a result, an interactive grid generation capability was developed and is herein documented to complement the TRUST code applications. This grid generation code (GRID) can be used in conjunction with any code based upon the integrated finite difference method (e.g., TRUP (Edwards 1968), ST (Mandelkern 1968) and Harshbarger 1970) and TRUP (Edwards 1968) and Harshbarger 1970). However, the special hardware facilities (i.e., vectorizer, some, etc.) required for graphic display systems used by GRID in an interactive graphics mode technology transfer per se is not available at this time. Therefore, this report is to convey the general utility and cost savings of interactive graphics in supplying a grid generation capability in support of integrated finite difference codes. In addition, this document will serve as a user's guide for the execution of the GRID interactive graphics package.

(a) Two codes FED (Schwarz 1973) and ORG (Lewis and Schwarzer 1978) were considered, but FED uses a unique computer language and ORG was inefficient because of core space requirements and manipulations necessary to reduce three-dimensional output into a two-dimensional format for use in TRUST.

DIGRD CODE DESCRIPTION

The digitize grid (DIGRD) code, an interactive grid generation code, was developed out of the need to construct and edit grids for the integrated finite difference model TRUST (Reisenauer et al. 1982), which solves a wide spectrum of fluid flow problems arising in variably saturated deformable porous media. To form the numerical analogue to the conservation equations of the TRUST model, certain geometric terms describing the integrated finite difference grid must be supplied to TRUST. In the two-dimensional world, these terms are the area of an element, the distance between an element's node and interface, and the length of the interface. An additional geometric requirement is that a connection drawn between a node and its neighboring node be normal to the interface between the two nodes. In Figure 1, for example, the interfaces (solid lines) define the area of the grid element associated with node 1. Connections between node 1 and its neighboring nodes are represented by dashed lines. A connection must be normal to the interface it crosses. The symbols d_1 and d_2 are the interface distances between element 1 and 2. The area associated with each node, the length of interface, and the interface distances, d_1 and d_2 , are broadly referred to as the connectivity data.

DIGRD facilitates construction of a grid and its geometric characterization by combining the logic necessary to compute the geometric terms with the ability to interactively alter the grid. To provide the immediate interface to

FIGURE 1. A Typical Integrated Finite Difference Node

TRUST, the areas and length measures determined within DIGRD are cast in the form of the Block 4 and Block 5 inputs necessary for the TRUST code. Block 4 consists of listing each node, its associated material number and three geometric factors, the product of which equals the element's area. Block 5 is a list of connected nodes, the distances from the connecting nodes to the interface, two geometric factors whose product equals the length of the connected interface, and the angle of intersection between the connection and interface. The angle of intersection is computed and reported only to give the user an indicator of the orthogonality existing in the grid. Orthogonality may be optimized through the use of the node center and interface interactive modes presented in the following section. An example of a grid generated by DIGRD for use in a uranium mill tailings analysis is shown in Figure 2.

DIGRD HARDWARE

DIGRD is designed as an interactive program for use on the Digital Equipment Corporation (DEC) PDP 11/55 minicomputer. To permit interactive grid construction and editing, the following PDP 11/55 accessory equipment is used during operation: a VT-100 terminal (hereafter referred to as "terminal"), a RAMTEK graphic display system (9400), a Refresh Vector Scope (DEC-VS60), and a Bendix computer graphic data grid digitizer. Additional equipment associated with the PDP 11/55 include a hard copy terminal, line printer, a tape drive, and a large volume storage disk.

DIGRD SOFTWARE

The DIGRD code operates in five interactive modes and has ten options for input, output, and storage operations. The functions that these modes and options perform are summarized in Table 1. Interactive modes include elements, connections, delete, node center, and interface. The principle subroutine structure for these five modes is displayed in Figure 3. (See Appendix A for a brief summary of each subroutines' function.) The ten options are grid calibration, window dimension, material type, node number, node connections, node center, save file I/O, TRUST file output, compress disk, and delete last element. These options are conveniently accessible during normal operation of any mode; the user does not have to exit a mode in order to use an option. The window dimension, material type, node numbers, and delete last element options are instructions permitting the entry or deletion of limited information. A subroutine structure for the remaining six options is given in Figure 4. The menu of modes and options is displayed on the right of the VS-60 display screen as shown in Figure 5. Note that the 'digitizer switch' is initialized in the 'off' position while the 'modes' are initialized on 'elements'. The status of the digitizer is shown by the box drawn around the active descriptor on the VS-60 menu display. Each is light-pen activated. Detailed instructions for operating each mode and option will be given in a logical sequence in the next section.

FIGURE 2. A DIGRD Generated Grid for a Uranium Mill Tailings Disposal Site

TABLE 1. Mode and Option Functions

Mode or Option	Function
<u>Mode</u>	
Elements	Constructs elements in the grid
Connections	Specifies connections between nodes
Delete	Deletes elements from the grid
Node Center	Re-positions the node in an element
Interface	Re-positions interfaces between elements
<u>Option</u>	
Grid Calibration	Calibrates digitizing table
Windows Dimension	Sets viewing window for RAMTEK scope
Material Type	Sets material type for node and associated element
Node Number	Sets node number of element being digitized
Node Connection	Input a connection file
Node Center	Input a node position file
Save File I/O	Create an output save file or input a save file to DIGRD
TRUST File Output	Create Block 4 and/or Block 5 TRUST files
Compress Disk	Deletes File-Q blocks storing deleted information
Delete Last Element	Deletes the last digitized element

FIGURE 3. Subroutine Structure for DIGRD's Five Interactive Modes

FIGURE 4. Subroutine Structure for Six of DIGRD's Options

DIGITIZER SWITCH
ON ☐ OFF ☒

DIGITIZING MODE
☒ ELEMENTS
CONNECTIONS
DELETE
NODE CENTER
INTERFACE
GRID CALIBRATION (YES)
WINDOW DIMENS(IN) 8.0
MATERIAL TYPE 3
NODE NO. 46
NODE CONNECTIONS
NODE CENTER
SAVE FILE I/O
TRUST FILE OUTPUT
COMPRESS DISK
DELETE LAST ELEMENT

X - MAP POS.
258.07

Y - MAP POS.
133.47

STOP

FIGURE 5. DIGRD's Menu of Modes and Options Shown as They Appear on the Right Side of the VS-0 Display. A light pen is used by the operator to select modes and/or options.

PROGRAM START-UP

Execution of the DIGRD code begins with its installation on the PDP 11/55 system. Following installation, the CALIBRATION option must be used to calibrate the Bendix digitizer. Three other options that may require use are WINDOW DIMENSION, MATERIAL TYPE and NODE NUMBER.

INSTALLATION

To execute the DIGRD code, one must sequentially: 1) identify the disk and name of the program, 2) identify the File-Q disk or unit (DK1), and 3) finally direct the program to either start or restart. The following is an example of the installation command sequence.

Terminal Input

```
>RUN DK2:DIGRD
>
  ENTER DISK , UNIT FOR FILE-Q FILES
DK1
  (1) - START
  (2) - RESTART
1
```

The start option is used when the user initially runs the program. The restart option can be used after the user has been working on a grid and has temporarily stopped the program. Files stored previously on the temporary storage disc, DK1, will automatically be accessible to the program after restart. Therefore, the restart option can be used in a situation where the code's execution was aborted (by the machine or user) and the user wishes to restart the program to continue editing or modifying the same grid.

CALIBRATION

After each start or restart, the Bendix digitizer must be calibrated so that distances digitized on the table are converted to the real length measure of the grid. The following steps must be performed in sequence to calibrate the digitizer.

- Fix the grid to be digitized to the Bendix digitizer table, using ordinary masking tape.
- Zero the digitizing table's cursor by placing the cursor in the left hand corner and pressing the red cursor button (#1).
- Touch the light pen to the GRID CALIBRATION option displayed on the VS-60.

- Position the cursor on the origin of the grid and press the cursor's white button (#2).
- Position the cursor on the maximum distance in the x-direction and again press the cursor's white button (#2).
- Enter the number of length units represented by this distance on the Bendix digitizer's keyboard.

While executing the calibration option, the following instructions appear on the terminal.

```
DIGITIZE ORIGIN
DIGITIZE MAX "X" DISTANCE
```

Once the digitizer has been calibrated and the digitizer switch is in the 'on' position, the Cartesian coordinates of the cursor's position are displayed at the bottom of the VS-60 screen (see Figure 5). By moving the cursor from the origin (0,0) to the maximum x distance, one can check whether the digitizer is properly calibrated.

WINDOW DIMENSIONS

This option allows one to change the dimensions of the Bendix digitizer viewing window that is displayed on the RAMTEK scope. The window dimension's default value is 10 inches. Therefore, a 10- by 10-inch square centered on the cursor position will be automatically displayed on the RAMTEK scope. If the user wishes to view a larger (or smaller) region, touch the light pen to the WINDOW DIMENS option displayed on the VS-60 and enter the dimensions of the desired digitizer window (in inches) on the terminal. A sample input follows:

Terminal Input:

```
ENTER THE WINDOW DIMENSION(IN)
25
```

Material Type

This option allows one to specify the material type of a node and its associated grid element. Before digitizing an element or series of like elements, touch the light pen to the MATERIAL TYPE option displayed on the VS-60 and enter the material type on the terminal for the elements you are about to digitize. A sample input follows:

Terminal Input:

ENTER THE MATERIAL TYPE

3

The material type default value is 1. Once specified, the material type remains unchanged until re-specified.

NODE NUMBER

The NODE NUMBER option allows one to specify the node number of the element one is about to digitize. The initial node number default value is 1. Node numbers are incremented by one each time an element is digitized. To specify a different initial node number, the user must touch the light pen to the NODE NUMBER option on the VS-60 and enter the node number on the VT-100 terminal. The terminal response and required input are displayed in the following example.

Terminal Input:

ENTER THE NODE NUMBER

25

Once the node number has been set, one needs to specify a node number only when non-consecutively numbered nodes are being digitized.

Terminal Input:

ENTER THE MATERIAL TYPE

The material type default value is 1. Once specified, the material type remains unchanged until re-specified.

NODE NUMBER

The NODE NUMBER option allows one to specify the node number of the element one is about to digitize. The initial node number default value is 1. Node numbers are incremented by one each time an element is digitized. To specify a different initial node number, the user must touch the right pen to the NODE NUMBER option on the V1-50 and enter the node number on the V1-100 terminal. The terminal response and request output are displayed in the following examples.

Terminal Input:

ENTER THE NODE NUMBER

50

Once the node number has been set, one needs to specify a node number only when non-consecutively numbered nodes are being digitized.

OPERATIONAL MODES

The five operational modes of DIGRD are ELEMENTS, CONNECTIONS, DELETE, NODE CENTER and INTERFACE. Each of these modes will be presented in detail. In order to use any of these modes the digitizing switch on the VS-60 screen must be turned on. This is accomplished by simply touching the light pen to the word ON displayed beneath DIGITIZER SWITCH on the VS-60 menu (see Figure 6). The status of the digitizer switch is indicated by the circled word: if on, the word ON is circled; if off, the word OFF is circled.

ELEMENTS

The elements mode is used to either construct or reconstruct a grid. Elements are created by sequentially entering the element with the digitizer's cursor. An entirely new grid can be generated, or elements can be deleted and reconstructed for an existing grid to better meet the orthogonality constraints of the integrated finite-difference method.

Instructions

- Touch the light pen to the VS-60 displayed ELEMENTS mode. When active, the word ELEMENTS is circled. Note that upon installation the ELEMENTS mode is active by default.
- Set the digitizing table's cursor at a corner of the element to be digitized. Press the cursor's white button (#2).
- Continue to digitize the element by moving from one corner to the next, pressing the cursor's white button (#2) at each corner. The corners must be entered sequentially; however, either a clockwise or counterclockwise sequence is acceptable.
- Close the element by pressing the cursor's blue button (#3) when the cursor is realigned with the first point. Thus, in order to enter the entire element boundary, the boundary string consists of one more than the number of corner points of the element, with the first point also becoming the last point.
- Press the green cursor button (#4) to display the region surrounding the cursor position on the RAMTEK scope.

Cursor Button Summary

- White (#2) digitizes the boundary points of the element.
- Blue (#3) closes the boundary on the first point of the boundary string when it appears as the last point.
- Green (#4) displays a region centered about the cursor position.

<p>DIGITIZER READY BTN 2 - DIGITIZE BNDY, 3 - END BNDY, 4 - DISPLAY</p>		<p>DIGITIZER SWITCH ☐ ON ☐ OFF</p>
		<p>DIGITIZING MODE ☐ ELEMENTS</p>
		<p>CONNECTIONS</p>
		<p>DELETE</p>
		<p>NODE CENTER</p>
		<p>INTERFACE</p>
		<p>GRID CALIBRATION (YES)</p>
		<p>WINDOW DIMENS(IN) 8.0</p>
		<p>MATERIAL TYPE 3</p>
		<p>NODE NO. 46</p>
		<p>NODE CONNECTIONS</p>
		<p>NODE CENTER</p>
		<p>SAVE FILE I/O</p>
		<p>TRUST FILE OUTPUT</p>
		<p>COMPRESS DISK</p>
		<p>DELETE LAST ELEMENT</p>
		<p>X - MAP POS. 258.07</p>
		<p>Y - MAP POS. 133.47</p>
		<p>STOP</p>

FIGURE 6. VS-60 Menu Showing the Digitizing Instructions at the Top Center of the Screen

Interactive Graphic Displays

The digitizing instructions and button numbers are displayed at the top of the VS-60 screen as shown in Figure 6.

The RAMTEK scope displays the boundary of an element as it is digitized. When the element is closed, the node number and node position (initialized at the center of the mass of the element) are displayed on the RAMTEK scope (see Figure 7). The display colors of the scope are used to graphically show the material type of each element. The color of the node number corresponds to the element's material type according to the following color scheme. For material type numbers one through seven, the element node display colors are respectively blue, green, cyan, red, magenta, yellow and white.

As each element is digitized, the VS-60 screen displays its node number. If the closing point of the element is not within 0.05 inches of the starting point, the error message 'Element Not Closed' appears. A sample terminal display for several successively digitized elements is shown below. NTOT refers to the node number and ELEM.INDEX indicates the sequential order in which the elements are digitized. The area of the element associated with the node is given in squared map units.

NTOT =	38	ELM. INDEX =	14
AREA OF REGION =	1154.657		
NTOT =	39	ELM. INDEX =	15
AREA OF REGION =	129.8426		
NTOT =	40	ELM. INDEX =	16
AREA OF REGION =	138.8300		
NTOT =	41	ELM. INDEX =	17
AREA OF REGION =	119.6520		
NTOT =	42	ELM. INDEX =	18
AREA OF REGION =	215.2713		
NTOT =	43	ELM. INDEX =	19
AREA OF REGION =	278.1266		
NTOT =	44	ELM. INDEX =	20
AREA OF REGION =	709.8018		
NTOT =	45	ELM. INDEX =	21
AREA OF REGION =	1229.909		
ELEMENT NOT CLOSED	0.3262636		

Option - Delete Last Element

This option allows the user to delete the last element digitized in the event an error has been made. Sequential instructions for use of this option are:

FIGURE 7. The RAMTEK Scope Display of DIGRD's Elements Mode

- Touch the light pen to the DELETE LAST ELEMENT option displayed on the VS-60 screen.
- The message "DELETE LAST ELEMENT? (Y,N)" appears on the terminal.
- Enter Y for yes if you wish to delete the last element or N for no (you've had a change of heart).

Several elements may be deleted by applying this option successively. The last digitized element of those remaining will be deleted. After deleting one or several elements, the remaining elements can be displayed on the RAMTEK scope by pressing the cursor's green (#4) button.

CONNECTIONS

The connections mode permits the user to specify the desired connectivity between a node (element) and the region surrounding it. Nodes in the neighborhood of a particular node are connected by a straight line. Those in the neighborhood that the user does not wish to connect need not be connected.

Instructions

- Touch the light pen to the VS-60 displayed CONNECTIONS mode.
- Press the cursor's white (#2) button, while the digitizing table's cursor is anywhere inside the starting node's (element's) boundary.
- Press the blue (#3) button anywhere inside an element connected to the starting element. Pause until either the RAMTEK scope draws the connection (in yellow) or until the VS-60 screen acknowledges that it has found the connecting element. While generating these connections, the VS-60 screen displays the starting node number and the connecting node number; if node information (e.g., coordinates) cannot be found, the error message 'node not found' is printed.
- Move the cursor to another element to be connected to the starting element and press the blue (#3) button. Continue to enter element connections for the starting element until all connections are established.
- Move the cursor to the next element for which connections are to be established and follow the preceding three instructions.
- Press the green (#4) cursor button to display nodes (material color), elements boundaries (white) and connections (yellow) on the RAMTEK scope.

Cursor Button Summary

- White (#2) identifies the starting element.
- Blue (#3) identifies the connecting elements.
- Green (#4) displays nodes, elements and connections on the RAMTEK scope.

Interactive Graphic Displays

A RAMTEK scope display of connections is shown in Figure 8. The node numbers shown on the scope are color coded on the RAMTEK to display material types. All element boundaries, shown here as solid lines, are solid white lines and all node connections, shown here as dashed lines, are solid yellow lines on the RAMTEK scope.

DELETE

The delete mode enables the user to delete elements from the grid. It can be used during the editing process to remove elements and hence improve the grid. Digitizing a new configuration of elements is done under the elements mode.

Instructions

- Touch the light pen to the VS-60 displayed DELETE mode.

FIGURE 8. The RAMTEK Scope Display of DIGRD's Connections Mode

- Place the digitizing table's cursor inside the boundary of the element to be deleted and press the cursor's white (#2) button.
- Wait until the VS-60 screen identifies the deleted element, e.g.,
ELEMENT DELETED = 25.
- Repeat the previous two instructions until all elements are deleted.
- Press the green (#4) cursor button to display the elements on the RAMTEK scope. The node numbers of deleted elements will blink on and off. Deleted elements are actually tagged for deletion but still occupy a File-Q block of hardware memory. In order to actually and finally delete the blocks containing deleted element data, one must compress the disk (see Option - Compress Disk).
- Prior to compressing the disk, an element can be restored by pressing the white (#2) cursor button while the cursor overlies the element. This second depression of the cursor button restores the element and the VS-60 screen identifies it, e.g.,

ELEMENT RESTORED = 25.

Cursor Button Summary

- White (#2) identifies the element to be deleted (if pressed once) or restored (if pressed twice).
- Green (#4) displays the elements in the window of the cursor. Those elements deleted are shown with blinking node numbers until the File-Q disk is compressed.

Interactive Graphic Displays

A RAMTEK scope display is shown in Figure 9. The grid shown in Figure 7 is displayed after the deletion of several elements in Figure 9. The node numbers displayed on the RAMTEK are color coded to the element material type. All element boundary lines are white on the scope.

After identifying an element to be deleted with the cursor's white (#2) button, files are searched to find that element's information. If the search is successful, the VS-60 screen will identify the deleted element, e.g.,

ELEMENT DELETED = 25.

If a deleted element cannot be found, the following message appears on the terminal,

SEQ SEARCH
ELEMENT NOT FOUND

FIGURE 9. An Example of DIGRD's Delete Mode Showing the Grid from Figure 7 After Deletion (and File-Q Compression) of Several Elements

When this occurs, a fresh RAMTEK scope display of the grid section in question should be produced (green cursor button) to determine if the element information has been previously deleted and compressed.

Option - Compress Disk

This option compresses the File-Q storage, thus removing all record of deleted elements and providing valuable hardware memory for the storage of

additional element information. Sequential instructions for the compress disk option are:

- Touch the light pen to the VS-60 displayed COMPRESS DISK option.
- Wait for the terminal message acknowledging that the compression is completed, e.g.,

```
COMPRESSING DISC  
UPDATING INDEX FILE  
DONE IIEL = 18
```

(IIEL gives the number of elements remaining after compression).

NODE CENTER

The node center mode permits the user to reposition an element's node. Orthogonality of the node connection and element boundary lines are constraints upon the grid for the integrated finite difference method. Hence, the ability to move the node and obtain an optimal degree of orthogonality is essential to the generation of any grid. The interactive graphics of this mode allow the user to visually optimize the orthogonality.

Instructions

- Touch the light pen to the VS-60 displayed NODE CENTER mode.
- Place the cursor anywhere inside the element whose node is to be repositioned and press the white (#2) button. The element, its connecting elements and connections, and all angles of intersection (connections and boundaries) are drawn on the VS-60 screen (see Figure 10). The position of the node tracks with the cursor.
- Move the cursor (node) while watching the VS-60 screen until the orthogonality is optimal with respect to the average absolute difference (actual-orthogonal). This absolute measure is printed in the upper left corner of the screen. Each of the connecting element numbers and their associated intersection angle are displayed on the right (see Figure 10).
- Press the cursor's blue (#3) button when the node has been positioned to a satisfactory location. This permanently repositions the node at the cursor location.
- Press the cursor's white (#2) button to display the node in its new position and permit its relocation if necessary.
- Press the cursor's green (#4) button to provide a fresh display of the elements and new node position on the RAMTEK scope.

NODE POSITIONING OF NODE NO. 38

AVERAGE ABS. DIF. =

NODE NO. ANGLE

45	69.2
39	79.0
40	85.6
41	89.8
42	89.8
43	85.2
44	74.3

DIGITIZER SWITCH

☒ ON ☐ OFF

DIGITIZING MODE

ELEMENTS

CONNECTIONS

DELETE

NODE CENTER

INTERFACE

GRID CALIBRATION (YES)

WINDOW DIMENS(IN) 8.0

MATERIAL TYPE 3

NODE NO. 46

NODE CONNECTIONS

NODE CENTER

SAVE FILE I/O

TRUST FILE OUTPUT

COMPRESS DISK

DELETE LAST ELEMENT

X - MAP POS.
258.07

Y - MAP POS.
133.47

STOP

FIGURE 10. An Example of DIGRD's Node Center Mode

- Move the cursor to a new element requiring node repositioning and repeat the above steps by first pressing the white (#2) button to create the VS-60 display.

Cursor Button Summary

- White (#2) displays the element and its connecting neighbors on the VS-60 screen.
- Blue (#3) permanently repositions the node at the cursor position.
- Green (#4) displays the elements, nodes and connections on the RAMTEK scope.

Interactive Graphic Displays

The VS-60 screen displays created by pressing the white cursor button permit the visual optimization of the nodal position. A typical display is shown in Figure 10. In addition to the VS-60 menu, the element, its connecting elements and their connections, and a summary of angle information is provided. The angle of each connection and boundary intersection is reported along with the absolute average difference (actual-orthogonal). The Cartesian coordinates of the cursor are also reported at the bottom of the VS-60 menu under the X and Y-MAP POS. As one moves the cursor, the associated software tracks the (X,Y) coordinate, moves the node and redraws the connections, and recomputes the angles and their absolute average difference. One can readily sweep the element domain with the cursor and interactively determine the best node position.

The RAMTEK scope displays elements, nodes, and corners when the green (#4) cursor button is pressed. The standard color-coded display discussed in the 'connections' node section is created.

INTERFACE

The interface mode gives the user an ability to adjust element boundary or interface lines to improve the orthogonality of connection and element boundary intersections. This editing mode functions similar to the 'node center' mode; the difference is that the cursor takes on the identity of an element boundary node common to several elements (see Figure 11).

Instructions

- Touch the light pen to the VS-60 displayed INTERFACE mode.
- Place the digitizing table's cursor near the element boundary or interface corner to be moved and press the cursor's white (#2) button. The cursor point and all interfaces connected to it will be displayed on the VS-60 screen. The position of the interface corner point will track with the cursor.

INTERFACE POSITIONING
AVERAGE ABS. DIF. = 3.2

NODE NO.	ANGLE
170-168	89.6
168-167	83.5
167-169	87.6
169-170	86.6

DIGITIZER SWITCH

☒ ON OFF

DIGITIZING MODE

ELEMENTS

CONNECTIONS

DELETE

NODE CENTER

INTERFACE

GRID CALIBRATION (YES)

WINDOW DIMENS(IN) 8.0

MATERIAL TYPE 3

NODE NO. 46

NODE CONNECTIONS

NODE CENTER

SAVE FILE I/O

TRUST FILE OUTPUT

COMPRESS DISK

DELETE LAST ELEMENT

X - MAP POS.
258.07

Y - MAP POS.
133.47

STOP

FIGURE 11. An Example of DIGRD's Interface Mode Display on the VS-60 Screen

- Move the cursor until the average absolute value (actual-orthogonal) displayed in the upper left corner of the VS-60 screen is minimized. The connecting elements and their intersection angles are displayed in the upper right corner of the VS-60 screen.
- Press the cursor's blue (#3) button when the interface has been repositioned to the user's satisfaction. This will permanently position the interface corner point at the cursor location.
- Press the cursor's green (#4) button to provide a RAMTEK scope display of the elements, nodes, and connections in the window of the cursor.
- Move the cursor to a new element boundary or interface corner which needs adjustment and repeat the above steps by first pressing the cursor's white (#2) button. Continue repositioning interfaces until all element boundary and connection intersections have been improved.

Cursor Button Summary

- White (#2) displays the interface corner and surrounding elements on the VS-60 screen and frees the interface corner to move with the cursor.
- Blue (#3) permanently repositions the interface corner at the cursor's location.
- Green (#4) displays the elements, nodes, and connections on the RAMTEK scope.

Interactive Graphic Displays

The VS-60 display of the interface corner and its adjacent elements appears to the right of the menu and includes the average absolute difference and individual intersection angles (see Figure 11). The cursor coordinates are shown at the bottom of the menu and track the movement of the cursor. As the cursor is moved, the associated software tracks the (X,Y) coordinate, moves the interface corner and its interfaces, and computes and displays the angles and their absolute average difference. The best corner position is readily determined by sweeping the element domain and visually optimizing the average angle. The RAMTEK scope display created by pressing the green (#4) cursor button is the standard color coded display of elements, nodes and connections discussed in the 'connections' mode section.

Additional Utility

In the process of digitizing a grid, each element boundary or interface corner is digitized several times. Human error being what it is, a single corner can have several differing coordinate definitions. The interface mode as described above can be used to consolidate these corner coordinates and establish a unique position. Figure 12 provides a before and after view from the RAMTEK scope of this corner consolidation procedure.

(a) Before

(b) After

FIGURE 12. A RAMTEK Scope Display of an Interface Corner (a) Before and (b) After Interface Repositioning

INPUT AND OUTPUT OPTIONS

Of the ten options presented in the DIGRD software section, six have been discussed. The first four (grid calibration, window dimension, material type and node number) appeared under the discussion of program start-up. Options for disk compression and deletion of the last element were presented in the delete and elements mode discussions, respectively. The four remaining options are for input and output. They are, in the order in which they appear on the VS-60 screen:

- Node Connections
- Node Center
- Save File I/O
- TRUST File Output.

A brief user-oriented description of each option is presented below.

NODE CONNECTIONS

The node connections option permits the user to input a node connection file for use by DIGRD. This is essentially an alternate means of introducing the connectivity data previously discussed in the connections mode presentation.

Instructions

- Touch the light pen to the VS-60 displayed NODE CONNECTIONS option. The terminal will respond with the following question,

'DO YOU WISH TO OPEN A CONNECTION FILE? (Y,N).'

- Enter a 'Y' on the terminal indicating a desire to read in a node connection file; otherwise, enter an 'N'.
- If the user response has been yes, the terminal will respond with,

'CLEARING CURRENT CONNECTIONS
ENTER THE CONNECTION FILE NAME'

- Enter the file name and extension of the connection file (e.g., CONN.FIL) on the terminal's next line.
- Upon completing the transfer of the connection file, the terminal will respond with the following text:

'SAVE FILE READ FINISHED
NEGATIVE CONNECTIONS SET UP
LIST THE CONNECTIONS FILE? (Y,N)'

- On the next terminal line, enter a 'Y' to obtain a hard copy (line printer) listing of the connection file; otherwise, enter a 'N' for no.

Terminal Dialogue Example

The following is a listing of the instructions, questions, and responses as they would appear on the terminal following a node connections session.

```
DO YOU WISH TO OPEN A CONNECTION FILE?(Y,N)
Y
CLEARING CURRENT CONNECTIONS
ENTER THE CONNECTION FILE NAME
CONN.FIL
```

Node Connection File Example

The connection file is free formatted. The number of connections in the file is given on the first line. Each of the remaining lines of the file contains a pair of nodes separated by a comma. The following list is a connection file example.

```
15
1,2
1,46
1,3
2,50
2,4
3,4
3,46
3,183
4,166
4,188
4,189
5,6
5,44
5,183
5,179
```

NODE CENTER

The node center option allows the user to input a file of node position coordinates for use by DIGRD. While in the elements mode, the node position was calculated to be at the element's center of mass. This is often not the case and the node center option provides the user a means of introducing more appropriate nodal coordinates.

Instructions

- Touch the light pen to the VS-60 displayed NODE CENTER option.
- The terminal responds with,

 'INPUT NODE CENTER FILE'

essentially asking the user for file name and extension of the input record.
- Enter the file name and extension of the node center file (e.g., NODE.FIL).
- The terminal responds with,

 'ENTER INPUT DEV., UNIT'

asking the user for the device identifier.
- Enter the disk drive and unit number (e.g., DK2).

Terminal Dialogue Example

The following is a listing of the instructions, questions and responses as they would appear on the terminal following a node center session.

```
INPUT NODE CENTER FILE
NODE.FIL
ENTER INPUT DEV.,UNIT
DK2
```

Node Center File Example

The node center file is free formatted and the first line gives the number of nodes in the file. Subsequent lines list the node numbers and their Cartesian (X,Y) coordinates in map units. A list of a typical node center file follows,


```

10
1,13.0,102.25
2,13.0,111.00
3,45.75,102.25
4,45.75,111.00
5,84.33,102.25
6,84.33,103.5
7,127.26,102.25
8,127.26,111.0
9,168.01,102.25
10,127.26,102.25
11,127.26,111.00
12,168.01,102.25
13,168.01,111.00
14,208.76,102.25
15,208.76,111.00

```

SAVE FILE I/O

The save file I/O option enables the user to either save or read a grid file. The save file that is either generated or read is a formatted (file 11) file.

Instructions

- Touch the light pen to the VS-60 displayed SAVE FILE I/O option.
- The terminal will respond with the following,

```
'(1) - WRITE ELEMENT SAVE FILE
(2) - READ ELEMENT SAVE FILE'
```

- Enter a '1' to write a save file; enter a '2' to read.
- The terminal will ask for the file name. Enter the file name and extension, e.g.,

```
'ENTER FILE NAME
SAVF.FIL'
```

- The terminal will now ask for the device and unit identifiers. Enter the disk unit identifier, e.g.,

```
'ENTER OUTPUT DEV,UNIT
DK2'
```

Terminal Dialogue Example for SAVE

An example of user and terminal dialogue for writing a save file is as follows.

```

(1) - WRITE ELEMENT SAVE FILE
(2) - READ ELEMENT SAVE FILE
1
ENTER FILE NAME
SAVF.FIL
ENTER OUTPUT DEV,UNIT
DK2
SAVE FILE WRITE FINISHED

```

Terminal Dialogue Example for READ

An example of user and terminal dialogue for reading a save file is as follows.

```

(1) - WRITE ELEMENT SAVE FILE
(2) - READ ELEMENT SAVE FILE
2
ENTER FILE NAME
SAVF.FIL
ENTER OUTPUT DEV,UNIT
DK2
CLEARING X-Y INDEX FILE
READING SAVE FILE
ESTABLISHING NEGATIVE CONNECTIONS
SAVE FILE READ FINISHED

```

Save File Format

The first line of the SAVE file is the number of elements in the grid. Next, each group of four lines is data associated with one element as follows:

- Line 1: Format (20I5); MAT(3)
Lists the material type; the number of points in the element's boundary, and the number of connecting elements. MAT is the array containing these variables and is dimensioned 3.
- Line 2: Format (3F12.2, 5X,2I6); CENTER(2), RAREA, INDEX
Lists the node (x,y)-coordinates in map units, the element's area and index. CENTER is the array containing the node coordinates and is dimensioned 2. RAREA is the variable for area; INDEX is the variable for the index.
- Line 3: Format (8F10.2); POINT [(2),MAT(2)]
Lists the (x,y) coordinates in map units of the boundary points of the element. POINT is the array containing the (x,y) coordinates; it is dimension 2 x the number of boundary points. Recall that the number of boundary points is one more than the number of corner points, since the first point is listed twice.

Line 4: `FORMAT (20I5); CONN [MAT(3)]`
Lists the node numbers of connecting nodes. CONN is the array containing the connecting numbers. It is dimensioned to the number of elements connected to the node.

Save File Example

The first seven elements of a save file are listed in Figure 13.

TRUST FILE OUTPUT

The TRUST file output option enables the user to create a readily transferable input file for the TRUST code. Both the Block 4 and Block 5 input files are functions of the previously generated grid data.

Instructions

- Touch the light pen to the VS-60 displayed TRUST FILE OUTPUT option.
- The terminal will ask for a yes or no (Y or N) response to the following questions

BLOCK 04 OUTPUT?-(Y,N)

- Enter a 'Y' to create a Block 4 input file; otherwise, enter 'N'. The Block 4 file is written to DK2 and is called 'TRUST4.OUT'.
- The terminal will ask for a yes or no (Y or N) response to the following question

'BLOCK 05 OUTPUT?-(Y,N)'

- Enter a 'Y' to create a Block 5 input file; otherwise, enter 'N'. The Block 5 file is also written to DK2 and is called 'TRUST5.OUT'.

Terminal Dialogue Example

An example terminal dialogue for the TRUST file output option is as follows,

```
BLOCK 04 OUTPUT?-(Y,N)
Y
BLOCK 4 OUTPUT COMPLETED
BLOCK 05 OUTPUT?-(Y,N)
Y
BLOCK 5 OUTPUT COMPLETED
```

Block 4 File Example

Figure 14 displays the form of the Block 4 output file. A brief description of the file contents was presented in the code description section.

248									
3	5	3							
	13.00		102.25	38.06	1				
	25.38	103.00	0.00	103.00	0.00	101.50	25.38	101.50	
	25.38	103.00							
2	48	3							
1	5	2							
	13.00		111.00	441.75	2				
	25.38	103.00	0.00	103.00	0.00	120.40	25.40	120.40	
	25.38	103.00							
50	4								
3	5	3							
	45.75		102.25	59.87	3				
	25.38	103.00	25.38	101.50	65.29	101.50	65.29	103.00	
	25.38	103.00							
4	46	183							
1	6	3							
	45.75		111.00	707.91	4				
	25.38	103.00	25.40	120.40	65.39	120.40	66.80	111.00	
	65.29	103.00	25.38	103.00					
166	188	189							
3	5	4							
	84.33		102.25	21.00	5				
	77.33	103.00	91.33	103.00	91.33	101.50	77.33	101.50	
	77.33	103.00							
6	44	183	179						
4	5	3							
	84.33		103.50	40.00	6				
	77.33	103.00	81.33	107.00	87.33	107.00	91.33	103.00	
	77.33	103.00							
180	181	182							
3	5	4							
	127.26		102.25	62.38	7				
	147.63	103.00	106.04	103.00	106.04	101.50	147.63	101.50	
	147.63	103.00							
8	9	179	42						

FIGURE 13. Save File Example

BLOCK 04

NODE#	MAT.NO.	DLONG	DWIDE	DRAD	Z-ELEV
1	1	19.8867	19.8867	1.0000	1.0000
2	1	25.4327	25.4327	1.0000	1.0000
3	1	25.5613	25.5613	1.0000	1.0000
4	1	25.4547	25.4547	1.0000	1.0000
5	1	25.6887	25.6887	1.0000	1.0000
6	1	25.2089	25.2089	1.0000	1.0000
7	1	24.0316	24.0316	1.0000	1.0000
8	1	23.5115	23.5115	1.0000	1.0000
9	1	17.4014	17.4014	1.0000	1.0000
10	1	26.2105	26.2105	1.0000	1.0000
11	1	32.4580	32.4580	1.0000	1.0000
12	1	32.1772	32.1772	1.0000	1.0000
13	1	31.2455	31.2455	1.0000	1.0000
14	1	31.0482	31.0482	1.0000	1.0000
15	1	30.5933	30.5933	1.0000	1.0000
16	1	29.8625	29.8625	1.0000	1.0000
17	1	28.2301	28.2301	1.0000	1.0000
18	1	16.8499	16.8499	1.0000	1.0000
19	1	24.9147	24.9147	1.0000	1.0000
20	1	32.2450	32.2450	1.0000	1.0000
21	1	28.0409	28.0409	1.0000	1.0000
22	1	33.6415	33.6415	1.0000	1.0000
23	1	33.0912	33.0912	1.0000	1.0000
24	1	33.6572	33.6572	1.0000	1.0000
25	1	32.5477	32.5477	1.0000	1.0000
26	1	26.4679	26.4679	1.0000	1.0000
27	1	13.7528	13.7528	1.0000	1.0000
28	1	21.0133	21.0133	1.0000	1.0000
29	1	26.5925	26.5925	1.0000	1.0000
30	1	8.4232	8.4232	1.0000	1.0000
31	1	6.8957	6.8957	1.0000	1.0000
32	1	9.3456	9.3456	1.0000	1.0000
33	1	10.4207	10.4207	1.0000	1.0000
34	1	11.4184	11.4184	1.0000	1.0000
35	1	11.5564	11.5564	1.0000	1.0000
36	1	27.1713	27.1713	1.0000	1.0000
37	1	26.9184	26.9184	1.0000	1.0000
38	1	27.9023	27.9023	1.0000	1.0000
39	1	11.1360	11.1360	1.0000	1.0000
40	1	11.7661	11.7661	1.0000	1.0000
41	1	10.6127	10.6127	1.0000	1.0000
42	1	13.8524	13.8524	1.0000	1.0000
43	1	14.7855	14.7855	1.0000	1.0000
44	1	5.6577	5.6577	1.0000	1.0000
45	1	7.5617	7.5617	1.0000	1.0000

FIGURE 14. Block 4 File Example

BLOCK 05

NODE#	NODE#	DIST1	DIST2	DLONG	DRAD	ANGLE
1	10	7.8848	13.6252	25.1202	1.0000	89.7
1	2	12.5506	20.0200	15.8503	1.0000	89.3
3	2	20.1206	20.0495	16.6000	1.0000	89.7
3	4	20.1214	19.9388	15.9610	1.0000	89.5
5	4	20.0697	19.9606	16.3304	1.0000	89.8
5	6	20.0720	20.1694	16.5204	1.0000	89.1
6	15	7.8682	11.5677	40.6869	1.0000	89.3
6	7	20.2183	19.9263	14.9551	1.0000	89.4
8	7	20.0709	19.9005	13.9600	1.0000	89.4
9	8	9.4534	20.0604	13.6000	1.0000	88.2
9	18	8.1135	11.3124	15.0057	1.0000	86.5
11	10	20.0004	12.5396	27.3004	1.0000	89.8
11	2	13.1797	8.1003	40.1372	1.0000	89.0
11	12	20.0020	20.4507	25.4103	1.0000	89.1
12	3	12.6219	8.0797	40.4036	1.0000	90.0
12	21	12.6456	13.3265	41.5423	1.0000	87.9
12	13	20.4928	19.7995	25.0412	1.0000	88.3
13	4	12.3073	8.0786	39.8625	1.0000	88.0
13	14	19.8241	20.1661	24.1177	1.0000	88.7
13	22	12.4851	14.5425	39.4441	1.0000	80.7
14	5	11.9275	8.1775	40.1501	1.0000	88.6
14	15	20.1669	20.1157	23.5776	1.0000	88.7
16	15	19.9234	20.2181	22.6435	1.0000	88.7
16	7	11.1595	7.2960	39.5924	1.0000	90.0
16	17	19.9172	18.5075	21.9872	1.0000	89.3
17	18	18.1484	6.3127	22.0102	1.0000	79.5
17	8	10.8110	6.9537	40.1125	1.0000	85.8
19	28	12.2799	8.6901	25.4501	1.0000	89.8
19	10	12.2800	13.7000	25.1000	1.0000	89.9
20	19	24.5513	12.6525	24.5608	1.0000	88.7
20	11	13.5979	13.3551	39.8549	1.0000	81.5
20	21	17.7981	17.6372	17.3094	1.0000	80.7
20	30	18.4689	5.5009	9.1605	1.0000	88.7
21	22	18.5784	18.0431	18.3114	1.0000	79.3
21	32	12.2175	3.5766	13.4205	1.0000	59.9
21	31	9.2267	1.7653	12.6704	1.0000	85.4
21	30	12.8066	3.4238	10.8097	1.0000	63.6
22	36	12.4130	8.8460	41.7000	1.0000	88.3
22	23	25.0783	20.1440	27.1678	1.0000	88.4
22	32	19.1209	6.7666	9.1781	1.0000	88.2
23	14	13.5368	11.9319	40.5442	1.0000	88.1
23	24	20.2653	24.3115	27.1372	1.0000	86.0
23	37	13.5376	8.8689	40.3827	1.0000	88.5
24	15	16.0862	11.6956	40.0016	1.0000	81.7
24	38	11.7316	9.3781	39.0410	1.0000	88.8

FIGURE 15. Block 5 File Example

PROGRAM EXIT

To exit from the DIGRD program, touch the light pen to the VS-60 displayed STOP option. The following message will appear on the terminal:

```
TTO -- STOP  
HIT <CR> TO EXIT >  
>
```

Depress the carriage return to exit from the program. Instructions for dismounting and removing the disks can be found in Appendix B.

PROGRAM EXIT

To exit from the DIGB program, touch the light pen to the V2-A0 displayed STOP option. The following message will appear on the terminal:

```
ITD -- STOP  
HIT CR - TO EXIT
```

When the carriage returns to exit from the program, instructions for its loading and running the disk can be found in Appendix B.

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APPENDIX A

SUBROUTINE DESCRIPTIONS

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SUBROUTINE DESCRIPTIONS

<u>Subroutine Acronym</u>	<u>Subroutine Function</u>
ANGLES	Computes and angles for Block 5 TRUST output.
CALB	Calibrates the x-axis of the grid into map units.
COMPRS	Deletes and compresses the File-Q disk after element data has been tagged for deletion.
CONODE	Establishes connections between adjacent elements.
DELEM	Tags an element and its connections for deletion from the File-Q storage disk.
DIGBND	Digitizes the boundary string of an element; computes its area and displays the element on the RAMTEK scope.
DIGREG	Saves digitized boundary points of an element into File-Q storage block; computes the node at the center of mass of the element and displays it on the RAMTEK scope.
DSPREG	RAMTEK display of elements, nodes, connections that lie within the window dimensions.
ELFILL	Sets element numbers in the two dimensional x-y index array. Index points are set within the boundary of an element. This index array is used by subroutine XYGET for rapid retrieval of element numbers.
ELMTRN*	Reads and writes an element's data to and from the File-Q disk block where it is stored.
GETINT	Finds list of elements associated with a given interface using node connection data to computer list of elements.
GETNOD	Locates the element containing the current x-y cursor position by calling subroutine XYGET to obtain the list of candidate elements. If the point is not found within any of the elements of the list, a sequential search through the entire element list takes place.
INDEX*	Index pointer table that functions to provide the element number if an index is given or provide the index if an element number is given. The index is the address of the File-Q block where storage of that element's data is located.

<u>Subroutine Acronym</u>	<u>Subroutine Function</u>
INTER	Computes the interface distances for Block 5 TRUST output.
NDCNTR	Reads in a node center coordinate file for use by the program.
NDCONN	Reads in a node connection list file for use by the program.
NDTEST*	Tests to see which line segment of a boundary string intersects a node connection.
PLTCUR*	Plots digitizer cursor position on RAMTEK scope.
PLTELM	Plots the fixed portion (i.e., element boundaries) of the node center mode on the VS-60 scope.
PLTINT	Plots static portion of interface display on VS-60 scope.
POSINT	Plots dynamic portion of interface display on VS-60 scope (i.e., moving interface segments). Also computes and displays intersection angles.
POSNOD	Plots the dynamic portion (i.e., moving connections) for the node center mode VS-60 display. Also computes and displays intersection angles.
RESAV	Reads a save file on to the File-Q disk so that the save file data may be used by this program.
SEGCRS*	Tests to see whether two line segments intersect and returns the intersection point where there is an intersection.
SETDSP	Sets up the fixed portion of the VS-60 menu display.
TRUST	Creates Block 4 and Block 5 TRUST output files.
UPDATE*	Updates the variables in the VS-60 menu display.
WRTSAV	Creates and writes a save file of the data stored on the File-Q disk.
XYGET*	Given the x-y cursor position, this routine returns the element number(s) associated with that position.

* Subroutine called by the majority of modes and options, and therefore, omitted from Figures 3 and 4 for clarity.

APPENDIX B

OPERATION OF THE PDP 11/55

APPENDIX B

OPERATION OF THE PDP 11/55

MOUNTING AND INSTALLING DISKS

There are 3 disks (DK0, DK1 and DK2) associated with the PDP 11/55; and one disk DB0, shared with and linking the PDP 11/55 with the PDP 11/70. DK0 is the system disk, permanently stored in the 11/55, where systems libraries are loaded. DK1 is a temporary storage disk. One can initialize DK1 and temporarily store data on it. In this particular situation, one assigns DK1 as a File-Q disk so it is accessible as a temporary storage disk for File-Q files.

DK2 must be manually loaded into the 11/55. In this case, load the disk containing the program, DIGRD, by inserting it into the DK2 disk drive and switch the button beneath the disk drive to the 'Run' position. Then, the following instructions must be typed on the terminal to mount the disk, set the Users's Identification Code (UIC), and set DK1 as a File-Q disk, respectively.

```
>MOU DK2:/OVR  
>SET /UIC=[7,7]  
>FLQ DK1:/ND
```

Once these instructions are complete, one can proceed to run the DIGRD program. If the system crashes during operation, the system will require rebooting.

DISMOUNTING AND REMOVING DISK

At the conclusion of a grid generation or editing session, type the following command on the terminal to dismount the user's DK2 disk.

```
>DMO DK2:
```

Flip the button beneath the DK2 disk drive down to the 'load' position. Wait (about 2 to 3 minutes) until the disk drive clicks, open the disk door and remove disk.

REBOOTING PROCEDURES

Should the PDP 11/55 crash during operation of a program, the following simple procedure will reboot the system.

- The load address for the PDP 11/55 is 773000. Check to see that switches 9,10, 12-17 are flipped up on the face of the computer and all others are down.

- On the hardcopy terminal, type 'DK' and hit the carriage return.
- Wait until there is a pause in the output from the hardcopy terminal and the computer asks for the date and time in this format.

hour:minute ☐ day-month-year

For example, type on the hard copy terminal:

14:31 ☐ 22-FEB-82

and hit the carriage return. The month is always a 3 letter abbreviation of the month and the time is always based on the 24 hr clock.

- The computer will print out several lines (a sample of which follows) which ends with @<EOF>. When the computer finishes with this hardcopy printout, it is ready for use. Remember, rebooting always dismounts disks and the system loses the user's UIC. Therefore, re-mount the DK2 disk and reset the UIC as previously described. DO NOT reinitialize DK1 if there are files on DK1 you wish to save or edit. Reinitializing or "new directing" (ie,/ND) will destroy these files.

Sample rebooting hardcopy output:

```
036074 000001 000702 000000
$DK

  RSX-11M V3.2 BL26   124K   MAPPED
>RED DK:=SY:
>RED DK:=LB:
>MOU DK:RSXM26
>@DK:[1,2]STARTUP
>* PLEASE ENTER TIME AND DATE (HR:MN DD-MMM-YY) [S]: 12:15 1-APR-82
>TIM 12:15 1-APR-82
>ACS SY:/BLKS=256.
>SET /UIC=[1,5]
>INS SPY/TASK=ACCLOG
>RUN ACCLOG
>SET /TERM=TT3:LA180S
>SET /UIC=[200,200]
>@ <EOF>
```

APPENDIX C

AUXILLIARY PROGRAMS

APPENDIX C

AUXILLIARY PROGRAMS

Two auxilliary programs facilitating the use of DIGRD have been created. They are PLOTELE and SAV. These two programs can be executed on the PDP 11/70. Instructions for the execution of the programs are given below.

PROGRAM: PLOTELE

PLOTELE uses the DIGRD save file to produce a calcomp plot of the grid. The plot includes element boundaries, connections, and node numbers. This plotting capability provides the user with a hard copy of the generated grid for a variety of purposes.

Makes a calcomp plot of a grid generated by DIGRD.

Sample Run of PLOTELE:

```
SCI>> RUN PLOTELE
16:51:30
ENTER THE SAVE FILE NAME
SAV.FIL
AV.FIL
248
ENTER THE SCALE FACTOR FOR PLOTTING
.03
DO YOU WISH TO PLOT CONNECTIONS?(1=Y,0=N)
0
TT00A  --  STOP
```

Terminal Input

1. Enter the name and extension of the save file.
2. Enter the scale factor for plotting. For example, if the grid is 300 ft wide (in map units) the user must fit the grid on the calcomp (which is ~3 ft wide), hence, the scale factor is 0.01.
3. Enter a '1' if you wish to include connections in the plot file; otherwise, enter a '0'.
4. Enter the name and extension of the connection file.

Calcomp Plot Example

Figure C.1 is an example of a PLOTELE execution for a uranium mill tailing disposal pit grid. Normally, a point is plotted at the precise location of the

1	5	10	24	28	32	36	45	54	59	62	64	248	256	264	272
2	6	11	25	29	33	37	46	55	60	63	241	249	257	265	273
3	8	12	26	30	34	38	39	47	48	56	58	242	250	258	274
4	9	13	14	17	22	23	40	44	49	50	57	232	243	251	275
		15	16	21	27	31	35	42	53	234	237	244	252	260	276
201	205	209	213	217	221	225	229	238	245	253	261	269	277		
202	206	210	214	218	222	226	230	239	246	254	262	270	278		
208	207	211	215	219	223	227	234	240	247	255	263	271	279		

FIGURE C.1. Example of a Grid Plot Generated by PLOTELE

node for each element or subregion. They and node numbers in particularly fine grid spacing areas have been omitted in the preparation of this figure for publication.

PROGRAM: SAV

The program SAV creates a save file for input to DIGRD from OGRE output. This permits a grid produced by OGRE to be modified by DIGRD.

Sample run of SAV:

```
SCI>> RUN SAV
12106136
  ENTER THE NODE FILE
TESS.DAT
  ENTER THE POLYGON FILE
TEST3.CLN
  ENTER THE CONNECTION FILE
CONNS.DAT
  ENTER BLK 4 DATA FILE
BLK4.DAT
  ENTER THE OUTPUT SAVE FILE NAME
SAV.FIL
TT00A  --  STOP
```

Terminal Input

1. Enter the name and extension of the node coordinate (x,y,z) location file.
2. Enter the name and extension of the polygon coordinate (x,y,z) boundary file.
3. Enter the name and extension of the connection file.
4. Enter the name and extension of the TRUST Block 4 input file.
5. Enter the name and extension of the save file the user is creating.

Save File Example from SAV

The save file format from SAV is identical to that employed in the SAVE FILE I/O option. The user is referred to the example shown in the discussion of the SAVE FILE I/O option.

node for each element or subregion. They and node numbers in particular. The grid spacing areas have been omitted in the preparation of this figure for publication.

PROGRAM - SAV

The program SAV creates a save file for input to DIBRD from DIBRD output. This permits a grid produced by DIBRD to be modified by DIBRD.

Sample run of SAV:

```

      1.  SAV
      2.  1000
      3.  ENTER THE WORD FILE
      4.  1000.DAT
      5.  ENTER THE POLYGON FILE
      6.  1000.DAT
      7.  ENTER THE CONNECTION FILE
      8.  1000.DAT
      9.  ENTER THE OUTPUT FILE NAME
      10. 1000.DAT
      11. 1000
      12. 1000
      13. 1000
      14. 1000
      15. 1000
      16. 1000
      17. 1000
      18. 1000
      19. 1000
      20. 1000
      21. 1000
      22. 1000
      23. 1000
      24. 1000
      25. 1000
      26. 1000
      27. 1000
      28. 1000
      29. 1000
      30. 1000
      31. 1000
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      86. 1000
      87. 1000
      88. 1000
      89. 1000
      90. 1000
      91. 1000
      92. 1000
      93. 1000
      94. 1000
      95. 1000
      96. 1000
      97. 1000
      98. 1000
      99. 1000
      100. 1000
  
```

Terminal Input

1. Enter the name and extension of the node coordinate (x,y,z) location file.
2. Enter the name and extension of the polygon coordinate (x,y,z) boundary file.
3. Enter the name and extension of the connection file.
4. Enter the name and extension of the TRUST block 4 input file.
5. Enter the name and extension of the save file the user is creating.

Save File Example from SAV

The save file format from SAV is identical to that employed in the SAV FILE I/O option. The user is referred to the example shown in the discussion of the SAV FILE I/O option.

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NRC FORM 335 (7-77)		U.S. NUCLEAR REGULATORY COMMISSION BIBLIOGRAPHIC DATA SHEET		1. REPORT NUMBER (Assigned by DDC) NUREG/CR-2845 PNL-4345	
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) DIGRD: An Interactive Grid Generating Program				2. (Leave blank)	
7. AUTHOR(S) H. P. Foote, W. A. Rice, and C. T. Kincaid				3. RECIPIENT'S ACCESSION NO.	
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Battelle Pacific Northwest Laboratory P.O. Box 999 Richland, Washington 99352				5. DATE REPORT COMPLETED MONTH YEAR October 1982	
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) Division of Health, Siting and Waste Management Office of Nuclear Regulatory Research U.S. Nuclear Regulatory Commission Washington, D.C. 20555				DATE REPORT ISSUED MONTH YEAR November 1982	
13. TYPE OF REPORT Topical Report				PERIOD COVERED (Inclusive dates)	
15. SUPPLEMENTARY NOTES				14. (Leave blank)	
16. ABSTRACT (200 words or less) Pacific Northwest Laboratory has completed the development and documentation of an interactive grid generating program (DIGRD, digitize grid). This program is designed to rapidly generate or modify grids necessary for the unsaturated flow code TRUST. In addition to the code, a user's manual was prepared. Unfortunately, the computer hardware that comprises the PNL interactive graphics capability is unique. Direct technology transfer is not possible, therefore, this report is intended to convey the utility of interactive graphics in supplying a grid generating capability. DIGRD has already been effectively used in the preparation of grids for the analysis of leachate movement from uranium mill tailings. The principal conclusion is that the interactive graphics employed in DIGRD are useful and economical in the development of complex grids. Grid generation activities that previously took between a half- and a full-man month can now be completed in less than a week. DIGRD users have recommended development of an uniform grid of either rectangles or equilateral triangles, which could be superimposed on any domain and then adjusted through the DIGRD program to match the boundaries of a tailings disposal facility. This improvement to the DIGRD package could further reduce the effort in grid generation while providing more optimal grids.					
17. KEY WORDS AND DOCUMENT ANALYSIS Uranium mill tailings grid computer graphics unsaturated flow leachate			17a. DESCRIPTORS		
17b. IDENTIFIERS/OPEN-ENDED TERMS					
18. AVAILABILITY STATEMENT Unlimited			19. SECURITY CLASS (This report) Unclassified		21. NO. OF PAGES
			20. SECURITY CLASS (This page) Unclassified		22. PRICE S