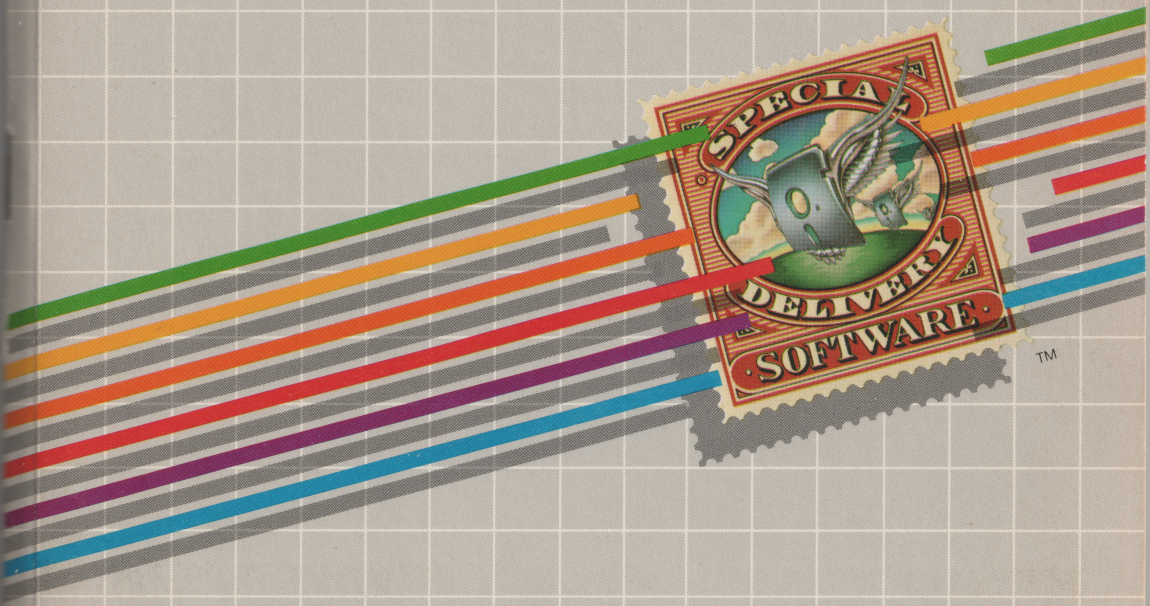
APPLE



USER'S GUIDE:
TOPOGRAPHIC
MAPPING PROGRAMS

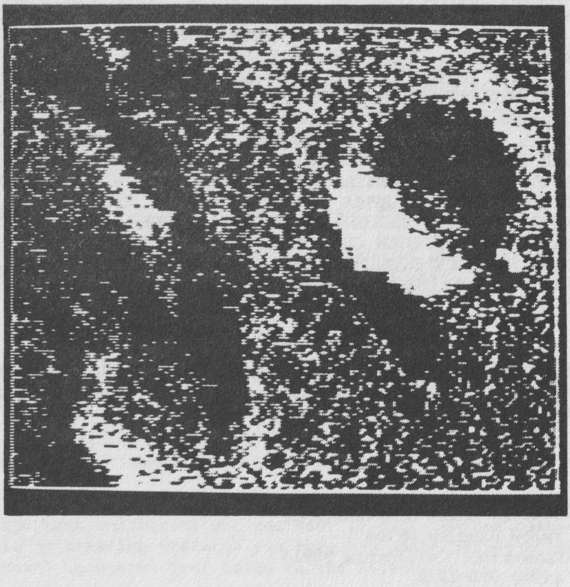


Illustration: A shaded-relief map of the area of the craters Aristarchus (upper right) and Herodotus (lower left) on the moon, generated by the surface display program PLASTIC. The direction of light is from the upper right.

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PREFACE

The set of programs included in the Topographic Mapping package are written in Applesoft BASIC. They are not copy protected. You will find a write-protected master diskette in your package and a back-up diskette. It is suggested that you make another copy of the master diskette before using the programs and put your master diskette in a safe place.

Some of the programs in this package require considerable time for the construction of images on the screen of the monitor. The time taken to construct the images is a function of the parameters selected for each image. Appendix D includes a table of sample execution times for each of the programs on the disk. Please refer to this appendix for estimates of the time required to load, calculate and plot images on the screen.

If you have an Apple Silentype printer you may want to modify some of the programs to transfer the image of your hi-res screen to the printer. This will enable you to maintain a record of the plots you have generated. In order to accomplish this you will have to add two lines to each of the programs for which you wish to have a printed image. The following procedure will allow you to do this:

-list the program for the routine you want to print.

-look for the following line towards the end of the program (the numbers are different for each program) ´<line no.> IF R$="NEXT" GOTO <LINE NO>´

-change that line to read ´<line no.> IF R$="NEXT" GOTO <LINE NO>:IF R$="P" THEN GOSUB 10000´

-add the following line to the end of the program ´10000 POKE-12524,0:POKE-12529,255:PR#1:PRINT CHR$(17):PR#0:RETURN

-unlock and save the program to the disk with the same name and lock the program to make sure it cannot be altered until you want to alter it again.

Now, when the completed image is plotted to the screen of your monitor and the message asks whether or not you want to plot another image by typing "next" or quit by pressing <return> you have the added option of pressing "P" and then <return> to output your image to the Silentype.

The data statements necessary to create images for the MERRIMAC area are listed in Appendix E. The author has provided instructions for entering these statements using the REGULAR program and suggests that the user enter the data. However, this data has already been entered and is stored on the diskette under the title ´REGULAR.MERR´. This will eliminate the need to enter the initial data statements for the MERRIMAC area.

I. INTRODUCTION

A. What These Programs Do.

These programs map spatial data using a variety of presentation methods. "Spatial data" means a set of observed values of a variable that varies continuously with its location, and which can be thought of as representing "elevations" on an undulating surface called the "statistical surface." Thus, this statistical surface may have "mountains," "plateaus," or "ridges" in areas of high values, and "valleys" or "basins" where there are low values.

This set of programs contains two data-generating programs and seven display programs. The display programs can be run with the data files supplied on your diskette. Often, however, the user will wish to use his or her own data. If so, the set of observed values must be recorded ("digitized") by the user, normally from a source map. He or she may record values at points that are evenly spaced in rows in columns, in which case the user enters the data into the program REGULAR in the form of DATA lines, which will then convert them into data files in a format that can be used by the display programs to generate maps. On the other hand, the data points on the map may be arbitrarily or randomly placed, in which case their X,Y coordinates need to be recorded along with the variable values (Z). Then these values, three for each point, need to be INPUT into the program IRREGULAR, which also produces data files to be used for mapping.*

The remaining seven programs give one a choice of methods of showing the statistical surface that represents the data. Here, it helps one's perception to imagine the statistical surface as an actual landscape, with data values representing elevations (often this will be literally true). From this point of view, the display programs do the following:

LAYER uses a method called "layer tinting" to plot selected colors to represent selected ranges of elevation.

SLOPE plots selected colors to represent selected ranges of slope (slope is expressed as gradient where, for example, 1.00 is a 100 % or 45° slope).

CONTOUR draws contour lines, which are lines drawn through points of equal, selected, elevations.

INCLINED shows the form of the surface as represented by its intersection with a set of equally-spaced inclined parallel planes.

BLOCK plots a "block diagram," which is an oblique, isometric-perspective view of the surface from above.

PLASTIC uses the "plastic relief shading" method to show the area's slopes by means of light and shadow.

VIEW allows the user to place himself in the landscape, "look" in a specified direction, and "see" the skyline along with any intervening crestlines.

---

*REGULAR and IRREGULAR are the only programs in this package that are not write-protected; this allows the user to enter DATA lines into REGULAR or to substitute READ/DATA statements for INPUT in IRREGULAR. To protect these two programs, you should copy them onto your own diskette.

B. Applications.

The most frequent application of these programs is to plot terrain maps; actual landscapes where the input variable is simply elevation (either above sea level or above some convenient reference level). The mapping methods used were originally developed to map terrain, so the types of relief maps produced will already be familiar to many users.

However, neither the programs nor the computer "care" whether the data to be plotted represent elevations or whether they represent any other variable that changes with geographical location. The only restrictions on this variable are, (i) that the data vary continuously (smoothly) from place to place, and (ii) that they can be defined for every point on the map (i.e., "point data"). Even these restrictions can be circumvented, because the user can "smooth" abruptly-changing data himself, and, also, can use data averages for finite areas (e.g., population densities for census tracts) and apply these averages to data points within them.

Thus, there is an infinite variety of data that can be mapped. Examples of naturally-occurring "point data" include elevation itself, and many climatological and meteorological quantities--annual rainfall, temperatures, and so on. Human phenomena (i.e., "socio-economic data") can also be mapped, although usually such data originally appear in the form of area averages; examples include population density, per capita income, property valuation, and so on. The user should realize, though, that it may be difficult to interpret the resulting "relief" maps of such abstract statistical surfaces--for example, the "slope" of a "per capita income surface" may not have any obvious meaning.

Indeed, it is possible to use these programs to depict surfaces so abstract that they exist only in the mind's eye--particularly, any continuous mathematical function of a single variable (Z) as a function of location (X,Y), if the Z-values for a set of data points have already been calculated by the user.

C. Hardware and Software.

This program package is written in Applesoft BASIC to run on an Apple-II microcomputer, equipped with 48K bytes RAM and an Applesoft floating-point BASIC ROM card. Also required is a single-drive magnetic diskette unit, operating under DOS 3.3, along with a television display which should have color if the programs LAYER or SLOPE are to be used. A printer is optional, but is useful in order to allow proofreading when data are entered into REGULAR.

The nine programs themselves occupy about a total of about 117 sectors on a diskette (assuming a reasonable amount of data in REGULAR). The data files generated by REGULAR or IRREGULAR are of two types--"-LORES" (low resolution) and "-HIRES" (high resolution), which can vary in size but which typically occupy about 50 and 75 sectors respectively. Thus, the DOS 3.3 diskette provided (496 sectors capacity) contains all the programs and two pairs of data files, and has remaining room for a third pair of data files if you wish to generate them (and they are not overly large).

D. Limitations.

These programs are designed to run on a microcomputer with a television display and consequently have limitations in terms of execution speed, and of spatial resolution and neatness of output. It is intended that the main uses of the programs will include the topographic study of an area, experiments in alternate methods of relief representation, and training in map interpretation, both by individual users and in the classroom. For these purposes, the programs produce satisfactory results. However, if one intends to publish results, or to engage in "production runs" for extensive areas, the user would be advised to use a paper plotter and perhaps even a larger computer system.

The size of data base that can be processed is ultimately limited by computer RAM memory, but input grids as large as 60 rows by 60 columns can be accomodated on an Apple-II 48K-RAM system.

The resolution, or detail, of output depends on the particular program. LAYER and SLOPE employ the 40H (horizontal) X 40V (vertical) Apple-II low-resolution grid. The high-resolution programs use, as a basic display unit, an area 4H X 4V high-resolution elements in size; thus a "filled screen" will contain a maximum of 70H X 40V resolution elements. However, when one of the high-resolution programs draws a line (e.g., a contour line), data are interpolated to give an apparent resolution of a single high-resolution element (the screen contains 280H X 160V such elements).

The program BLOCK has the limitation that it produces block diagrams without hidden-line removal, in order to avoid excessive execution time. Line overlaps can be avoided by proper choice of a viewpoint and by avoiding excessive vertical exaggeration. (In order to produce an intelligible picture, the program VIEW eliminates "hidden" lines, but takes considerably longer to run.)

The execution times for all the programs in this package are non-trivial, and sample execution times for them are given in Appendix D. One factor to remember is that, with the data-generating programs, REGULAR generates disk files considerably more rapidly than does IRREGULAR, which means that the user should sample data from a regular grid whenever possible. Also, when the display programs are initially run, LAYER and SLOPE take about 2 minutes to read a data file, while the high-resolution programs need about 3 minutes for this task. Once the data have been read into RAM, one can generate as many maps as one wishes of the same area without having to re-read the data from diskette.

E. Execution Errors.

In the mapping programs, the commonest causes of execution errors are mistakes in the programs' inputs themselves, or attempting to read a disk file that was improperly generated. These mistakes may cause various types of system errors during program execution. An "error-catching" subroutine will then indicate the Applesoft/DOS 3.3 error number and the line on which it occurred. What then happens is:

If "Control-C" was pressed, the program will clear all variable values and restart.

If any other error occurs, the program will end.

In either case, if you were running one of the mapping programs, and that program was currently reading a disk file, that file will be closed. If you were running REGULAR or IRREGULAR, and a disk file was being generated, that file will be deleted. This last instance may leave an empty data ("T") file on your diskette, so CATALOG and DELETE any such.

The translations of the error numbers displayed may be found in the Applesoft BASIC Programming Reference Manual (pp. 115-117, 136) or in the DOS Manual (pp. 114-122, 200). These types of errors are system-detectable. The system will not detect inappropriate numerical inputs which allow the program to execute but which generate incorrect or useless results (for example, a block diagram with a vertical exaggeration of 0), so the user should read and digest this manual's instructions for the appropriate program.

II. FIRST STEP—DATA PREPARATION

NOTE: In the instructions that follow, examples of input to be typed in by the user are underlined for clarity. (Do not attempt to underline when actually running the programs.) Some input examples are followed by explanatory notes in parentheses; such notes themselves should not be entered. Note also that "<CR>" represents RETURN, and that "0" represents zero, as opposed to "O", which represents the letter O.

A. Steps Involved in Creating Maps.

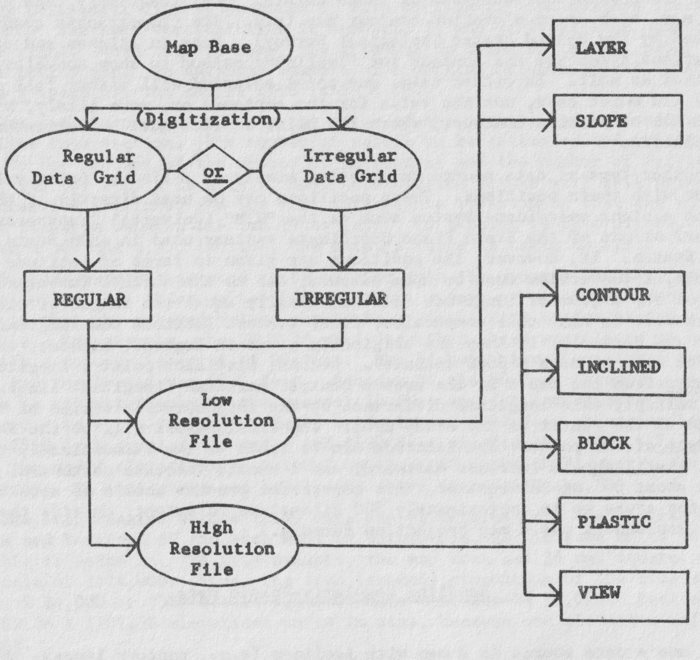
The three steps involved in creating a final map of spatial data are: First, to code elevation or other data from a source (it is assumed that you will initially list your data on paper, on a map, or both, before entering them into a program). Second, to enter these data into either REGULAR or IRREGULAR, as appropriate, and then to run that program, generating one or two data disk files. The third step is to select and run one or more data display programs, which will access the appropriate disk files.

Initially, you may avoid the first two steps because two pairs of pre-generated low- and high-resolution data files are on your diskette. One pair is called "SIERRA BROOKS" (an area in the northern Sierra Nevada in California), and the other is called "ARISTARCHUS" (an area on the moon containing the craters Aristarchus and Herodotus); in both cases, the data are elevation values. These files can be directly accessed by running the data display programs.

After experimenting with these pre-recorded data, it is likely that you will wish to map your own data for your own areas of interest. If that is the case, you will need to work through all three steps listed above.

Figure 1 (page 5) shows the flow of data from the original source, through the data-generation programs, to the data display programs.

FIGURE 1. RELATIONSHIP OF DATA BASES, DATA REDUCTION, AND RELIEF DEPICTION PROGRAMS



Note: Rectangles represent programs; ovals represent data.

B. Data Sources.

The purpose of this program package is to display a statistical surface--a surface whose height above its base is proportional to the value of a quantity that varies with location. The most common example of such a surface is the actual terrain of an area, where the variable quantity is elevation. Actually, any spatially-varying continuous numerical quantity can so be mapped. Thus, any of a variety of data sources may be appropriate.

To begin with, one needs a data source which gives the variable value at points, along with the locations of those points. Most frequently, one uses a source map, such as an elevation contour map (e.g., the "topographic quadrangles" published by the United States Geological Survey). Maps in atlases and other publications often use the contour (or "isoline") method to show non-elevation quantities as well. In either case, any point selected will either fall on a contour (in which case, use the value for the contour) or, more likely, will fall between two successive contours, where the point's value must be estimated by interpolation.

Another type of data source may consist simply of a list of point values together with their positions. These positions may be used directly if they are given in a plane coordinate system such as the "UTM" (Universal Transverse Mercator) or one of the State Plane Coordinate systems used in each State of the United States. If, however, the positions are given in terms of latitude and longitude, a conversion must be made because, due to the earth's curvature, the length of one degree of longitude does not usually equal the length of one degree of latitude. To make this conversion, first convert latitude and longitude into degrees and decimals, if they are originally given in degrees, minutes, and seconds (1 degree = 60 minutes = 3600 seconds). Second, find each point's longitude difference from the map's or the area's central meridian (longitude line). Third, multiply this longitude difference by the trigonometric cosine of the latitude at the center of the study area. The final result will be the X-coordinate of the point. The latitude can be taken as the Y-coordinate, taking account that X should increase eastward, and Y should increase northward. (Within about 60° of the equator, this conversion process should be accurate enough for areas up to approximately 300 kilometers in extent; outside these limits, you should use a map projection formula.)

C. Handling Regularly-Spaced Data.

If one's data source is a map with isolines (e.g., contour lines), the preferred means of data sampling is to use a regularly-spaced grid. Such a grid consists of equally-spaced vertical lines (columns) and equally-spaced horizontal lines (rows), and both sets of lines should be perpendicular to each other, so the study area will be divided into rectangles. More convenient yet is to have the vertical spacing equal the horizontal spacing, resulting in a square grid.

Before the grid is drawn, one must decide upon its size--involving how many vertical and how many horizontal lines, the spacings of the lines, and the resulting total dimensions of the area. As a general rule, from 25 to 40 vertical, and the same number of horizontal, lines is a reasonable number, approximating the resolution of the display programs. Usually, the dimensions of the area of interest, at map scale, are set, so dividing these by the number of lines (minus one) will give the line spacing. For example, in the examples that follow, the study area was 14 cm. square at map scale, and 29 horizontal and 29 vertical lines divided the area into a 5 mm. square grid. (This is an example of choosing the dimensions, and the number of lines, to correspond with the grid of a sheet of graph paper.)

When the grid has been drawn, the lines should be numbered for reference. The top horizontal line is numbered 1, with horizontal line numbers increasing downward. The left vertical line is numbered 1, and vertical line numbers increase to the right. When this is done, the grid can be drawn on tracing paper and taped to the source map. An enlarged example of a portion of such a grid is shown in Figure 2 (page 8); the entire grid is 29 X 29.

The task is now to estimate the value of the variable of interest at each grid line intersection. The number of values to be estimated and written down is equal to the product of the number of horizontal and the number of vertical lines (e.g., 841 for a 29 X 29 grid). Most intersection points will fall between pairs of successive isolines, and one must interpolate by assuming that the variable varies linearly between the two lines (e.g., if a point is 3/10 of the distance between a 300 and a 350 isoline, the point's value is taken as 315).

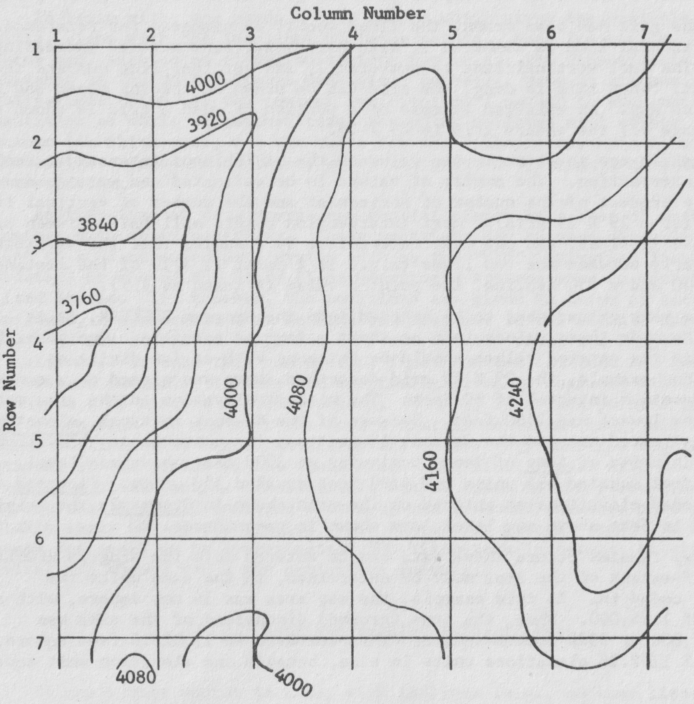
Because many values need to be entered into the program REGULAR, it is convenient to code these values into as short a form as possible. One general guide is that the entered values should be integers with as few digits as possible. For example, the 29 X 29 grid described above was placed on a contour map with a contour interval of 80 feet. The highest elevation in the area was 4590 feet, and the lowest was 2860 feet. Because of the 80-foot interval, elevations had to be estimated only to the nearest 10 feet so, for convenience, elevations were coded in units of tens of feet, beginning at 3000 feet above sea level. Thus, 2860 feet equaled -14 units and 4590 feet equaled 159 units. Figure 3 (page 9) shows the coded elevations as entered on the grid shown in Figure 2; the original elevations, in feet above sea level, are shown in parentheses.

One step remains before these data can be entered into the program REGULAR. The X- and Y-extent of the area must be determined, in the same units the variable is coded in. In this example, the map area was 14 cm. square, with a map scale of 1:24,000. Thus, the true (ground) dimensions of the area was 14 cm. X 24,000 or 3360 meters square. This converts to 11,023.6 feet square, or 1102.36 X 1102.36 elevations units in size, because one elevation unit equals 10 feet.

The purpose of this conversion is to allow topographic slopes to be accurately calculated. If the variable of interest is not elevation, the concept of slope (i.e., rate of change of variable with distance) is not very meaningful, and one need not bother with the conversion.

Note that the positions (coordinates) of the data points are not recorded. This is because, with a regular grid, the order of the elements in the list (i.e., their rows and columns) uniquely define their positions.

FIGURE 2. SAMPLE REGULAR MAP DATA GRID. (Northwest Portion of MERRIMAC, Enlarged 4X from Original.)



(Elevations are in feet above mean sea level.)

FIGURE 3. SAMPLE CODED ELEVATION DATA GRID. (Based on Contour Lines shown in Figure 2.)

(4070) 107	(4070) 107	(4080) 108	(4000) 100	(4020) 102	(4040) 104	(4070) 107
(3930) 93	(3940) 94	(3920) 92	(4080) 108	(4080) 108	(4070) 107	(4140) 114
(3840) 84	(3820) 82	(3980) 98	(4100) 110	(4140) 114	(4180) 118	(4240) 124
(3740) 74	(3840) 84	(4000) 100	(4100) 110	(4150) 115	(4250) 125	(4290) 129
(3800) 80	(3920) 92	(4000) 100	(4100) 110	(4160) 116	(4240) 124	(4250) 125
(3880) 88	(4020) 102	(4050) 105	(4090) 109	(4130) 113	(4210) 121	(4240) 124
(3950) 95	(4040) 104	(4000) 100	(4040) 104	(4090) 109	(4190) 119	(4160) 116

(Upper figures, in parentheses, give actual elevation in feet above mean sea level. Lower figures are values coded in tens of feet relative to 3000 feet MSL.)

D. Handling Irregularly-Spaced Data.

"Irregularly-spaced data" means any group of data points which do not fall into equal-spaced rows and equal-spaced columns. This occurs when (i) one has an isoline source map but deliberately chooses irregularly-spaced points, (ii) one's map shows values only at selected points, or (iii) one has a list of values for irregularly-spaced locations.

In the first two cases, you will be using a map and will need to overlay it with graph paper in order to record the X,Y-coordinates of the points along with their variable values. In all three cases, if you are recording elevations, the coordinates should be converted to the elevation units used. For example, one might be using millimeter graph paper on a map of 1:250000 scale. Thus, 1 mm. would represent 250,000 mm. or 250 meters, which equals 820.2 feet. Thus, if one is using an elevation unit of 10 feet, in this example, each millimeter would represent 82.02 elevation units, and all X,Y-coordinates should be multiplied by this factor.

As is the case with regularly-spaced data, if the variable of interest is not elevation, the concept of slope has no physical meaning and this unit conversion need not be made.

In the second and third cases above, where one does not have an isoline map, one's choice of points is limited to those supplied. In the first case, you may select the locations of the sample points, and some general guidelines can be used. First, the more points, the better--the program IRREGULAR requires at least 5 points but, in practice, at least 20 or more, well-distributed throughout the study area, are needed to generate realistic maps. Second, points should be concentrated where the variable changes rapidly and also at locations of unusually high or low values (the equivalents of "peaks" and "valleys").

Finally, before running IRREGULAR, the following data should be organized:

1. The X-coordinates of the left and right edges of the study area (converted to elevation units if the variable is elevation).*
2. The Y-coordinates of the bottom and top edge of the study area (again, converted to elevation units if the variable is elevation).*
3. The number of data points.
4. A list of data, point-by-point, giving each point's X-coordinate, Y-coordinate, and variable value (call this last Z).*

---

* These coordinates should be in the Cartesian system, where the right-edge X-value is greater than the left-edge X-value and the top-edge Y-value is greater than the bottom-edge Y-value.

III. NEXT STEP—RUNNING THE DATA GENERATING PROGRAMS

A. General.

Now, the data collected in the previous step are entered into the appropriate data generation program so that it can generate one or two disk files which are to be accessed by the display programs. Regularly-spaced data are entered into REGULAR, while irregularly-spaced data are entered into IRREGULAR. In either case, one has three options: 1 = generate a -LORES file only, 2 = generate a -HIRES file only, or 3 = generate both types of file (thus, 3 is the most often-chosen option).

Any -LORES file so generated will contain up to 40 rows by 40 columns of data, with rows equally spaced and with columns equally spaced, but with the column spacing 1.5 times that of the rows in order to correspond with the Apple-II low-resolution television format. -HIRES data files contain up to 40 equally-spaced rows, but can contain up to 70 equally-spaced columns, to fit the Apple-II high-resolution format; row and column spacings are equal with -HIRES files. You select the data file names yourself, which will apply to both the -LORES and the -HIRES file, but, when you CATALOG, you will see that "-LORES" is appended to your name for the -LORES file and "-HIRES" is appended to the -HIRES file name.

B. REGULAR.

Before REGULAR can be run, the data you have recorded must be entered upon DATA lines (in the line range 101-999). REGULAR is not write-protected, in order to permit you to add and/or modify these DATA lines. Do not change any lines outside the range 101-999 or the program may not work properly, if at all. For safety, copy a backup copy of REGULAR onto your own diskette.

Before entering new data into REGULAR, use the command DEL 101,999 to insure that no previous data will be mixed with the data you enter. Be careful with the DEL command, checking the line number range before you press RETURN, so that you do not accidentally erase any of the "working parts" of the program. When you have done this, new data are entered as follows:

```
101 DATA <Output file option:  1, 2, or 3>
102 DATA "<Type here the name you wish to give your output file(s)>"
103 DATA <Number of rows in input grid>,<Number of columns in input grid>
104 DATA <X-range  of area>,<Y-range  of area>
105 DATA ┐
 :       } <Variable values, entered in order; left-to-right for each row,
 :       |   rows in order downward.>
999 DATA ┘
```

Because there will be many of them, the variable values should be entered carefully, separated by commas on each DATA line, but with no comma following the last value on a line. The data should be entered row by row, reading by column from left to right within a row. When you have completed one row, go to the row immediately below it until all rows have been entered. Although not strictly necessary, it helps in proofreading if each row of data occupies a constant number of DATA statements (for example, a row with 29 columns could be entered as two DATA statements, with 15 values in the first and 14 in the second).

Data line numbering can be done so that the line number reflects the row number (e.g., lines 110 and 115 can be used for row 1, 120 and 125 for row 2, and so on). Finally, spaces can be added preceeding short numbers so that all entries take the same number of spaces; when proofreading, this will allow you to vertically scan the data to check for such blunders as decimals rather than commas, extra commas, repeated or omitted digits, and so on. It is almost impossible to type in hundreds of values without some mistakes, so proofreading is essential before running REGULAR. The reason why REGULAR uses READ/DATA statements, rather than INPUT, is to allow data to be checked and corrected before running.

As an example, below are the first eight DATA lines in REGULAR, employing the elevation data shown (in part) in <u>Figure 3</u>; compare the lines below with the instructions on the previous page:

```
101 DATA 3
102 DATA "MERRIMAC"
103 DATA 29,29
104 DATA 1102.36,1102.36
110 DATA 107,107,108,100,102,104,107,117,116,115,117,120,126,137,142
115 DATA 144,146,149,154,158,159,151,139,144,156,158,141,126,112
120 DATA  93, 94, 92,108,108,107,114,126,121,116,117,122,124,132,140
125 DATA 147,148,148,148,146,151,147,137,133,143,149,152,129,119
```

When all the data have been entered into REGULAR, checked and corrected, the program should be ready to RUN. Before typing "RUN", however, CATALOG the diskette in the disk drive to see that there is no existing file with the name you wish to use, and that there remains sufficient disk capacity for the file(s) that will be generated. (A DOS 3.3 diskette has a total capacity of 496 sectors; a typical "-LORES" file takes about 50 sectors and a "-HIRES" file about 75.) You can use the DOS 3.3 FID program to find the free space still remaining on your diskette. If either of these problems are found, substitute another (already initialized) diskette that does not have these problems.

All REGULAR does is generate disk files, so not much will appear to be happening, except for the intermittent operation of the disk drive. At the appropriate times in the run, your screen will display "PROGRAM REGULAR IN OPERATION", "-LORES FILE IS BEING GENERATED.", and "-HIRES FILE IS BEING GENERATED". When the program ends, the disk drive light will turn off and the Applesoft bracket (]) will appear on your screen.

C. IRREGULAR

Assuming that one wishes to employ irregularly-spaced data, and that they have been recorded as described above (page 10), the data are entered as input while IRREGULAR is running. Because IRREGULAR is <u>not</u> write-protected, you may, if you wish, change the INPUT statement on line 220 to a READ statement, in which case you can place DATA in the line range 2501 - 7998. As with REGULAR, to protect the original copy of IRREGULAR, you should copy a backup copy of IRREGULAR onto your own diskette.

Before typing RUN, CATALOG and check your diskette, as described for REGULAR above. Then, during the course of execution, IRREGULAR will prompt you for the following information:

```
NAME OF DATA FILE:
LEFT EDGE X  :
RIGHT EDGE X :
BOTTOM EDGE Y:
TOP EDGE Y   :
NUMBER OF POINTS (<=5):
INPUT DATA FILE OPTION; 1 = LORES, 2 =
HIRES, 3 = BOTH:

NOW, INPUT THE DATA, ONE POINT AT A
TIME; X(I), Y(I), Z(I):
I = 1:
  .
  .
  .
```

For the last prompt, data are entered point-by-point, with the three values (X,Y,Z) for each point on each input line. To help the user keep track, the point's number is displayed for each input prompt. Because input data cannot subsequently be edited, check each input line before pressing RETURN. If you press RETURN before correcting an error, use Control-C to restart the program.

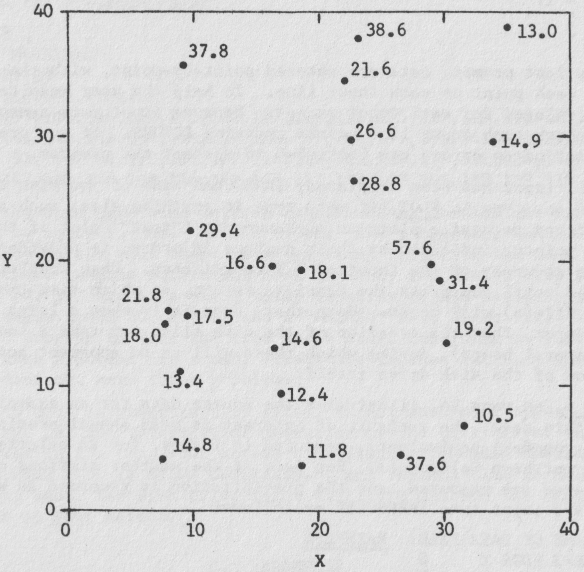
When all input has been completed, IRREGULAR asks if you wish the points plotted. If so, type in PLOT (if not, type in anything else, such as a carriage return). If you request a plot, an alphanumeric ("text") plot of the positions of the data points, indicated by their numbers in order, is provided as a rough check of the accuracy of the inputted X,Y coordinates. When completed, this plot may be viewed until you press the carriage return, at which time the generation of the disk file(s) will begin. Note that, especially when a large number of data points are input, that the creation of the disk files may take a long time (possibly several hours), during which there will be no apparent activity except the operation of the disk drive itself.

Figure 4, on page 14, illustrates the source data for an example of IRREGULAR input. In this case, the variable of interest is mean annual precipitation (rainfall + snowfall equivalent), measured in inches, for 23 selected weather stations in northern California. For each of the weather stations on the map, the X,Y coordinates are measured, and the precipitation is recorded as well. Then, these data are input into IRREGULAR as follows:

```
NAME OF DATA FILE:  RAINFALL
LEFT EDGE X  :  0
RIGHT EDGE X :  40
BOTTOM EDGE Y:  0
TOP EDGE Y   :  40
NUMBER OF POINTS (<=5):  23
INPUT DATA FILE OPTION; 1 = LORES, 2 =
HIRES, 3 = BOTH:  3

NOW, INPUT THE DATA, ONE POINT AT A
TIME; X(I), Y(I), Z(I):
I = 1:  9.2,35.8,37.8
I = 2:  23.0,37.9,38.6
  .
  .
  .
I = 23:  31.6,7.0,10.5
```

(The order of points in input does not matter, as long as the correct Z is matched with the correct X and Y.)

FIGURE 4. SAMPLE SOURCE MAP FOR IRREGULAR DATA. (Data are Mean Annual Precipitation Values for 23 Selected Weather Stations in Northern California. Values are in Inches.)



IV. LAST STEP—RUNNING THE DISPLAY PROGRAMS

A. General.

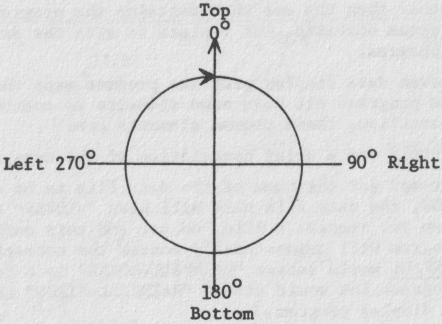
Having generated one or more data files by running REGULAR or IRREGULAR, you may now use one or more of the data display programs to generate maps. The instructions that follow assume a single-disk drive. Thus, if the data files are on a diskette other than the one that contains the program used, LOAD the program from the program diskette, but replace it with the data file diskette before you RUN the program.

Although the seven data display programs produce maps that are quite distinct from each other, the programs all have some elements in common. In order of their appearance during execution, these common elements are:

1. A program title and a brief description of the type of map produced.
2. An input prompt for the name of the data file to be accessed. In the disk CATALOG, the data file name will have "-LORES" or "-HIRES" as a suffix; when you request a file, do not add this suffix because the display program will automatically access the correct type. (e.g., typing <u>RAINFALL</u> would access "RAINFALL-LORES" in a low-resolution display program, but would access "RAINFALL-HIRES" in a high-resolution display program.)
3. At this point, the program will take about 2 - 3 minutes to read the data from diskette.
4. When diskette input is ended, the program will display some summary information--the number of rows and columns of data read from the file; the minimum and maximum values of <u>Z</u>, along with its range; and the map scale for rows and for columns. (NOTE: Program SLOPE provides some additional information and also takes about 2 minutes at this point to compute slopes.)
5. Now, the user will be asked to input the <u>depiction parameters</u> for his map. What is called for varies from program to program, but the values input will strongly influence the appearance of the map drawn. (Here, the user is free to experiment, although "reasonable" ranges of values will be suggested under the instructions for the individual programs.)
6. After the above inputs, a map will be plotted.
7. When the map is finished, the user is given the opportunity to change the depiction parameters and to draw a different map using the same original data; the disk file need not be read over again unless one wishes to map an entirely different area.

In selecting the proper depiction parameters, note that several of the display programs (INCLINED, BLOCK, PLASTIC, and VIEW) refer to "azimuth", "horizontal angle", or "direction." These terms mean the same thing, and refer to directions in degrees, based on the original data grid as illustrated in Figure 5 below.

FIGURE 5. DIRECTION SYSTEM (AZIMUTHS) USED IN PROGRAMS INCLINED, BLOCK, PLASTIC, AND VIEW.



Notes: Azimuths increase Clockwise.
0° is equivalent to 360°.

B. Low-Resolution Display Programs.

The two display programs LAYER and SLOPE use the Apple-II low-resolution graphics mode (up to 40H X 40V elements displayed) in up to 16 separate colors, including black and white. In using these programs, the proper choice of color is important, bearing in mind that most people cannot quickly differentiate more than about five colors at one time. In order to help in choosing these colors, which are identified by number, both programs allow the user to display a color "menu" on their television monitor.

1.) LAYER receives its name from the technique it employs , called "layer tinting." This means that each elevation (Z) range one selects is given its own color, so the final map appears to be made up of different-colored layers. In order to do this, the user inputs the number of elevation ranges he wishes, then, for each range, its lowest elevation along with the color to be used. (The highest elevation in a range is determined by the lowest elevation for the next higher range, except for the highest range, whose upper limit will be the highest elevation for the entire map.) It is necessary that data for the ranges be input in order, from lowest to highest.

As an example of running LAYER, using the "MERRIMAC" data employed on pages 8,9, and 13, the program tells us that the lowest elevation in the area is -14 units, and the highest is 159 units (range = 173 units). In this example, we wish to show five "layers" (ranges) of approximately equal width over the entire elevation range. To do so, we input depiction parameters as shown in the sample run below:

LAYER

```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II LORES
LAYER-TINTED ELEVATION MAP.

INPUT DATA FILE NAME (SKIP '-LORES'
PART):  MERRIMAC
   ⋮

THE DATA FILE HAS NOW BEEN READ, GIVING
   NO. ROWS = 40    NO. COLS. = 40
   MINIMUM VALUE = -14
   MAXIMUM VALUE = 159
   RANGE         = 173
   1 MAP ROW = 27.559 UNITS
   1 MAP COL.= 42.3984615 UNITS

NOW, CHOOSE ELEVATION INTERVALS:
INPUT NUMBER OF INTERVALS (<=15):  5

TYPE 'COLORS' IF YOU WISH A COLOR MENU,
OR PRESS RETURN TO CONTINUE:  COLORS

(color menu is displayed)

PRESS RETURN TO CONTINUE: <CR>

FOR EACH INTERVAL, INPUT ITS LOWEST
ELEVATION, ITS APPLE-II COLOR NUMBER.
(INPUT IN ASCENDING ORDER OF ELEVATION.)
INTERVAL 1: -14,8
INTERVAL 2: 20,4
INTERVAL 3: 60,5
INTERVAL 4: 100,9
INTERVAL 5: 140,1

(map is drawn)

MAP DONE!  INPUT 'END' TO END OR 'NEXT'
FOR ANOTHER SET OF INTERVALS:  END

(program ends)
```

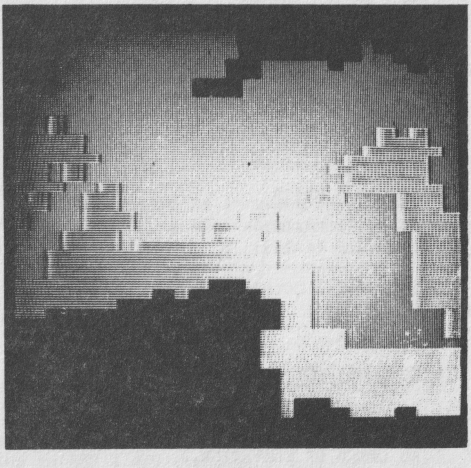
Assuming that the color controls on your television display are set properly, the above input would give these results:

Elevations -14 to +19 units would be brown (color #8);
Elevations +20 to +59 units would be dark green (color #4);
Elevations +60 to +99 units would be grey (color #5);
Elevations +100 to +139 units would be orange (color #9);
Elevations 140 units or above would be magenta (color #1).

After the map is completed, the user may input END to end the program, or NEXT to generate another map of the same area, using different elevation ranges, different colors, or both.

A black-and-white reproduction of the map produced by the sample run above is shown in Figure 6, below.

Figure 6. LAYER Output Using "MERRIMAC" Data.



2.) Program SLOPE resembles LAYER in that it employs the Apple-II low-resolution graphics mode with up to 16 colors displayable. However, unlike LAYER, SLOPE displays terrain slope categories rather than elevation categories. As with the other display programs, the first user input is the data file name. When the data file has been read into the program, the elevations are converted into slopes (expressed as decimal gradients), a process that takes about two minutes. During this time, slopes are computed row-by-row, with the user being informed as to which row is currently being computed.

For each data point, slopes, based on elevation difference and distance, are initially computed to each of its four nearest neighboring points (except for edge points, that have only three neighbors, or corner points, which have only two). The greatest such slope is taken to be the slope at the point being processed.

The maximum and minimum slope for the entire map are also computed, and then displayed. The next output is the map scale, in elevation units per row and per column. This is followed by a table of slope statistics. This table divides the total slope range into 10 equal-width ranges, along with the percentage of the map's area that falls within each range. This last information is given in order to help the user decide which slope categories to depict with distinct colors.

The user's next step is to decide on the number of slope intervals to be displayed (up to 16), aided, if he wishes, by the display of a color menu. Then, the user inputs, for each slope interval in ascending order, its lower limit and its color number. When all intervals desired have so been specified, the map is drawn. When the map is finished, the user inputs "END" to end the program, or "NEXT" to generate another map of the same area, with different intervals, different colors, or both.

Below is a sample run of SLOPE using the "MERRIMAC" data file. As before, user inputs are underlined.

SLOPE

```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II LORES
SLOPE-CATEGORY MAP.

INPUT DATA FILE NAME (SKIP '-LORES'
PART):  MERRIMAC
NOW COMPUTING SLOPES FOR 39 ROWS
ROW 0
ROW 1
  •
  •
  •
ROW 39

MAXIMUM SLOPE = 1.0251119
MINIMUM SLOPE = 0

1 MAP ROW = 27.559 UNITS
1 MAP COL.= 42.3984615 UNITS
```

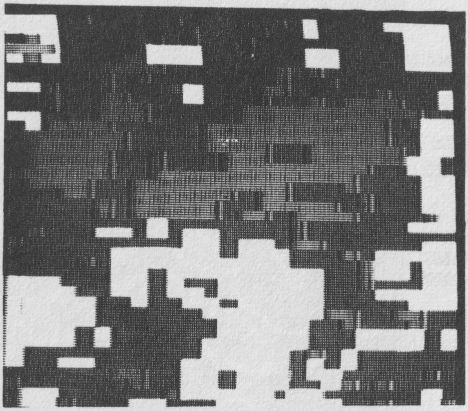
TABLE OF SLOPE STATISTICS

```
LOWER LIMIT  UPPER LIMIT    PCT. AREA

0            .10251119      9.2
.10251119    .205022379     34.6
.205022379   .307533569     30.2
.307533569   .410044759     18
.410044759   .512555948     6.8
.512555948   .615067138     .7
.615067138   .717578328     .1
.717578328   .820089518     0
.820089518   .922600707     .1
.922600707   1.0251119      .3

NOW, CHOOSE SLOPE INTERVALS--
INPUT NUMBER OF INTERVALS (<=15): 5

TYPE 'COLORS' IF YOU WISH A COLOR MENU,
OR PRESS RETURN TO CONTINUE: COLORS

(color menu is displayed)

PRESS RETURN TO CONTINUE: <CR>

FOR EACH INTERVAL, INPUT ITS LOWEST
SLOPE, ITS APPLE-II COLOR NUMBER.
(INPUT IN ASCENDING ORDER OF SLOPE.)
INTERVAL 1: .00,8
INTERVAL 2: .15,4
INTERVAL 3: .30,5
INTERVAL 4: .45,9
INTERVAL 5: .60,1

(map is drawn)

MAP DONE!  INPUT 'END' TO END OR 'NEXT'
FOR ANOTHER SET OF INTERVALS:  END
```

The choices of slope intervals and colors above would give a color sequence, from gentle slopes to steep slopes, of: brown - dark green - grey - orange - magenta. The percentage area in each color, respectively, would be about 25 percent, 47 percent, 23 percent, 5 percent, and 0.6 percent.

A black-and-white reproduction of the slope map produced by the sample run above is shown in Figure 7 (top of next page).

Figure 7. SLOPE Output Using "MERRIMAC" Data.



C. High-Resolution Display Programs.

The five high-resolution display programs, CONTOUR, INCLINED, BLOCK, PLASTIC, and VIEW, use the Apple-II high-resolution graphics mode with up to 280H X 160V elements displayed. They are intended for black-and-white displays, using either a black-and-white television display or a color display with the color turned down. These programs access the "-HIRES" versions of the disk data files. The data resolution is normally 4H X 4V screen elements, although the programs CONTOUR, INCLINED, and VIEW "smooth" the data by interpolation in order to give the appearance of single-element resolution. With these programs, it typically takes about 3 minutes to read a disk file into the program.

1.) CONTOUR draws contour lines--unlabeled lines through points of equal elevation (Z-value). The depiction parameters input by the user are the range of elevations to be contoured, and the elevation interval between successive contours within that range. After his first map is drawn, the user can add additional contours to it, varying the elevation range covered along with the interval, so that the same map may include variable contour intervals (e.g., a close interval for level areas and a wider interval for steep areas). All specifications of contour ranges and intervals should be in the same elevation units as the original data.

A sample of inputs and outputs during a run of SLOPE, using the "MERRIMAC" data file, is given below.

CONTOUR

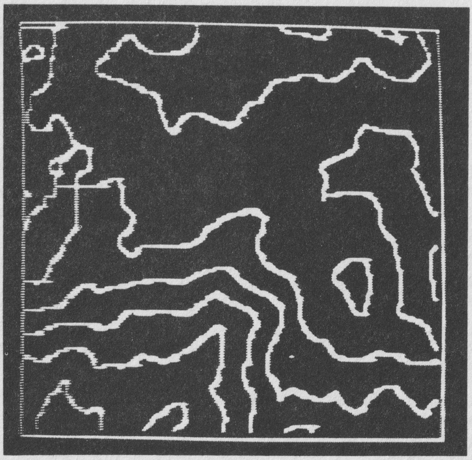
```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II HIRES
CONVENTIONAL CONTOUR MAP.

INPUT DATA FILE NAME (SKIP '-HIRES'
PART):  MERRIMAC
  •
  •
  •
THE DATA FILE HAS NOW BEEN READ, GIVING:
   NO. ROWS = 40  NO. COLS.= 40
   MINIMUM VALUE = -14
   MAXIMUM VALUE = 159
   RANGE         = 173
   1 MAP ROW = 27.559 UNITS
   1 MAP COL.= 27.559 UNITS

TO CONTINUE, PRESS RETURN: <CR>

(outline of map is drawn)

INPUT CONTOUR LIMITS IN Z-UNITS--
   LOWEST VALUE    : 0
   HIGHEST VALUE   : 150
   CONTOUR INTERVAL: 25

(the map is drawn, one contour at a time, with the elevation of the
 current contour given)

INPUT 'MORE' IF YOU WISH CONTOURS ADDED
'ERASE' IF YOU WISH TO DRAW A NEW SET,
OR 'END' TO END THE PROGRAM: END
```

The map drawn, using the inputs above, is shown in Figure 8 (next page).

Note that contours are not labeled. The elevations of specific contour lines may be identified in three ways: (i) when the map is being drawn, the elevation of the contour currently being drawn is given; (ii) if you can identify the lowest (or highest) contour, you can count up (or down) using the contour interval; (iii) you can run LAYER, setting the limits of the color layers equal to your contour values.

2.) The program INCLINED also draws contour lines, but of a different type than the conventional, horizontal, ones drawn by CONTOUR. In CONTOUR, the contour lines can be thought of as the intersections of parallel, equal-spaced, horizontal planes with the topographic (or statistical) surface. In INCLINED, these planes are tilted. The resulting appearance is radically different, with the inclined contours being widely-spaced where the topographic surface is

Figure 8. CONTOUR Output Using "MERRIMAC" Data.



approximately parallel to the set of planes, and close together when the surface intersects the planes at a steep angle. Using this program involves experimenting with three depiction parameters; (i) the tilt of the planes in respect to the horizontal; (ii) the "plane azimuth", or direction of a horizontal line on a plane (i.e., the planes will be most inclined at right angles to this direction); (iii) the vertical (perpendicular) spacing between the planes, expressed in elevation units. To help in choosing the last, the program (after reading the data file) informs the user how many elevation units are represented by one map row and by one map column (these two values should be approximately equal). As a rough guide, a reasonable choice of plane spacing is approximately equal to this value, with a plane tilt in the range 20° - 45°. In choosing the plane azimuth, note that 0° represents the top of the screen, regardless of how the rows and columns are oriented in respect to true north (see azimuth diagram on page 16).

A sample set of inputs and outputs for INCLINED, using the "MERRIMAC" data file, are given on the next page.

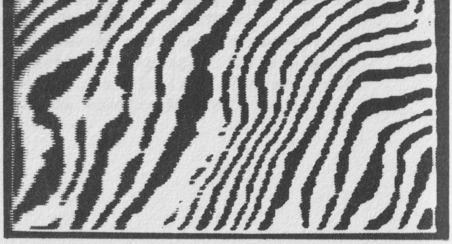
INCLINED

```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II HIRES
INCLINED-CONTOUR MAP.

INPUT DATA FILE NAME (SKIP '-HIRES'
PART): MERRIMAC
   .
   .
   .
THE DATA FILE HAS NOW BEEN READ, GIVING:
  NO. ROWS = 40  NO. COLS.= 40
  MINIMUM ELEVATION = -14
  MAXIMUM ELEVATION = 159
  ELEVATION RANGE   = 173
  1 MAP ROW = 28.265641 UNITS
  1 MAP COL.= 28.265641 UNITS

INPUT TILT OF INCLINED PLANES; IN
DEGREES > -90 & <+90; 0 = HORIZONTAL,
+ = UPWARDS, - = DOWNWARDS: 30
INPUT PLANE AZIMUTH, IN DEGREES, 0-180
(0 = VERT.; 90 = HORIZ.): 45
INPUT VERTICAL SPACING OF PLANES, IN
ELEVATION UNITS: 25

(map is now drawn)

MAP IS DONE; TYPE 'NEXT' FOR ANOTHER
MAP OF THE SAME AREA, OR PRESS RETURN
TO END: <CR>
```

The map produced by the above inputs is shown in Figure 9 (to the right).

Note that, in order to make the intersecting planes more evident, the zones between the planes are alternately shaded black and white. A visual analog would be the pattern of shadow cast by a venetian blind on the landscape.

Figure 9. INCLINED Output Using "MERRIMAC" Data.



3.) The program BLOCK produces a block diagram, which is an oblique view of the map area in orthogonal perspective (no vanishing points). The landscape is traced out by a "fishnet" made up of two sets of parallel lines, one set perpendicular to the other, which follow the configuration of the land. This program does not remove "hidden" lines, so view angles and vertical exagerration should be chosen so as to minimize them (see below). Also, in order to avoid congestion, only every other data row and data column is used to define these lines.

BLOCK's user can control three depiction parameters:

(i) The "horizontal view angle", which is the direction one is looking toward. This is expressed in degrees, in the direction system diagrammed on page 16.

(ii) The "vertical view angle", which is the angle of depression of view. This is expressed in degrees, and should be in the range 0 (horizontal) to +90 (vertical). A negative angle would produce a reversed landscape, seen from beneath, so, if the user inadvertently inputs a negative angle, it is converted to positive. Also note that vertical, or near-vertical, views will produce "flat" results, while horizontal, or near-horizontal, views will maximize hidden lines and will be difficult to interpret.

(iii) The "vertical exaggeration", which is the factor by which elevations are to be multiplied (it is also the ratio between the vertical and the horizontal scales). If 1 is input, the elevation scale is the same as the horizontal scale; if 2 is input, the elevation scale is twice the horizontal scale, and so on. Generally, the user will wish to employ a vertical exaggeration greater than 1 in order to make relief features more evident. Excessively large values should be avoided, however, because they will cause lines to overlap ("hidden lines") and may even cause parts of the landscape to disappear off the top of the screen.

Another reason that the landscape may go off the top of the screen occurs if all the elevations are very high (e.g., mountains or plateaus), because BLOCK scales elevations from the zero Z-value (e.g., sea level). This is another reason (see page 7) for measuring elevations from a convenient reference level not greatly different from the lowest elevation.

Below is an example of inputs and outputs for the program BLOCK, using the "MERRIMAC" data file.

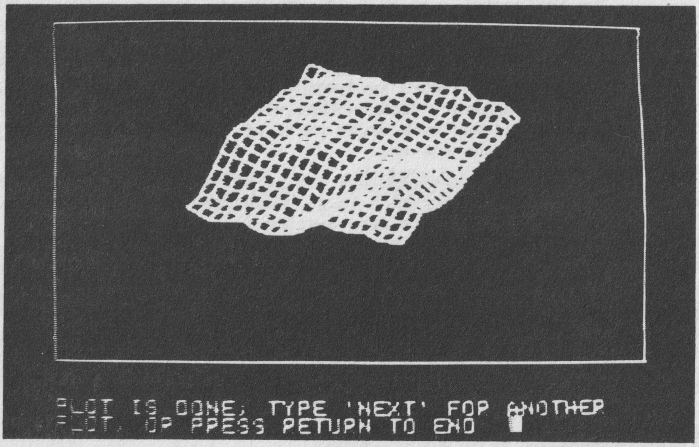
BLOCK

```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II HIRES
BLOCK DIAGRAM.

INPUT DATA FILE NAME (SKIP '-HIRES'
PART): MERRIMAC
  :
  :
THE DATA FILE HAS NOW BEEN READ, GIVING:
   NO. ROWS = 40  NO. COLS.= 40
   MINIMUM ELEVATION = -14
   MAXIMUM ELEVATION = 159
   ELEVATION RANGE   = 173
   1 MAP ROW = 28.265641 UNITS
   1 MAP COL.= 28.265641 UNITS
```

```
TO CONTINUE, PRESS RETURN: <CR>

INPUT HORIZONTAL VIEW ANGLE--THE
DIRECTION YOU ARE LOOKING TOWARD, IN
DEGREES, WITH 0 AT THE MAP'S TOP: 330
INPUT VERTICAL VIEW ANGLE--THE ANGLE
YOU ARE LOOKING DOWN, FROM 0
(HORIZONTAL) TO 90 (VERTICAL): 30
INPUT VERTICAL EXAGGERATION: 2.0

(the block diagram is now drawn)

PLOT IS DONE; TYPE 'NEXT' FOR ANOTHER
PLOT, OR PRESS RETURN TO END: <CR>
```

The block diagram produced by the above sample run is shown in Figure 10.

Figure 10. BLOCK Output Using "MERRIMAC" Data.



```
PLOT IS DONE; TYPE 'NEXT' FOR ANOTHER
PLOT, OR PRESS RETURN TO END
```

4.) PLASTIC generates a shaded relief map of the study area; its name is derived from the technique, called "plastic relief shading." The program's assumption is that an imaginary light source illuminates the landscape so that slopes facing the light are bright, those facing away from the light are dark, and level areas are intermediate in tone. The technique differs somewhat from an actual photograph of the landscape because features do not cast shadows upon other features; this is in order not to obscure detail. Because the Apple-II does not provide a continuous grey scale, shades of light and dark are simulated by randomly-placed white dots on a dark background; closely-spaced dots represent light tones and widely-spaced dots represent dark tones.

The user of PLASTIC controls two depiction parameters:

(i) The direction the light source is coming from, expressed in degrees following the direction system diagrammed on page 16. A conventional direction is from the upper left (315°); at any rate, the light should usually be from above (i.e., 270° - 360° or 0° - 90°) to prevent the terrain appearing reversed.

(ii) The "shading factor," where a low value (e.g., under 2) produces gentle shading (suitable for areas of rugged relief) and a high value (e.g., over 2) gives contrasty shading (effective where the relief is gentle); for details on the effect of this factor, see Appendix C.

Below are sample inputs and outputs for PLASTIC, using the "MERRIMAC" data file.

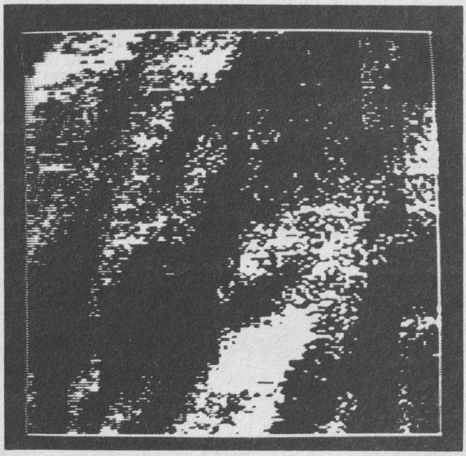
PLASTIC

```
THIS PROGRAM ACCESSES AN ELEVATION DATA
FILE AND OUTPUTS AN APPLE-II HIRES
PLASTIC-SHADING RELIEF MAP.

INPUT DATA FILE NAME (SKIP '-HIRES'
PART): MERRIMAC
   •
   •
   •
THE DATA FILE HAS NOW BEEN READ, GIVING:
  NO. ROWS = 40  NO.COLS.= 40
  MINIMUM ELEVATION = -14
  MAXIMUM ELEVATION = 159
  ELEVATION RANGE   = 173
  1 MAP ROW = 28.265641 UNITS
  1 MAP COL.= 28.265641 UNITS

TO CONTINUE, PRESS RETURN: <CR>

INPUT DIRECTION LIGHT IS COMING FROM,
FROM 0-360 DEGREES, WITH 0 = TOP, 90 =
RIGHT, 180 = BOTTOM, 270 = LEFT: 315

INPUT SHADING FACTOR (E.G., <=2 FOR
STEEP SLOPES, >2 FOR GENTLE): 2

(shaded map is now drawn)
```

```
MAP IS DONE; TYPE 'NEXT' FOR ANOTHER
MAP OF THE SAME AREA, OR PRESS RETURN
TO END:  CR
```

The sample run above produced the shaded relief map shown in Figure 11.

Figure 11. PLASTIC Output Using "MERRIMAC" Data.



5.) The final relief depiction program, VIEW, does not produce a map at all, but rather a view of the landscape as seen from a selected point, looking in a selected direction. VIEW depicts the horizon, and intervening crestlines, as seen from the viewpoint, using a hidden-line algorithm so that features near the observer will block out features "behind" them. If it is visible, the limits of the study area will also be shown. Naturally, any features outside the area for which there are data, even if actually visible in the landscape, will not be shown by this program. The effect of the earth's curvature is ignored.

The user of VIEW controls two sets of depiction parameters:

(i) The location of the observer, expressed in X,Y,Z coordinates, where all three values are in elevation units; X and Y give one's horizontal position and Z represents elevation. To aid in selecting appropriate values for these, the program outputs the ranges of X, Y, and Z. X and Y may be selected so as to give a viewpoint from either inside or outside the study area, but, if one places oneself outside, the direction of view should be toward the study area (see below) or nothing will be seen. It is also important to select Z so that the observer is at least slightly above ground level at the point chosen.

(ii) The direction of view. The observer is assumed to be looking through a "window", displayed in rectangular outline on the screen, which is defined by the azimuths of the left edge and of the right edge of the field of view; azimuths being measured according to the system illustrated on page 16. The azimuth of the left edge should be less than that of the right edge, unless the field of view includes the azimuth of 0° (360°). The difference between the two azimuths gives the width of the field of view. The program assumes a horizontal direction of view, with a vertical view angle equal to 0.5714 times the horizontal. A large angular field of view produces an effect similar to that of a photograph taken through a wide-angle lens, while a small field of view simulates a photograph taken through a telephoto lens. (The apparent positions of features are plotted on a cylindrical equidistant projection, with the projection "equator" running horizontally across the center of the screen; the position of the theoretical horizon is indicated by tick marks on the left and right margins.)

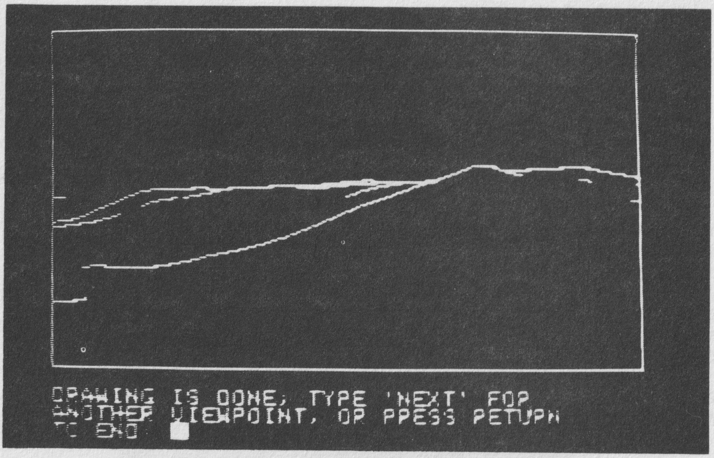
Below is a sample run of VIEW, using the "MERRIMAC" data file.

VIEW

```
    THIS PROGRAM ACCESSES AN ELEVATION DATA
    FILE AND OUTPUTS AN APPLE-II HIRES VIEW
    OF THE LANDSCAPE.

    INPUT DATA FILE NAME (SKIP '-HIRES'
    PART): MERRIMAC
      .
      .
      .
    THE DATA FILE HAS NOW BEEN READ, GIVING:
      40 ROWS BY 40 COLUMNS
      ELEVATION RANGE -14 TO 159 UNITS
      1 ROW OR COL. = 28.265641 UNITS
      LEFT X = 0; RIGHT X = 1102.36
      BOTTOM Y = 0; TOP Y = 1102.36

    INPUT THE POSITION OF THE VIEWPOINT:
      X = 669
      Y = 79
    ELEVATION ABOVE DATUM = 80

INPUT AZIMUTHS IN DEGREES, INCREASING
TO THE RIGHT FROM 0 (MAP TOP) TO 360.
  LEFT EDGE AZIMUTH : 270
  RIGHT EDGE AZIMUTH: 60

(view is now drawn)

DRAWING IS DONE; TYPE 'NEXT' FOR
ANOTHER VIEWPOINT, OR PRESS RETURN
TO END: <CR>
```

The view generated by the sample run on the previous page is shown in Figure 12.

Figure 12. VIEW Output Using "MERRIMAC" Data.



```
DRAWING IS DONE; TYPE 'NEXT' FOR
ANOTHER VIEWPOINT, OR PRESS RETURN
TO END:
```

APPENDICES

Appendix A. Television Format

The format of the user's television display, which is the ratio between horizontal and vertical distances on plots, governs the shape of the output generated by the display programs. In these programs, it is assumed that, in the high-resolution mode, one horizontal unit equals one vertical unit. Thus, the low-resolution aspect ratio should be 279:159 or 1.755:1. Actual television displays may differ from this, but usually their format can be adjusted by their "HEIGHT" or "V LIN" controls (or their equivalent). To test and adjust your display, write and run the following program:

```
10 HGR
20 HCOLOR = 3
30 HPLOT 60,0 TO 219,0 TO 219,159 TO 60,159 TO 60,0
40 END
```

Measure the resulting figure, which should be a square. If not, adjust your television display until your measurements indicate the figure is square.

Appendix B. Interpolation Algorithms

Several of the programs in this package use interpolation to estimate elevations ($\hat{Z}$) at arbitrary points which do not coincide with data points. Three different algorithms are used. (In the formulae below, the estimated value is shown as $\hat{Z}$, while the data point elevations are given with subscripts; e.g., Z_i).

1.) REGULAR. Here, output grid points (those that go into the data file) are interpolated from input grid points (those that make up the DATA statements). Each output point is surrounded by four input points (subscripts 1, 2, 3, and 4). The distances (D_i) to each of the four are computed, and an interpolated value, weighted by the inverse-square distance to each of the four input points, is found as follows:

$$Z = \frac{\sum_{i=1}^{4} \frac{Z_i}{D_i^2}}{\sum_{i=1}^{4} \frac{1}{D_i^2}}$$

2.) IRREGULAR. Here, for each output grid point, the <u>five</u> nearest input data points are determined, and an inverse-square distance-weighted interpolation is made, analogous to the method used for REGULAR; simply substitute "5" for "4" for the upper limit of the subscript in the formula above.

3.) **CONTOUR, INCLINED, and VIEW.** In these three programs, the task is to interpolate the value at an arbitrary point by using the values at the four output grid points that surround it. The X- and Y-distances from the arbitrary point (X_p,Y_p) to the data point (X_i,Y_i) are scaled in terms of the row and column spacing (DR,DC) as follows:

$$X' = (X_p - X_i)/DC \quad ; \quad Y' = (Y_p - Y_i)/DR$$

Then, using the variable values at the four data points (Z_i), a four-parameter polynomial is fitted to the four data points (whose transformed X',Y' coordinates will simply be 0,0;1,0;0,1; and 1,1):

$$\hat{Z} = A + BX' + CY' + DX'Y'$$

The formula above, with appropriate values of A, B, C, and D, is used to estimate Z for all screen points that are bounded by the four data points used. It should be noted that this formula gives an exact fit to the four data points (the number of parameters equals the number of points). Thus, sharp breaks where different sets of data points are used are avoided.

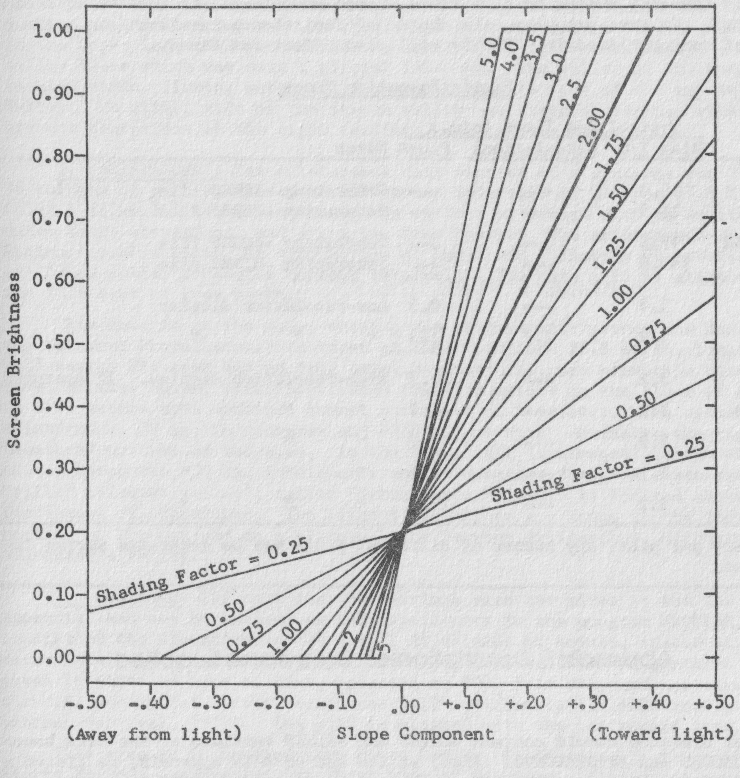
Appendix C. Plastic-Shading Algorithm

In the program PLASTIC, the slope for each data point is computed as based on the elevation difference, and the horizontal distance, between the data point and its neighbors. The local surface is assumed to be an inclined plane, tilted in the direction of maximum slope. From this, the slope component perpendicular to the light source is computed, and is taken as positive if facing the light, and negative if facing away. This slope component is designated S; the shading factor is SF, and the screen brightness is called SC. Then,

$$SC = SF*S + .2$$

The screen brightness level is constrained to the limits 0.00 - 1.00, where 0.00 is black and 1.00 is white, and a level surface always has a brightness of 0.20 (which appears as a medium grey to the eye). On the next page, <u>Figure 13</u> graphs how the screen brightness is governed by both the slope component and the shading factor, the latter being chosen by the user. For any given area, picking too low a shading factor will result in a "washed out" appearance. On the other hand, too high a shading factor will create obvious "breaks" between the data elements.

FIGURE 13. SCREEN BRIGHTNESS GRAPH FOR PROGRAM PLASTIC. (Screen Brightness is Shown as Affected by (i) Slope Component in Direction of Light Source, and (ii) User's Choice of Shading Factor.)



Appendix D. Sample Execution Times

The sample execution times listed below are for an original data grid measuring 31 rows by 31 columns, a -LORES output grid measuring 26 X 39, and a -HIRES grid of 40 X 40. With the program IRREGULAR, 23 input points were used. In actual use, run times will be roughly proportional to the number of elements in a grid (usually number of rows times number of columns; in IRREGULAR, number of points). In some programs, the choice of depiction parameters (e.g., the number of contour lines in CONTOUR) will also affect run times.

<u>Sample Execution Times</u>

	Typical Run Times (min.)			
Program	**Disk I/O**	**Calculations**	**Plot***	**Notes**
REGULAR	15.0	---	---	Generating -LORES file
"	18.9	---	---	Generating -HIRES file
IRREGULAR	97.8	---	---	Generating -LORES file
"	149.8	---	---	Generating -HIRES file
LAYER	1.9	---	0.9	Low-resolution display
SLOPE	1.9	2.7	1.3	" " "
CONTOUR	3.2	---	30.5	High-resolution display. 12 contours.
INCLINED	3.2	---	41.9	" " "
BLOCK	3.2	---	1.2	" " "
PLASTIC	3.2	---	8.2	" " "
VIEW	3.2	---	21.4	" " "

*Times are per plot; any number of different plots may be generated during the same run.

Appendix E. Description of Data Bases Supplied

Your diskette should contain -LORES and -HIRES versions of two data bases, SIERRA BROOKS and ARISTARCHUS. Also, at the end of this appendix, is listed a set of data for the area MERRIMAC, which can be entered as DATA lines in REGULAR and used to generate -LORES and -HIRES files for that area as well.

1. SIERRA BROOKS--The data for Sierra Brooks consist of elevations for 31 rows and 31 columns of points, spaced at 240-meter intervals in an area 7.20 X 7.20 km. (51.84 sq.km.). Elevations are given in units of tens of feet relative to 5000 feet MSL (Mean Sea Level), taken from an advance print of the U.S. Geological Survey "Loyalton NW" quadrangle (1:24000 scale; 40-foot contour interval; 1977). The grid is aligned with the top toward true north.

This area is in northeastern Sierra County, California, in the northern portion of the Sierra Nevada, with elevations ranging from 4920 to 7200 feet MSL. In the upper left (NW) portion of the map is part of Sierra Valley, a large flat valley floor which was once a glacial lake bed. The valley of Smithneck Creek is also shown, flowing northward from the bottom (south) of the map into Sierra Valley. To either side of the stream valley are steep mountains, with the highest elevations on the right (eastern) edge of the map.

2. ARISTARCHUS--The Aristarchus data consist of elevations for 31 rows and 36 columns of points, spaced at 2500-meter intervals in an area 87.5 X 75.0 km. (6562.5 sq.km.). Elevations are given in tens of meters with an arbitrary datum (zero elevation), and are taken from the map "The Aristarchus-Herodotus Region," published by the Association of Lunar and Planetary Observers in 1968 (1:250000 scale; 250-meter contour interval). The data grid is aligned with top 24°.5 east of true north.

This area is on the moon, showing the craters Aristarchus and Herodotus in the "Oceanus Procellarum," centered at lunar latitude 23°.8 north, longitude 48°.5 west. The moon has no "sea Level," so an arbitrary elevation datum is used. Based on this datum, elevations range from 150 meters on the floor of Aristarchus to 4750 meters at a mountain summit northeast of Herodotus. The crater Aristarchus, 39 km. in diameter and 4350 meters deep, dominates the right (eastern) portion of the area. In the lower left (southwest) is the shallow crater Herodotus, 35 km. in diameter and 1450 meters deep. A steep-sided "rille" (sinuous valley), called "Schroeter's Valley," is located above (northeast of) Herodotus. The highest elevations are found in the left top portion of the map and on a plateau lying between Aristarchus, Herodotus, and Schroeter's Valley.

3. MERRIMAC--The data for the Merrimac area are given at the end of this Appendix, and may be entered as DATA statements in the program REGULAR. They consist of the elevations of 29 rows X 29 columns of points, spaced at 120-meter intervals in an area 3.36 X 3.36 km. (11.29 sq.km.). Elevations are given in units of tens of feet, relative to 3000 feet MSL, and are taken from the U.S. Geological Survey "Soapstone Hill" quadrangle (1:24000 scale; 80-foot contour interval; 1979). The grid is aligned with the top toward true north.

This area is in northeastern Butte County, California, in the northern Sierra Nevada, centered on the ghost town of Merrimac. Elevations range from 2860 to 4590 feet MSL, generally rising toward the north (top). The dominant topographical trend is NNE-SSW, with the valleys of Coon Creek, Peavine Creek, and Get Up and Get Creek found in west-to-east order near the bottom (south) of the map.

On the next page are the MERRIMAC data lines, which can be entered into REGULAR in order to generate -LORES and -HIRES files for this region.

```
101  DATA  3
102  DATA  "MERRIMAC"
103  DATA  29,29
104  DATA  1102.36, 1102.36
110  DATA  107,107,108,100,102,104,107,117,116,115,117,120,126,137,142
115  DATA  144,146,149,154,158,159,151,139,144,156,158,141,126,112
120  DATA   93, 94, 92,108,108,107,114,126,121,116,117,122,124,132,140
125  DATA  147,148,148,148,146,151,147,137,133,143,149,152,129,119
130  DATA   84, 52, 98,110,114,118,124,133,127,121,124,124,131,139,149
135  DATA  144,138,137,139,137,143,140,132,125,132,138,148,138,124
140  DATA   74, 84,100,110,115,125,129,134,130,133,134,139,139,147,147
145  DATA  140,132,129,130,126,131,130,127,116,126,130,132,125,114
150  DATA   80, 92,100,110,116,124,125,127,129,134,130,143,145,150,143
155  DATA  132,128,123,124,121,124,123,119,110,118,122,123,120,109
160  DATA   88,102,105,109,113,121,124,118,124,126,132,139,140,143,138
165  DATA  128,126,120,116,116,119,116,112,107,111,113,114,115,110
170  DATA   95,104,100,104,109,119,116,113,116,122,134,126,129,135,132
175  DATA  123,124,121,114,112,112,111,106,103,108,107,106,111,120
180  DATA   93,108, 98,100,108,113,111,111,115,121,130,119,119,124,126
185  DATA  119,120,119,115,110,106,107,104, 99,102,103,100,106,120
190  DATA   89, 97, 97, 98,103,107,107,109,116,123,124,115,115,119,124
195  DATA  116,118,118,113,108,104,104,103, 97, 94, 96, 97,102,117
200  DATA   93, 91, 97,100, 98,102,106,109,113,120,119,108,113,119,118
205  DATA  114,117,116,111,107,102,100,101, 96, 89, 90, 91,100,115
210  DATA   99, 96,102, 99, 98,102,103,104,111,114,112,107,117,118,115
215  DATA  112,112,110,106,104, 99, 98, 96, 92, 88, 85, 93,108,117
220  DATA   94, 98,100, 99,101,103,100,101,110,110,107,107,115,114,111
225  DATA  109,110,106,104,103,101, 98, 96, 95, 91, 83, 86,101,109
230  DATA  102, 99,100,101,100, 97, 94,103,108,107,106,107,108,108,107
235  DATA  106,108,105,101, 99, 99,100,102,102, 98, 89, 80, 95,108
240  DATA   95, 98,102,103, 98, 91, 94,103,103,103,105,106,105,104,102
245  DATA  100,103,100,107,108,106,106,106,106,102, 91, 80, 93,103
250  DATA   95,107,111,106, 99, 91, 92, 97,102,109,106,104,102,100, 96
255  DATA   95, 99,102,108,108,107,112,112,110,101, 89, 79, 80, 89
260  DATA  100,108,109,102, 95, 85, 95,104,104,106,105,104,100, 92, 88
265  DATA   95,102,108,110,108,109,115,118,113,105, 99, 91, 77, 76
270  DATA  106,108,104, 98, 87, 82, 92,108, 98, 96, 99, 97, 96, 86, 76
275  DATA   93,102,109,110,113,116,120,122,119,112,102, 93, 82, 73
280  DATA  107,108, 98, 95, 83, 78, 89, 94, 90, 85, 92, 83, 81, 76, 76
285  DATA   89,100,104,108,113,123,126,130,129,117,106, 93, 85, 70
290  DATA  102,103, 96, 84, 76, 78, 84, 80, 79, 71, 79, 76, 64, 59, 72
295  DATA   82, 90, 91, 99,111,119,125,130,131,119,106, 97, 89, 72
300  DATA   96, 94, 90, 77, 70, 76, 70, 63, 68, 59, 64, 63, 54, 48, 62
305  DATA   67, 75, 78, 97,106,115,121,127,128,117,106, 96, 89, 73
310  DATA   76, 79, 76, 68, 60, 70, 60, 50, 55, 50, 52, 54, 43, 37, 43
315  DATA   50, 56, 69, 90,105,111,115,125,126,117,103, 95, 92, 84
320  DATA   64, 63, 54, 52, 48, 57, 51, 44, 41, 46, 44, 41, 36, 25, 30
325  DATA   40, 54, 71, 91,103,106,108,121,120,115,108,107,103, 94
330  DATA   45, 46, 34, 35, 36, 41, 44, 37, 32, 36, 37, 33, 22, 17, 32
335  DATA   48, 65, 78, 92,101, 99,105,112,108,107,108,109,107, 98
340  DATA   29, 33, 27, 20, 20, 32, 35, 32, 26, 28, 28, 22, 16, 16, 36
345  DATA   47, 65, 87,100, 92, 94,100,103,103, 96,100,106,104,103
350  DATA   12, 21, 16,  5, 10, 25, 23, 24, 17, 23, 19, 14,  8, 20, 38
355  DATA   52, 68, 86, 87, 86, 93, 92, 92, 92, 85, 85, 92, 95, 92
360  DATA    1, 14,  8, -5, 11, 21, 12, 13, 11, 20,  9,  1, 17, 30, 39
365  DATA   51, 63, 78, 76, 83, 83, 77, 85, 84, 76, 75, 84, 84, 81
370  DATA    1,  8, -3, -4, 12,  6,  1,  9, 13, 12,  3,  2, 17, 25, 33
375  DATA   40, 58, 77, 68, 72, 76, 71, 81, 77, 68, 68, 75, 80, 75
380  DATA    4,  5,-10,-11,  0, -5,  5, 13, 12,  0, -6, -4, 14, 18, 28
385  DATA   42, 60, 69, 59, 60, 59, 69, 74, 72, 67, 60, 68, 78, 68
390  DATA    5,  4,-11,-14, -8, -5,  5,  3,  6, -7, -2,  5, 11, 18, 29
395  DATA   46, 60, 60, 45, 44, 59, 69, 66, 66, 64, 58, 70, 67, 66
```

Appendix F. Glossary

This User's Guide has used several technical cartographic terms which are defined here.

Coordinate--A numerical value that defines a point's position in terms of its distance, measured in a specified direction, from a reference point, line, or surface.

Depiction Parameter--A numerical value, used in a particular mapping technique, that controls the appearance of its results.

Digitize--The process of converting map information into numerical form.

Gradient--Slope as expressed in terms of the elevation change over a given horizontal distance, divided by that horizontal distance. Gradient is expressed as a unitless decimal.

Isoline--A line on a map that passes through all points of equal value of the variable of interest, but through no other points. Also called "contour line."

Isometric--Also called "orthogonal;" the perspective of a view of an object as seen from so great a distance that it can be drawn without vanishing points.

Layer Tinting--The process of dividing a map into zones, where each zone represents a particular range of the variable of interest, and then assigning a unique color or shade to each zone.

Plane Coordinate Syatem--Rectangular (Cartesian) coordinates measured upon a flat map projection of the earth's surface, thus avoiding the need for a separate third dimension to allow for the curvature of the earth.

Plastic Relief Shading--A relief display technique in which slopes facing in a particular direction are light, slopes facing in the opposite direction are dark, and the degree of light or dark depends on the amount of slope. The appearance is similar to that of a model which is illuminated from one direction, except that features do not cast shadows upon other features.

Statistical Surface--An imaginary surface whose height at any point (measured above a reference surface) is proportional to the value of the variable of interest at that point.

Vertical Exaggeration--The process of depicting the vertical dimension in a map at a larger scale than the horizontal dimension. The amount of vertical exaggeration is equal to the ratio of the vertical scale to the horizontal scale.

Appendix G. Selected References

If you are interested in finding out more about the surface display techniques used in these programs, and several additional techniques as well, it would be profitable to read one or more the the books below. There are many more references on the same topics, but each of these has its own bibliography.

David Greenhood. *Mapping*. Chicago: University of Chicago Press, 1964.

E. Bruce MacDougall. *Computer Programming for Spatial Problems*. New York: John Wiley, 1976.

F. J. Monkhouse and H. R. Wilkinson. *Maps and Diagrams*. 3rd Ed. London: Methuen, 1971.

Arthur Robinson, Randall Sale, and Joel Morrison. *Elements of Cartography*. 4th Ed. New York: John Wiley, 1978.

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