*TERRAIN ANALYSIS BY COMPUTER**NOVEMBER 1967**NO. 31**by**A.K. TURNER**and**R.D. MILES**Joint
Highway
Research
Project**PURDUE UNIVERSITY
LAFAYETTE INDIANA*

Technical Paper

TERRAIN ANALYSIS BY COMPUTER

To: G. A. Leonards, Director
Joint Highway Research Project

November 28, 1967

File: 1-6-1

From: H. L. Michael, Associate Director
Joint Highway Research Project

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The attached Technical Paper "Terrain Analysis by Computer" was presented by the authors, A. Keith Turner and Robert D. Miles, at the Soil Science Section of the Indiana Academy of Science on October 21, 1967. A request for approval of such presentation was approved by the Bureau of Public Roads prior to the presentation. An abstract of the paper was submitted to them to secure this approval.

The material in the paper was developed from the current HPR-1 (5) research on "Evaluation of Numerical Surface Techniques Applied to Highway Location Analysis."

The paper is now presented for approval of publication by the Indiana Academy of Science in its Proceedings. The paper will also be submitted to the ISHC and the BPR for their review, comments and approval.

Respectfully submitted,

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Technical Paper
TERRAIN ANALYSIS BY COMPUTER

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Project: C-36-72A

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TERRAIN ANALYSIS BY COMPUTER

A. Keith Turner and Robert D. Miles

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INTRODUCTION

Geomorphology is becoming an increasingly quantitative science. Many geomorphologists now view the landscape as a series of open physical systems tending toward energy equilibrium (1). Such scientists naturally attempt to describe terrain in unambiguous meaningful quantitative terms. Accurate, reproducible, numerical descriptors of terrain have become of great concern to several scientific disciplines; including engineering geology, military geology, soil science, and land locomotion engineering. This paper describes techniques for the analysis of terrain using the computer. Further additions and refinements to the techniques are anticipated.

This research was sponsored by the Indiana State Highway Commission and the Bureau of Public Roads; however, this paper has not had the benefit of their review. The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads or the Indiana State Highway Commission.

The authors also wish to acknowledge the assistance of Dr. V. L. Anderson, Department of Statistics, Purdue University, who reviewed the statistical implications of this study.

TERRAIN SAMPLING PROCEDURES

Map digitization, the reduction of graphical to numerical data, is required before computer analysis is possible. Development of simple, logical, and reproducible sampling procedures is an important prerequisite to satisfactory terrain analysis. Sampling can be performed at a series of irregularly spaced points or at a regular spacing forming a sample grid.

Irregularly spaced samples can often describe the terrain better with equal or smaller numbers of sample points than can grid systems which tend to sample repetitiously in uniform areas. Irregularly spaced samples are favored by surface fitting operations, such as trend surface analysis, since the smaller number of sample points minimizes computational complexities.

With gridded samples, the position of a sample in the array automatically denotes its X and Y coordinates. This feature may ease data storage problems within the computer and can be used to advantage when computations require knowledge of adjacent points, since lengthy data search routines are unnecessary. While data are most frequently collected on rectangular coordinate systems, polar coordinates have been used. Stone and Dugundji (11) discuss the merits of various systems.

This research used gridded data to analyze the roughness and variability of homogenous areas. These values in turn allowed the determination of appropriate irregularly spaced sampling distributions of larger areas. Gridded samples were also used to develop hypsometric integrals of various terrain types.

DESCRIPTIVE MEASURES OF HOMOGENOUS TERRAIN

Two techniques for computer analysis of homogenous terrain types have been evaluated. One of these measures the surface roughness; the other is a technique for estimating the hypsometric integral whereby the labor of calculating this measure is substantially reduced.

Estimation of Surface Roughness

A technique for measuring roughness has been suggested by Hobson (4). This study has used a modified version of his program VECTOR.

Description of Program VECTOR

A rectangular array of elevation readings is the basic input data. A set of intersecting triangular planar surfaces are defined by groups of three adjacent elevation readings (Figure 1A). Two different sets of triangles can be obtained from the same data by redefining the triangle corners as shown in Figure 1B. Type 1 triangles have "northeast-southwest" diagonals; while Type 2 triangles have the opposite diagonals.

Normals to these planes are represented by unit vectors. Mean vector orientation, vector strength, and vector dispersion are computed using methods defined by Fisher (3) and described by Watson (15). Vector strength, R_1 , is obtained by using the direction cosine method (5). The standardized vector strength, R , (where R equals R_1 divided by the number of triangles) ranges in value from zero for no preferred

A

DEFINITION OF TRIANGULAR PLANES FROM ELEVATION MATRIX

B

TYPE 1 TRIANGLES

TYPE 2 TRIANGLES

C

"SMOOTH" TERRAIN

LOW VECTOR DISPERSION

D

"ROUGH" TERRAIN

HIGH VECTOR DISPERSION

FIGURE 1-- PROGRAM VECTOR ANALYSIS PROCEDURES

(modified after Hobson)

orientation to one for identical orientation. Fisher's dispersion factor, K , (3) indicates the variability or spread of the unit vectors; it takes on small values for highly dispersed distributions and extremely high values for low dispersions.

"Smooth" areas generally have high vector strengths and low dispersions (high K values) as shown in Figure 1C. Such areas may be flat or may have a regional tilt. "Rough" areas of non-systematic elevation changes yield low vector strengths and high vector dispersion, thus low K values (Figure 1D).

Description of Test Sites

Twenty-five sample areas were used; twelve of these were located in Indiana. Eleven sites were measured on 1:24,000 scale topographic maps; the twelfth was located on a 1:62,500 scale map and corresponds to one of the 1:24,000 scale test sites. These sites represent several characteristic Indiana landforms including karst plains (2 sites); hills (3 sites), plateaus (1 site), escarpments (2 sites), ground moraine (2 sites), ridge moraine and dunes (1 site), and outwash plains (1 site). A thirteenth site was selected to analyze drumlin topography; part of the Weedsport Quadrangle (1:24,000), New York State, was used for this purpose. Twelve micro-terrain maps were selected for analysis from a series of specially surveyed maps prepared by Stone and Dugundji (11). These maps were prepared with contour intervals ranging between one-tenth and one foot and scales from 1:180 to 1:4800. A variety of California terrain types is represented including flood plains, badlands, and a variety of desert landforms (playas, pediments, wadis, dunes).

Results of Terrain Analysis by Program VECTOR

Analysis of twenty-five test sites, encompassing a variety of land-forms and map scales, by program VECTOR suggests that meaningful terrain analysis can be performed on the computer. The following summarize the results of the current analyses:

- 1) Program VECTOR is equally suitable for analysis of micro and macro terrains; provided that maps of suitable scale and contour intervals are available for the test sites.
- 2) Fisher's dispersion factor, K, is an excellent descriptor of terrain roughness. Roughness is described as "the presence of non-systematic elevation changes" (see Figure 1C and 1D). Fisher's dispersion factor is defined as

$$K = \frac{N - 1}{N - R_1}$$

where N is the number of observations (triangles), and R₁ is the vector strength (3,4).

For smooth surfaces, all the unit vectors tend to the same orientation; thus R₁ approaches N, and N - R₁ tends to zero, and accordingly K approaches infinite. Conversely, for very rough terrains R₁ tends to zero, and thus K approaches one. The smallest K value obtained in this study was 31. This was measured for a wadi in the Mohave Desert (11, Figure 29) while the largest K value, 374,773, was measured for a playa surface (11, Figure 55). Indiana sites gave less extreme values. The roughest Indiana site was part of the New Albany Escarpment (K = 81) while the smoothest site was the ground moraine just west of Tipton (K = 30,044). Because of the very large range of K values, the log K transformation is frequently useful.

FIGURE 2- EFFECT OF TRIANGLE TYPE ON 'K'

3) All test sites were analyzed by program VECTOR using Type 1 and Type 2 triangles (Figure 1B). No important differences were observed in any of the measures as a result of type of triangles used in the analysis. Figure 2 shows the values of log K for Type 1 triangles plotted versus log K for Type 2 triangles; all points lie close to the 45° line.

4) Since K is a measure of vector dispersion it may be correlated with measures of the variability of attitudes of the triangular planes. The log (variance of dips) was plotted against log K (Figure 3B) and a least squares linear regression line fitted. The linear correlation coefficient, $r = -0.964$, indicates a strong correlation between log (variance of dips) and log K.

If log (maximum dip) is plotted against log K (Figure 3A) and a least squares regression line fitted, $r = -0.950$. The difference between the two correlation coefficients is not statistically significant. A strong correlation between log (maximum dip) and log K is geomorphically reasonable; since steep slopes are normally associated with rough topography. However, given two areas with the same maximum slope value, one might have a much greater range in slope values, and hence a larger variance of dip and greater roughness. Thus maximum dip may not be quite as good a descriptor of terrain roughness as variance of dip.

Initially it was believed that a similar correlation might exist between log (variance of strikes) and log K. Figure 3C is a plot of log (variance of strikes) versus log K. The linear correlation coefficient $r = 0.009$ indicates essentially no linear correlation exists between log (variance of strikes) and log K. This may be due in part to

FIGURE 3—RELATIONSHIPS BETWEEN 'K' AND STRIKE AND DIP VARIABILITY

the test sites all having highly variable strike values. Careful examination of the results suggests that K may be related to a function of the variabilities of both strikes and dips. At the present time, however, a satisfactory model has not been discovered, although several have been tried.

5) The orientations of the triangular planar elements become progressively poorer estimators of the true terrain roughness as the sample spacing increases, as shown in Figure 4. A filtering action takes place so that smoothing of the terrain occurs; statistics, such as K, derived from the triangle orientations reflect this smoothing.

Photographic enlargements up to four diameters of several test sites were produced, sampled, and analyzed using program VECTOR. Since all these data sets were rectangular arrays, it was also possible to analyze alternate columns and rows. These procedures allowed the examination of the effects of grid size (sample spacing) on results of program VECTOR analysis.

Testing of these comparisons for significance requires the use of non-parametric statistics. Strahler (12,14) showed that slopes have normal distributions. In contrast, the distributions of dips of the triangular planes are not normal, but vary widely from skewed to almost exponential distributions. Similar uncertainties surround the distributions of K and of strikes of these planes. Transformation of these distributions to more nearly normal form would allow the use of parametric statistics. The Walsh test, described by Siegel (10), is a suitable non-parametric test, and was used to evaluate K values measured for Indiana sites. The test showed that samples collected on a 500 foot spacing gave significantly smoother K values (at the 95% confidence level)

Original Profile

**FIGURE 4— EFFECT OF SAMPLE SPACING ON TERRAIN
ROUGHNESS ESTIMATION**

than did samples collected on a 125 foot spacing. The investigator must consider the effect of sample spacing on roughness estimators when determining the roughness of any area and set his grid size accordingly.

Most terrain types have a characteristic slope length. Statistics derived from grid spacings equal to or less than the equivalent map distance will probably show much less dependence on grid size than will values obtained from larger grids. One method of selecting a grid size would be to estimate the characteristic slope lengths for the terrain to be studied and use a grid size slightly smaller than the equivalent map distance.

Another method is possible if the primary purpose of determining the roughness is to compare areas so as to design suitable stratified sampling procedures, as described in a following section. In such a case a grid size equal to the minimum sampling distance needed for the purposes of analysis, applied to all subareas, will allow their comparison on equal terms.

Estimation of the Hypsometric Integral

A second method of comparing two or more homogenous areas is to compare their hypsometric integrals. The hypsometric integral was devised by Strahler (13). It is a dimensionless measure of subsurface volume of a drainage basin. Strahler suggested that, under certain conditions, this integral would provide a quantitative expression of stage of basin denudation and Schumm (9) successfully used it for this purpose.

Strahler's method of measuring the hypsometric integral is somewhat tedious and this may explain why this morphometric measure has been little used. Chorley and Morley (2) suggested a simplification. They approximated drainage basins by a regular geometrical form, a lemniscate, and were able to more easily calculate the hypsometric integral. However, their technique resulted in values which varied from Strahler's values. They suggested a transformation to correct their values.

Description of Program GCON

The availability of a computer program GCON, originally written in the MAD language by Professor W. R. Tobler, University of Michigan, Ann Arbor, suggested a second method of estimating the hypsometric integral. This program accepts gridded elevation values and performs linear interpolation on them to produce contour maps on the normal computer line printer. Various scaling and contour interval specification options are available.

The program defines a map as an array of printing positions; N characters per line wide and M lines long. Thus there are $N \times M$ character spaces in the entire map. Each character position is evaluated in turn and the appropriate interval list is incremented by one. Thus a frequency table is readily produced of percent area within each contour interval.

Accuracy of this integration procedure is controlled by the fixed size of the unit incremental area, a single character. Thus larger map sizes will increase the accuracy of the area determinations. Visual comparison of the computer-developed contour map with the original

topographic map allows the investigator to estimate the reliability of his estimated hypsometric integral.

While the program requires rectangular map areas, analysis of irregular watersheds can be accomplished by setting all areas outside the watershed to arbitrarily very high values. The maximum and minimum contour levels corresponding to the highest and lowest values for the watershed are included as data. The program calculates the elevation range and excludes all elevations lying more than one range above the watershed's highest point, or one range below the lowest point. The frequency table will accordingly show the number of character spaces within each contour level in the basin. These values can be quickly transformed for plotting the hypsometric curve. A new subroutine has been developed to allow the computer to make this transformation, plot the curve, and estimate the area below the curve - the hypsometric integral.

Results of Analysis

The above concepts were tested by re-analyzing seven drainage basins whose hypsometric integrals were measured by Strahler (13). Figure 5A is a copy of Strahler's map of one of these basins; Figure 5B is a copy of a computer-generated contour map of the same basin. Figure 6 is a plot of the hypsometric curve for the same basin. Strahler's values are also plotted showing the close agreement between the two methods. Table 1 tabulates the results for all seven drainage basins. Chorley and Morley's uncorrected values for the same basins are also listed for comparison.

FIGURE 5-DRAINAGE BASIN, VERDUGO HILLS, CALIFORNIA.

FIGURE 6— HYPSONETRIC CURVE, DRAINAGE BASIN IN VERDUGO HILLS (see Figure 5)

TABLE 1

Comparison of Hypsometric Integrals

Values from Strahler (13)				Computer Estimated Hypsometric Integral	Approximated Hypsometric Integral from Chorley and Morley (2)
Figure Number	Single-Basin Hypsometric Integral	Composite Values			
		Mean Hypsometric Integral	Estimated Population Standard Deviation		
14	79.5%			78.7%	86.0%
15	43.0%			43.5%	41.0%
16	17.6%			16.3%	12.7%
17-1		59.7%	6.55%	62.5%	59.6%
17-2		54.2%	5.20%	54.4%	53.2%
17-4		46.8%	4.58%	43.6%	44.5%
17-5		40.8%	5.88%	46.2%	35.7%

METHODS OF STRATIFIED SAMPLING OF MAP SHEETS

Most topographic quadrangle maps cover a variety of terrain types. Such areas may be termed "compound" as opposed to "simple" terrains which show only one type of landform. In statistical terminology such compound map areas contain more than one population.

Suppose a researcher wishes to digitize a map area as shown in Figure 7A. He might partition the map into three "simple" areas as shown in Figure 7B. The investigator may decide on a total number of sample locations for the entire map, or he may decide on some sampling density for any one of the simple areas. In either case, if he wishes to sample all areas with equal reliability, he must distribute the number of sample points for each subarea according to its relative area and its relative variability.

The percent of the total map area contained in any subarea is easily estimated. It can be obtained by a planimeter if greater accuracy is desired. Thus, the problem resolves into determining a suitable numerical descriptor of the variability of the various terrain types.

Terrain Variability Measures

A perfectly smooth, planar, horizontal surface can be adequately described by a single elevation value; any planar inclined surface requires three elevation values, and associated X and Y coordinates, to describe it. Gently curved surfaces require still more data points to satisfactorily describe their overall orientation. The overall orientation of subareas might be described in a number of ways. The range of the elevations is the simplest value to obtain, requiring no prior sampling procedure.

A. BLOCK DIAGRAM OF MAP AREA (after Lobeck)

AREA TABLE

SUBAREA	% AREA
1. bedrock hills	47
2. ground moraine	17
3. flood plain	36

B. MAP SUBDIVIDED FOR STRATIFIED SAMPLING

FIGURE 7-- STRATIFIED SAMPLING PROCEDURES

TABLE 2

Results of Program VECTOR Analyses

Test Site Number	Terrain Type	Elevation Range (ft)	Roughness K	log K	Variability v (ft)
A. Turner Test Sites					
02393-1	escarpment	315	85	1.929	163.5
02393-3	escarpment	278	82	1.914	145.1
03022-1	hills	340	397	2.599	131.0
02487-1	hills	277	220	2.342	118.5
02039-2	hills	212	158	2.199	96.5
W-1	drumlins	183	222	2.346	78.3
02039-1	karst plain	166	723	2.859	57.2
02039-3	karst plain	170	1329	3.124	54.6
02393	plateau	81	1759	3.245	25.0
02393-2	ridge moraine and dunes	53	2892	3.461	15.3
02329-2	ground moraine	60	24664	4.392	13.7
02329-1	outwash plain	28	18024	4.256	6.6
02625-1	ground moraine	26	30044	4.478	5.8
B. Stone and Dugundji Sites (subarea numbers are figure numbers)					
M-29	Boulder-free wadi	25.0	31	1.491	16.8
M-57	Pleistocene lake terrace	10.8	51	1.708	6.3
M-33	Micro-badlands	9.0	117	2.068	4.4
M-45	Sand-sheet	10.5	309	2.490	4.2
M-49	Complex dunes	8.7	161	2.207	3.9
M-53	Turret dunes	7.0	133	2.124	3.3
M-41	Playa drainage channels	5.3	233	2.367	2.2
M-37	Floodplain mounds	3.0	269	2.430	1.2
M-39	Floodplain ridges	2.3	189	2.276	1.0
M-35	Salt ploygons	1.4	102	2.009	0.7
M-47	"Devil's Cornfield"	1.15	975	2.989	0.4
M-55	Playa	0.47	374773	5.573	0.084

A particular subarea's roughness will also affect the number of sampling points required to describe it. It has already been shown that K, Fisher's dispersion factor, is an ideal numerical descriptor of roughness. Since K values can range from one to extremely large numbers the variability factor, v, is defined as

$$v = \frac{(\text{Range of elevations (feet)})}{\log (K)}$$

v can range from zero for completely flat surfaces which must by definition be smooth, to the range in elevations for extremely rough areas ($K = 0$, thus $\log (K) = 1$). Table 2 lists values of elevation range, K, $\log (K)$, and the resulting v for all twenty-five test sites.

If the variability factor and the percent area belonging to each subarea on a map sheet, such as Figure 7B, are known and the total number of samples to be distributed on the map is decided on, the following equation will distribute the points among the various subareas

$$n_i = \frac{v_i a_i N}{\sum v_i a_i}$$

where i is the subarea number, v_i is the variability of the ith subarea, a_i is the percent area of the ith subarea, and N is the total number of samples on the map. Such a distribution of sample points among the various subareas, will result in approximately equal sampling reliability over an entire map area.

CONCLUSIONS

Homogenous terrain types can be compared using measures of roughness, variability, and the hypsometric integral. The digital computer can aid in the calculation of these measures. In addition to their geomorphic

applications these measures could be used as predictors of several engineering construction costs, such as highway grading costs, since they are associated with terrain geometry.

The variability factor can be used to determine appropriate irregularly spaced sampling distributions of larger compound areas covering one or many map sheets. The importance of these techniques should not be underestimated. McIntyre (7) states that irregularly spaced random samples may better digitize topographic maps than gridded data under at least some conditions. Computer analysis of these compound areas by techniques such as trend-surface analysis will open the way to a number of interesting studies.

Map comparison procedures, as suggested by Miller (8), are one obvious application. Geometric analysis of at least more regular terrain types, such as drumlinized topography, by the methods developed by Whitten (16) and Loudon (6) could have useful applications to glacial geology, geomorphology, and civil engineering. The author is currently examining the applicability of trend surface analysis to the highway location problem.

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APPENDIX A

Maps of Turner's Test Sites

FIG. A-1. Test site 02393-1; Escarpment, Medora Quadrangle (1:24,000)

FIG. A-2. Test site 02393-3; Escarpment, Medora Quadrangle (1:24,000)

FIG. A-3. Test site 03022-I; Hills, Oolitic Quadrangle (1:62,500)

FIG. A-4. Test site 02487-I; Hills, Owensburg Quadrangle (1:24,000)

FIG. A-5. Test site 02039-2; Hills, Bedford West Quadrangle (1:24,000)

FIG. A-6. Test site W-1; Drumlins, Weedsport Quadrangle N.Y. (1:24,000)

FIG. A-7. Test site 02039-1; Karst Plain, Bedford West Quadrangle (1:24,000)

FIG. A-8. Test site 02039-3; Karst Plain, Bedford West Quadrangle (1:24,000)

FIG. A-9. Test site 02393-4; Plateau, Medora Quadrangle (1:24,000)

Fig. A-10. Test site 02393-2; Ridge Moraine and Dunes, Medora Quadrangle (1:24,000)

FIG. A-11. Test site 02329-2; Ground Moraine, Lafayette West Quadrangle (1:24,000)

FIG. A-12. Test site 02625-I; Ground Moraine, Tipton Quadrangle (I: 24,000)

FIG. A-13. Test site 02329-I; Outwash Plain, Lafayette West Quadrangle (I: 24,000)

APPENDIX B
Computer Program VECTOR

FIG. B-1 PROGRAM VECTOR - TYPICAL DECK SETUP


```

$ID 3402*2*10**TURNER* PROGRAM VECTOR
$EXECUTE IBJOB
$IBJOB
$IRFCTC MAIN
*****
PROGRAM VECTOR -- PURDUE UNIVERSITY VERSION
THIS PROGRAM ANALYSES SURFACE ROUGHNESS
*****
TWO TECHNIQUES ARE USED--1) ELEVATIONS ARE ANALYSED FOR MEAN RANGE
VARIANCE, STANDARD DEVIATION, ETC. 2) GROUPS OF THREE POINTS ARE USED
TO DEFINE PLANES WHOSE ORIENTATION IS DETERMINED. MEASURES OF VECTOR
STRENGTH AND DISPERSION ARE USED TO ESTIMATE ROUGHNESS. TYPE 1
AND TYPE 2 TRIANGLES CAN BE FITTED. A VARIABILITY FACTOR, V, IS
CALCULATED FROM THE RANGE OF ELEVATIONS/THE ROUGHNESS MEASURE, K.
*****
THIS PROGRAM USES THE FOLLOWING SUBROUTINES ---
TILTS -- WHICH CALCULATES STRIKES AND DIPS FROM VECTOR COSINES.
STATS -- WHICH CALCULATES STATISTICAL MEASURES.
WULFF -- WHICH GENERATES WULFF NET STEREOGRAMS FROM VECTORS.
HISTO -- WHICH GENERATES HISTOGRAMS OF STRIKE AND DIP DISTRIBUTIONS.
*****
CARD ORDER IS -----
A) CARDS WHICH APPEAR ONCE. ---
1) SPATA
2) TITLE CARD (TITL) COLS 7-80
A GENERAL TITLE WHICH WILL APPEAR AS A HEADING AT THE BEGINNING
OF EACH DATA SET.
B) CARDS WHICH ARE REQUIRED AS PART OF EACH DATA SET. ---
1) SIZE/SCALE CARD (M,N,XSTEP,YSTEP,DIRN)
M=(COLS1-3) IS THE NUMBER OF ROWS.
N=(COLS4-6) IS THE NUMBER OF COLUMNS.
XSTEP=(COLS 11-20) IS THE SIZE OF COLUMN SPACING IN ELEVATION UNITS.
YSTEP=(COLS 21-30) IS THE SIZE OF ROW SPACING IN ELEVATION UNITS.
DIRN=(COLS 31-40) IS AZIMUTH IN DEGREES OF Y AXIS.
2) OUTPUT OPTION CARD (IPL0T,ISKIP,IHIST(1),IHIST(2),ITYPE)
IPL0T=(COL 1) IF IPL0T=1,STR
IPL0T=(COL 1) IF IPL0T=1,STEREOGRAM OF NORMAL VECTORS IS PRODUCED.
ISKIP=(COL 5) IF ISKIP=1, A LISTING OF TRIANGLE STRIKES AND DIPS
IS SUPPRESSED.
IHIST=(COLS 10-11) IF IHIST(1)=1, A HISTOGRAM OF DIPS IS PLOTTED.
IF IHIST(2)=1, A HISTOGRAM OF STRIKES IS PLOTTED.
ITYPE=(COL 12) IF ITYPE=1, TYPE 1 TRIANGLES ARE FITTED.
IF ITYPE=2, TYPE 2 TRIANGLES ARE FITTED.
IF ITYPE=3, TYPES 1 AND 2 TRIANGLES ARE FITTED.
( IF THIS CARD IS BLANK STANDARD OUTPUT IS PRODUCED,---TYPE 1 TRI-
ANGLES, A LISTING OF ALL TRIANGLE STRIKES AND DIPS, AND NO
STEREOGRAM OR HISTOGRAMS. )
3) FORMAT CARD (FMT) ---COLS 7-80
SPECIFIES FORMAT OF DATA SET WHICH FOLLOWS
4) PROBLEM CARD (PROB) COLS 7-80
A TITLE WHICH WILL SERVE TO IDENTIFY THE DATA SET.
5) SERIES OF DATA CARDS GIVING ELEVATION MATRIX.
*****
PROGRAM MODIFIED FROM R.D. HOBSON, KANSAS COMPUTER CONTRIBUTION 14
*****
A. KEITH TURNER
PURDUE UNIVERSITY
AUGUST 1967
*****
DIMENSION E(20,20),XNORM(800),YNORM(800),ZNORM(800),DEPS(800),
ISTR(800),TITL(12),FMT(12),PROB(12)
DIMENSION IHIST(2)
*****
READ TITLE,MASTER,AND DATA FORMAT CARDS
*****

```



```

108 READ(5,108) TITL
500 FORMAT(6X,12A6)
109 READ(5,109) M,N,XSTEP,YSTEP,DIRN
109 FORMAT(2I3,4X,3F10, )
1000 READ(5,1000) I,PLOT,ISKIP,(IHIST(I),I=1,2),ITYPE
1000 FORMAT(I1,3X,I1,4X,2I1,I1)
1000 READ(5,108) FMT
C *****
C WRITE OUT HEADINGS
*****
WRITE(6,110)
110 FORMAT(1H1,10X,30HCOMPUTATIONS BY PROGRAM VECTOR )
WRITE(6,116)
116 FORMAT(1H0,49H----- //)
WRITE(6,108) TITL
WRITE(6,116)
WRITE(6,100) M,N,XSTEP,YSTEP,DIRN,FMT
100 FORMAT(1H0,14HVALUES READ IN//,12H NO OF ROWS=,I3,12H NO OF COLS=,
113,7H XSTEP=,F8,2,7H YSTEP=,F8,2,18H Y-AXIS DIRECTION=,F8,2,13H
20DATA FORMAT=,12A6 )
READ(5,108) PROR
WRITE(6,116)
WRITE(6,130) PROR
130 FORMAT(1H0,32HCOMPUTATION RESULTS FOR SUBAREA ,12A6 )
WRITE(6,116)
C *****
C READ AND WRITE ELEVATION MATRIX
*****
DO 31 I=1,M
31 READ(5,FMT) (E(I,J),J=1,N)
WRITE(6,131)
131 FORMAT(1H0,23HORIGINAL ELEVATION DATA //)
DO 32 I=1,M
WRITE(6,132) (E(I,J),J=1,N)
132 FORMAT(12F10,0)
32 WRITE(6,133)
133 FORMAT(1H0)
CALL STATS(M,N,20,20,F,EBAR,EBAR,ESIG,EMAX,EMIN)
WRITE(6,116)
WRITE(6,210)
210 FORMAT(1H0,38HSTATISTICAL MEASURES OF ELEVATION DATA )
WRITE(6,133)
WRITE(6,208) EBAR,EBAR,ESIG,EMAX,EMIN
WRITE(6,116)
C *****
C GENERATE NORMALS TO TRIANGLES
*****
MM=M-1
NN=N-1
C *****
C ITYPE DETERMINES TYPE OF TRIANGLE BEING FITTED
*****
IF (ITYPE.LT.1.OR.ITYPE.GT.3) ITYPE=1
GO TO (51,52,51),ITYPE
51 K=1
C *****
C DO LOOP THROUGH 50 FITS TYPE 1 TRIANGLES
C ( FIRST TRIANGLE IS DEFINED BY POSITIONS (1,1),(1,2),(2,1) )
C *****
NNK=1
WRITE(6,555) NNK
555 FORMAT(1H1,32HTHE PROGRAM IS NOW FITTING TYPE ,I1,11H TRIANGLE, )
WRITE(6,116)
DO 50 I=1,MM
I1=I+1
DO 50 J=1,NN
JJ=J+1
A=(E(I,JJ)-E(I,J))*YSTEP
B=(E(I,J)-E(I1,J))*XSTEP
C=XSTEP*YSTEP
DIV=SQRT(A**2+B**2+C**2)
XNORM(K)=A/DIV
YNORM(K)=B/DIV
ZNORM(K)=C/DIV
K=K+1
A=(E(I,JJ)-E(I1,J))*YSTEP
B=(E(I,JJ)-E(I1,J))*XSTEP
C=XSTEP*YSTEP
DIV=SQRT(A**2+B**2+C**2)

```

```

XNORM(K)=A/DIV
YNORM(K)=B/DIV
ZNORM(K)=C/DIV
50  K=K+1
    NK=K-1
    GO TO 57
    K=1
*****
DO LOOP THROUGH 53 FITS TYPE 2 TRIANGLES
( FIRST TRIANGLE IS DEFINED BY POSITIONS (1,1),(2,1),(2,2) )
*****
NNK=2
WRITE (6,555) NNK
WRITE (6,116)
DO 53 I=1,NK
  I=I+1
  DO 53 J=1,NN
    JJ=J+1
    A=(E(I,J)-E(I,JJ))*YSTEP
    B=(E(I,J)-E(I,JJ))*XSTEP
    C=XSTEP*YSTEP
    DIV=SQRT(A**2+B**2+C**2)
    XNORM(K)=A/DIV
    YNORM(K)=B/DIV
    ZNORM(K)=C/DIV
    K=K+1
    A=(E(I,J)-E(I,JJ))*YSTEP
    B=(E(I,JJ)-E(I,JJ))*XSTEP
    C=XSTEP*YSTEP
    DIV=SQRT(A**2+B**2+C**2)
    XNORM(K)=A/DIV
    YNORM(K)=B/DIV
    ZNORM(K)=C/DIV
    K=K+1
    NK=K-1
57  IF (ISKIP-1) 58,59,5B
*****
CALCULATE STRIKE AND DIP OF ALL TRIANGLES
BUT IF ISKIP=1 DO NOT LIST VALUES
*****
58  WRITE (6,200)
200  FORMAT (1H0,31HSTRIKE AND DIP OF ALL TRIANGLES //)
    WRITE (6,201)
201  FORMAT (1H0,1X,35HTRIANGLE NUMBER      STRIKE      DIP )
59  CONTINUE
    DO 60 K=1,NK
      ALPHA=XNORM(K)
      BETA=YNORM(K)
      GAMMA=ZNORM(K)
      CALL TILTS(ALPHA,BETA,GAMMA,STRIKE,DIP,DIPN)
      DPS(K)=DIP
      STR(K)=STRIKE
60  CONTINUE
    IF (ISKIP-1) 68,69,6B
68  WRITE (6,202) (K,STR(K),DPS(K),K=1,NK)
202  FORMAT (1H,3(7X,13,11X,18,4,2X,18,4))
69  WRITE (6,116)
CONTINUE
*****
C  COMPUTE MEAN AND STANDARD DEVIATIONS OF STRIKES AND DIPS
*****
CALL STATS(1,NK,1,800,STR,STRBAR,STRVAR,STRSIG,STRMAX,STRMIN)
CALL STATS(1,NK,1,800,DPS,DPSBAR,DPSVAR,DPSIG,DPSMAX,DPSMIN)
WRITE (6,207)
207  FORMAT (1H0,44HSTATISTICAL MEASURES OF STRIKES OF TRIANGLES )
    WRITE (6,208) STRBAR,STRVAR,STRSIG,STRMAX,STRMIN
208  FORMAT (1H,5HMEAN=F10.4,12H VARIANCE=F10.4,22H STANDARD DEVI
ATIONS=F10.4,11H MAXIMUM=F10.4,11H MINIMUM=F10.4 )
    WRITE (6,209)
209  FORMAT (1H0,41HSTATISTICAL MEASURES OF DIPS OF TRIANGLES )
    WRITE (6,208) DPSBAR,DPSVAR,DPSIG,DPSMAX,DPSMIN
    WRITE (6,116)
    I=1
*****
C  CALL HISTO FOR HISTOGRAMS OF STRIKES AND DIPS
C  *****
    IF (IHIST(1),NE,1) GO TO 220
    CALL HISTO(NK,DPSMAX,0.0,DPS,PROB,1,NNK)
220  I=I+1

```

```

IF(IHIST(1).NE.1) GO TO 221
CALL HISTO(NK,STRMAX,STRMIN,STR,PROB,1,NNK)
221 CONTINUE
*****
C COMPUTE VECTOR STRENGTH
*****
TOTX=0.0
TOTY=0.0
TOTZ=0.0
DO 70 K=1,NNK
TOTX=TOTX+XNORM(K)
TOTY=TOTY+YNORM(K)
70 TOTZ=TOTZ+ZNORM(K)
ZR=TOTX*TOTX+TOTY*TOTY+TOTZ*TOTZ
*****
C VECTOR STRENGTH SHOWN BY EITHER R1 OR P1 DISPERSION BY ESTK
*****
R1=SQRT(ZR)
FNK=NNK
R=P1/FNK
ESTK=(FNK-1.0)/(FNK-R1)
556 WRITE(6,556)
FORMAT(1H1)
WRITE(6,116)
204 WRITE(6,204) R1,R
FORMAT(1H0,35HMEASURES OF VECTOR STRENGTH ARE R1=,F12.4,7H, R=,
1F9.6,134H, WHERE R=P1/NUMBER OF TRIANGLES. )
WRITE(6,205) ESTK
205 FORMAT(1H,58HVECTOR DISPERSION,MEASURED BY FISHERS DISPERSION FAC
TOR,IS,F12.4,40H, LOW VALUES INDICATE VARIABLE TERRAIN. )
V=(EMAX-EMIN)/ALOG10(ESTK)
300 WRITE(6,300) V
FORMAT(1H0,60HTHE VARIABILITY FACTOR, V = ELEVATION RANGE/LOG(ESTK
1) , IS ,F10.3)
*****
C COMPUTE VECTOR MEAN AND MEAN PLANE ORIENTATION
C DIRECTION COSINES OF MEAN VECTOR
*****
ALPHA=TOTX/R1
BETA=TOTY/R1
GAMMA=TOTZ/R1
999 WRITE(6,999) ALPHA,BETA,GAMMA
FORMAT(1H0,51HTHE DIRECTION COSINES OF THE MEAN VECTOR ARE ALPHA=,
1F10.5,17H, BETA=,F10.5, 8H, GAMMA=,F10.5)
CALL TILTS (ALPHA,BETA,GAMMA,STRIKE,DIP,DIRN)
WRITE(6,206) STRIKE,DIP
206 FORMAT(1H0,59HTHE ORIENTATION OF THE MEAN PLANE IS AS FOLLOWS---
1STRIKE=,F8.4,16H, DIP=,F8.4)
WRITE(6,116)
*****
C WHEN IPLOT=1, CALL WULFF TO PLOT A STEREOGRAM OF THE TRIANGLES
*****
IF(IPLOT.NE.1) GO TO 501
CALL WULFF (NK,XNORM,YNORM,ZNORM,PROB,NNK)
501 IF (ITYPE.EQ.3.AND.NNK.EQ.1) GO TO 52
GO TO 500
END
$IBFTC TILT
SUBROUTINE TILTS(ALPHA,BETA,GAMMA,STRIKE,DIP,DIRN)
C *****
C PROGRAM TO DETERMINE STRIKE AND DIP OF PLANES
C *****
ANGG=ARCOS(GAMMA)
AC=SQRT((ALPHA)**2+(BETA)**2)*SIGN(1.0,ALPHA)*SIGN(1.0,BETA)
COSTH=BETA/AC
STRIKE=((1.5708-ARCOS(COSTH))*57.2957)+DIRN
DIP= ANGG*57.2957
RETURN
END
$IBFTC STAT
SUBROUTINE STATS(ROWS,COLS,II,JJ,X,XBAR,XVAR,XSIG,XMAX,XMIN)
C *****
C PROGRAM TO FIND STATISTICAL MEASURES
C *****
INTEGER ROWS,COLS
DIMENSION X(II,JJ)
N0=ROWS*COLS
XS0=0.0
XSUM=0.0

```

```

      XMAX=X(1,1)
      XMIN=X(1,1)
      DO 10 I=1,ROWS
      DO 10 J=1,COLS
      IF (X(I,J).GT.XMAX) XMAX=X(I,J)
      IF (X(I,J).LT.XMIN) XMIN=X(I,J)
      XSUM=XSUM+X(I,J)
10    XSQR=XSQR+X(I,J)*X(I,J)
      XBAR=XSUM/FNO
      XVAR=(XSQR-FNO*XBAR*XBAR)/FNO
      XSIG=SQRT(XVAR)
      RETURN
      FNO
SIRFTC WULF
      SUBROUTINE WULFF (KOUNT2,TX,TY,TZ,PROP,ITYPE)
      *****
      THIS SUBROUTINE PLOTS A SCATTER DIAGRAM OF A GROUP OF DIRECTION
      COSINES. THE DIAGRAMS MAY BE USED AS OVERLAYS ON A 20 CENTIMETER
      DIAMETER WULFF NET. THE NUMBER IN EACH RECTANGLE INDICATES THE
      NUMBER OF POINTS FALLING IN THAT RECTANGLE.
      *****
      THIS SUBROUTINE MODIFIED AFTER SUBROUTINE WULFF IN ---
      LOUDON,T.V.-1964-@COMPUTER ANALYSIS OF ORIENTATION DATA IN STRUCTURAL
      GEOLGY-OFFICE OF NAVAL RESEARCH,GROG. BRANCH,TECH. REPT.13,
      ONR TASK NUMBER 389-135, 129 PAGES.
      *****
      B. KEITH TURNER,
      PURDUE UNIVERSITY, 1967.
      *****
      DIMENSION IROW(48,40),TX(800),TY(800),TZ(800)
      DIMENSION PROP(12)
      *****
      INITIALIZE, PUTTING -9 IN THE AREA OUTSIDE THE STEREOGRAM.
      *****
      WRITE(6,105)
      *****
      SEE COMMENT ON CONSTANTS BELOW
      *****
      P=1.0/(3.937*6.0)
      Q=1.0/(3.937*5.0)
      *****
      FOR POINTS ON THE CIRCUMFERENCE OF THE PRIMITIVE CIRCLE,
      (MP/2)**2+(NQ/2)**2 = 1, BY THE THEOREM OF PYTHAGORAS.
      *****
      DO 6 M=1,48
      R=M
      R=ABS(R-24.0)
      DO 2 N=1,40
      IROW(M,N)=0
      N2 = SORT((1.05-(R*P)**2)/Q**2) + 0.5
      N3 = 20 -N2
      N2 = 20+N2
      DO 7 N=N1,N3
      IROW(M,N)=-9
      DO 6 N=N2,40
      IROW(M,N) = -9
      *****
      COMPUTE THE NUMBER OF POINTS IN EACH RECTANGLE OF THE STEREOGRAM.
      *****
      DO 3 I=1,KOUNT2
      UP =TZ(I)
      IF(UP) 1,28,28
      TX(I)=-TX(I)
      TY(I)=-TY(I)
      *****
      IN THE NEXT TWO EXPRESSIONS, 3.937 IS THE RADIUS OF THE NET IN INCHES,
      6.0 IS THE NUMBER OF LINE OF OUTPUT PER INCH, 5.0 IS THE NUMBER OF
      TWO-DIGIT CHARACTERS PER INCH, 0.5 IS A ROUNDING FACTOR.
      *****
      28 M=((TY(I)/(1.0+ABS(TZ(I))))*3.937*(-6.0))+1.0+3.937*6.
      N=((TX(I)/(1.0+ABS(TZ(I))))*3.937*(-5.0))+1.0+3.937*5.
      *****
      DOUBLE THE DISPERSION

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```

C *****
C IF(M,GE,25) GO TO 31
M=2*M-24
IF(N,LE,20) N=2*N-20
IF(N,GE,21) N=2*N-21
GO TO 32
31 M=2*M-25
IF(N,LE,20) N=2*N-20
IF(N,GE,21) N=2*N-21
32 IF(M,LE,1) M=1
IF(M,GE,48) M=48
IF(N,LE,1) N=1
IF(N,GE,40) N=40
3 IROW(M,N)=IROW(M,N)+1
C *****
C CONVERT THE NUMBER OF POINTS/RECTANGLE TO PERCENT
C *****
DO 33 M=1,48
DO 33 N=1,40
33 IROW(M,N)=100.*FLOAT(IROW(M,N))/FLOAT(KOUNT2))+0.5
C *****
C PRINT THE RESULTS
C *****
DO 4 M=1,24
4 WRITE(6,100) (IROW(M,N),N=1,20),(IROW(M,N),N=21,40)
WRITE(6,104)
DO 5 M=25,48
5 WRITE(6,100) (IROW(M,N),N=1,20),(IROW(M,N),N=21,40)
WRITE(6,106)
WRITE(6,109) PROB,ITYPE
WRITE(6,101) KOUNT2
WRITE(6,103)
WRITE(6,108)
WRITE(6,107)
C *****
100 FORMAT(1H,20X,20I2,1H,20I2)
101 FORMAT(1H,14,13H MEASUREMENTS )
103 FORMAT(1H,11H HISTOGRAM SHOWING DISTRIBUTION OF POINTS, IN PERCE
INT PROJECTED ON LOWER HEMISPHERE OF 20-CENTIMETER WULF NET )
104 FORMAT (19X,85H WEST .....(3).....
1.....EAST(2) )
105 FORMAT (1H1,57X,5H NORTH )
106 FORMAT(56X,5H SOUTH(1) )
107 FORMAT(1H,138X,45H -- )
108 FORMAT(1H,99H DISTRIBUTION HAS BEEN EXAGGERATED BY DOUBLING EAST-W
EST AND NORTH-SOUTH DISTANCES FROM THE CENTER. )
109 FORMAT(1H,11H SUBAREA IS ,12A6,17H TRIANGLE TYPE = ,1I)
RETURN
END
$IRFC HIST
SUBROUTINE HISTO(N,XMAX,XMIN,X,PROB,KK,ITYPE)
C *****
C THIS SUBROUTINE PLOTS HISTOGRAMS. EACH HISTOGRAM HAS 40 INTERVALS
C AND THE HIGHEST CLASS IS SET EQUAL TO 100 ARBITRARY UNITS
C *****
DIMENSION K(40),X(N),IHIST(2),PROB(12)
DATA STAR/1H*/,(IHIST(KK),KK=1,2)/6H DIP ,6H STRIKE/
C *****
C CALCULATE SIZE OF INTERVALS, SET NUMBER OF OBSERVATIONS PER INTERVAL TO 0
C *****
XTEPVL=(XMAX+1.-XMIN)/40.
DO 20 I=1,40
K(I)=0
20 *****
C *****
C PLACE EACH OBSERVATION IN APPROPRIATE INTERVAL
C *****
DO 60 I=1,N
M=((X(I)-XMIN)/XTEPVL)+1.0
K(M)=K(M)+1
60 *****
C *****
C FIND HEIGHT OF MAXIMUM INTERVAL = KMAX
C *****
SET KMAX = 100 STARS, AND CALCULATE NUMBER OF OBSERVATIONS/STAR.
C *****
KMAX=K(1)
DO 70 I=1,40
IF(K(I).GT,KMAX) KMAX=K(I)
70 FACK=100./FLOAT(KMAX)

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```

80      DO 80 M=1,40
        K(M)=FACK*FLOAT(K(M))+0.5
        FACK=1.0/FACK
C      *****
C      PRINT TITLES
C      *****
        WRITE(6,110) 1HIST(KK),PROB
110     FORMAT(1H1,13HHISTOGRAM OF ,A6,20H VALUES FOR SUBAREA ,12A6)
        WRITE(6,130) I,TYPE
130     FORMAT(1H0,19HTYPE OF TRIANGLE = ,11)
        WRITE(6,100) FACK
100     FORMAT(1H0,19HEACH * REPRESENTS ,F10.3,14H OBSERVATIONS,////)
C      *****
C      PRINT OUT HISTOGRAM
C      *****
        XREGN=XMIN
        DO 90 I=1,40
          XEND=XREGN+XTERVL
          NN=K(I)
          WRITE(6,120) XREGN,XEND,(STAR,J=1,NN)
120     FORMAT(1H9,F12.6,1X,1H-,1X,F12.6,3X,100A1)
          XREGN= XEND
          RETURN
        END
90
SDATA
20 20 A PROGRAM TO ANALYSE TERRAIN ROUGHNESS
1 1 113
(25F4.1)
WREDSPOOT 1. DRUMLIN FIELD NEW YORK STATE
460 480 497 448 436 472 437 440 446 496 524 500 520 532 468 476 469 490 522 490
460 474 515 456 457 450 437 465 455 482 515 531 520 571 494 490 458 550 500 420
450 488 540 460 468 525 435 500 485 450 479 514 582 594 569 474 458 535 473 466
481 458 515 463 471 551 439 490 510 472 475 464 574 557 526 452 458 485 448 447
483 450 494 458 468 470 441 458 501 475 460 440 465 510 486 445 480 464 445 447
469 476 438 475 439 439 437 438 452 462 441 438 457 467 460 441 450 490 445 444
484 476 448 470 479 438 435 435 477 435 447 450 461 445 451 438 440 481 444 444
541 478 444 449 501 439 452 478 477 478 460 462 473 460 476 436 477 451 445 445
470 476 477 517 470 462 510 511 460 494 463 479 503 452 476 478 449 450 449 449
444 470 439 542 444 455 526 505 499 512 462 464 472 435 472 443 464 501 458 462
419 440 429 517 450 450 495 523 475 482 458 450 442 446 454 457 489 563 473 501
416 423 426 503 447 452 449 481 455 445 435 432 428 461 457 492 465 540 503 502
462 415 427 429 429 449 515 465 449 473 455 428 428 440 497 524 478 515 530 490
525 418 439 442 420 446 463 479 483 562 510 450 428 444 540 513 475 467 532 466
509 419 444 432 510 439 570 520 495 582 530 471 432 429 529 419 501 462 465 459
455 417 435 422 510 470 550 549 499 527 491 483 471 426 476 505 480 444 448 450
412 431 445 425 482 474 488 513 492 471 444 444 448 444 479 492 449 445 437 453
423 441 500 420 440 464 442 435 462 422 418 415 453 482 425 462 437 437 454 471
421 465 463 425 465 474 429 435 478 418 417 417 456 511 439 438 431 446 479 484
421 435 419 419 481 479 432 433 420 418 427 417 438 505 460 418 446 466 495 483

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COMPUTATIONS BY PROGRAM VECTOR

A PROGRAM TO ANALYZE TRIANGLE HEIGHTNESS

VALUES READ IN

NO OF RUNS= 20 NO OF COLS= 20 XSTEP= 500.00 YSTEP= 500.00 Y-AXIS DIRECTION= 0.

DATA FORMAT=(20F4.1)

COMPUTATION RESULTS FOR SUBAREA WEEDSPUNT 1. DRUMLIN FIELD NEW YORK STATE

ORIGINAL ELEVATION DATA

480.	440.	447.	444.	435.	432.	437.	460.	445.	496.	524.	508.
520.	536.	485.	476.	459.	486.	522.	490.				
460.	474.	513.	446.	457.	450.	437.	465.	455.	489.	515.	531.
520.	571.	494.	480.	458.	550.	500.	490.				
450.	444.	540.	440.	408.	525.	435.	500.	485.	460.	478.	514.
502.	506.	509.	474.	458.	530.	473.	466.				
481.	454.	515.	463.	471.	551.	439.	490.	510.	472.	475.	464.
574.	557.	526.	452.	458.	485.	446.	447.				
483.	430.	494.	458.	468.	470.	441.	458.	501.	475.	460.	440.
465.	510.	445.	465.	440.	464.	445.	447.				
469.	476.	434.	475.	439.	437.	438.	452.	462.	441.	438.	
457.	467.	480.	441.	450.	490.	445.	444.				
484.	474.	444.	470.	474.	438.	435.	435.	437.	435.	447.	450.
401.	445.	421.	436.	440.	461.	444.	444.				
541.	474.	444.	444.	501.	434.	452.	438.	437.	438.	460.	462.
474.	460.	430.	476.	437.	451.	445.	445.				
470.	476.	477.	517.	470.	462.	519.	511.	460.	494.	463.	470.
503.	472.	436.	444.	444.	450.	448.	448.				
444.	470.	437.	467.	444.	455.	536.	595.	489.	512.	462.	484.
472.	434.	434.	463.	444.	501.	458.	463.				
414.	440.	424.	517.	450.	450.	445.	523.	475.	482.	458.	458.
442.	446.	454.	447.	444.	563.	473.	501.				
416.	423.	420.	403.	447.	452.	449.	481.	455.	445.	435.	432.
424.	401.	457.	442.	465.	540.	503.	503.				
462.	415.	427.	474.	424.	444.	515.	465.	449.	473.	455.	428.
426.	460.	433.	544.	474.	515.	530.	490.				
525.	414.	431.	462.	420.	444.	463.	479.	483.	562.	510.	450.
424.	444.	540.	514.	475.	467.	532.	466.				
504.	414.	447.	432.	510.	434.	570.	520.	485.	552.	530.	471.
432.	444.	524.	440.	501.	452.	465.	458.				
455.	417.	434.	424.	510.	470.	550.	549.	499.	527.	491.	463.
431.	426.	476.	504.	480.	444.	440.	450.				
412.	411.	445.	425.	443.	476.	486.	513.	492.	471.	444.	444.
446.	444.	434.	462.	444.	445.	437.	453.				
423.	441.	503.	424.	440.	444.	443.	445.	462.	422.	418.	418.
451.	404.	420.	462.	437.	437.	454.	471.				
421.	455.	403.	474.	405.	474.	424.	435.	438.	418.	417.	417.
456.	511.	434.	436.	431.	440.	479.	484.				
421.	415.	414.	414.	401.	474.	432.	433.	420.	418.	427.	417.
434.	504.	450.	414.	446.	460.	495.	493.				

STATISTICAL MEASURES OF ELEVATION DATA

MEAN= 467.4225 VARIANCE= 1251.1000 STANDARD DEVIATION= 35.3709 MAXIMUM= 595.0000 MINIMUM= 412.0000

THE PROGRAM IS NOW KILLING TYPE 2 TRIANGLES.

STATISTICAL MEASURES OF STRIKES OF TRIANGLES

MEAN= 4.0002 VARIANCE= 7311.6497 STANDARD DEVIATION= 85.0780 MAXIMUM= 90.0001 MINIMUM= 46.9768

STATISTICAL MEASURES OF HITS OF TRIANGLES

MEAN= 4.4722 VARIANCE= 9.4079 STANDARD DEVIATION= 3.1318 MAXIMUM= 17.2086 MINIMUM= 4.0

MEASURES OF VECTOR STRENGTH ARE $R = .718, 7472$, $R = 0.995495$, WHERE $R = 1/\text{NUMBER OF TRIANGLES}$.
 VECTOR DISPERSION MEASURED BY FISHER'S DISPERSION FACTOR IS 221.0542 , LOW VALUES INDICATE VARIABLE TERRAIN.
 THE VARIABILITY FACTOR, $V = \text{ELEVATION RANGE}/(\text{LOG ESTK}) + 15$, 79.016
 THE DIRECTION COSINES OF THE MEAN VECTOR ARE $\text{ALPHA} = -0.00052$ $\text{BETA} = 0.00018$ $\text{GAMMA} = 1.00000$
 THE ORIENTATION OF THE MEAN PLANE IS AS FOLLOWS--- $\text{STRIKE} = 18.6209$, $\text{DIP} = 0.0313$

HISTOGRAM OF DIP VALUES FOR SUBAREA WEEDSPRINT 1, DRUMLIN FIELD NEW YORK STATE

TYPE OF TRIANGLE = 2

EACH * REPRESENTS 0.570 OBSERVATIONS.

0	0.45521*	*****
0.455214	0.910428	*****
0.910428	1.365642	*****
1.365642	1.820857	*****
1.820857	2.276071	*****
2.276071	2.731285	*****
2.731285	3.186499	*****
3.186499	3.641713	*****
3.641713	4.096927	*****
4.096927	4.552141	*****
4.552141	5.007355	*****
5.007355	5.462569	*****
5.462569	5.917783	*****
5.917783	6.372997	*****
6.372997	6.828212	*****
6.828212	7.283426	*****
7.283426	7.738640	*****
7.738640	8.193854	*****
8.193854	8.649068	*****
8.649068	9.104282	*****
9.104282	9.559496	*****
9.559496	10.014710	*****
10.014710	10.469924	*****
10.469924	10.925138	*****
10.925138	11.380352	*****
11.380352	11.835566	*****
11.835566	12.290780	*****
12.290780	12.745994	*****
12.745994	13.201208	*****
13.201208	13.656422	*****
13.656422	14.111636	*****
14.111636	14.566850	*****
14.566850	15.022064	*****
15.022064	15.477278	*****
15.477278	15.932492	*****
15.932492	16.387706	*****
16.387706	16.842920	*****
16.842920	17.298134	*****
17.298134	17.753348	*****
17.753348	18.208562	*****

SUBAREA 15 WEEDSPRINT 1, DRUMLIN FIELD NEW YORK STATE

TRIANGLE TYPE = 2

722 MEASUREMENTS

STEREODIAGRAM SHOWING DISTRIBUTION OF POINTS, IN PERCENT, PROJECTED ON LOWER HEMISPHERE OF 20-CENTIMETER WULFF NET

DISTRIBUTION HAS BEEN ENLARGED BY DRUMLIN EAST-WEST AND NORTH-SOUTH DISTANCES FROM THE CENTER.

APPENDIX C
Computer Program GCON

FIRST
DATA
DECK

SPECIAL CARD

(REQUIRED ONLY IF TOUR = 1 OR 2).

GRIDDED ELEVATION
DATA

FORMAT CARD

FMT (COLS 1 - 72)

TITLE CARD

TITL (COLS 1-72)

MASTER CONTROL CARD

ROWS, COLS, CON, TOUR, LINES, LIST, INCHES, IHYP SO

\$ DATA

PROGRAM GCON
SOURCE DECK

\$ID

FIG. C-1 PROGRAM GCON - TYPICAL PROGRAM SETUP

```

5 ID 3402*2*10**TURNER* PRINTER/HYPSOMETRIC
6 EXECUTE 13JOB
7 JOB ZERO
8 IFTC MAIN

```

```

PROGRAM GCON--FORTRAN IV VERSION. (TRANSLATED FROM THE MAP LANGUAGE AT PURDUE
UNIVERSITY.) THE PROGRAM PRODUCES CONTOUR MAPS OF GRIDDED DATA ON THE LINE
PRINTER. LINEAR INTERPOLATION OCCURS WITHIN THE GRID SQUARES.

```

```

THE MAXIMUM MAP WIDTH IS 12.7 INCHES, THE WIDTH OF THE PAPER. THE MAXIMUM NUM-
BER OF COLUMNS OF INPUT DATA IS A FUNCTION OF THE SPECIFIED MAP WIDTH.
IF PS=(COL-COLS)/(COLS-1) (SEE DEFINITIONS BELOW) IS LESS THAN 2, FEWER
THAN 2 PRINTING POSITIONS WOULD BE ASSIGNED TO EACH COLUMN SPACE AND SO AN
UNSATISFACTORY MAP WOULD RESULT. THUS THE PROGRAM WILL NOT PLOT A MAP IF PS IS
LESS THAN 2, AND ACCORDINGLY THE MAXIMUM NUMBER OF COLUMNS FOR A MAP OF
MAXIMUM WIDTH IS 42. IF MORE COLUMNS ARE REQUIRED THE MAP MUST BE MADE IN
SECTIONS BY USING ONLY PART OF THE DATA IN EACH PASS. THE NUMBER OF COLUMNS
SHOULD BE THE SAME IN EACH PASS FOR THE MAPS TO BE AT THE SAME SCALE. TO DO
THIS IT MAY BE NECESSARY, AND IS ADVISABLE, TO REPEAT SOME COLUMNS.

```

```

CARD ORDER IS -----

```

```

A) CARDS WHICH APPEAR ONLY ONCE --
1) $DATA

```

```

B) CARDS WHICH ARE REQUIRED FOR EACH DATA SET --

```

```

1) MASTER CONTROL CARD (ROWS,COLS,CON,TOUR,LINES,LIST,INCHES, IHYPSO)
THIS CARD SERVES TO SPECIFY THE TYPE OF MAP AND ASSOCIATED OUTPUT
REQUIRED FOR THIS DATA SET.

```

```

ROWS=(COLS 1-2), IS THE NUMBER OF ROWS.

```

```

COLS=(COLS 3-4), IS THE NUMBER OF COLUMNS.

```

```

CON=(COLS 5-6), IS THE NUMBER OF CONTOUR INTERVALS, MAXIMUM NUMBER=19,
(CON=DATA RANGE DIVIDED BY DESIRED CONTOUR INTERVAL)

```

```

TOUR=(COL 7), IF TOUR=0, PROGRAM USES MAX AND MIN FROM DATA FOR UPPER
AND LOWER LIMITS OF CONTOURS.

```

```

IF TOUR=1, DESIRED TOP AND BOTTOM CONTOURS READ IN FROM
SPECIAL PROGRAM CARD (SEE BELOW).

```

```

IF TOUR=2, VARIABLE CONTOURS READ IN (LOW TO HIGH).
IN THIS CASE SET CON EQUAL TO THE NUMBER OF VALUES TO
BE READ IN.

```

```

IF TOUR=3, CONTOUR INTERVAL RECORDS 1/2 STANDARD DEVIATION
UNITS. (MAX=+3 SIGMA, MIN=-3 SIGMA)

```

```

LINES=(COL 8), IF LINES=0, CONTOUR LINES ARE PRINTED.

```

```

IF LINES=1, ALTERNATE (EVEN VALUED) CONTOUR BANDS PRINTED.
IF LINES=2, COMPLETE BANDS ARE PRINTED (ALL PRINT POSNS.)

```

```

LIST=(COL 9), IF LIST=1, INPUT DATA IS LISTED.

```

```

IF LIST=0 OR BLANK, NO LIST PRODUCED.

```

```

INCHES=(COLS 10-13), INCHES IS MAP WIDTH IN INCHES. IF GREATER THAN 12.7
OR BLANK, THE PROGRAM USES 10.

```

```

COL=MAP WIDTH IN CHARACTERS=INCHES* 10.0
COL=MAX(1, HYPSO=1, HYPSOMETRIC ANALYSIS PERFORMED ON DATA.

```

```

2) TITLE CARD-(TITL) COLS 1-72

```

```

A TITLE WHICH WILL SERVE TO IDENTIFY THE DATA SET.

```

```

3) FORMAT CARD-(FORM) COLS 1-72

```

```

THIS CARD SPECIFIES THE FORMAT OF THE GRIDDED DATA.

```

```

4) GRIDDED ELEVATION DATA

```

```

5) SPECIAL CARD(S) (REQUIRED ONLY WHEN TOUR=1 OR 2)

```

```

IF TOUR=1, THIS CARD SPECIFIES MINIMUM AND MAXIMUM ELEVATION VALUES.

```

```

ZMIN (COLS 1-10), ZMAX (COLS 11-20),

```

```

IF TOUR=2, THIS CARD SPECIFIES A FORMAT (INCON) TO BE USED IN READING IN
A SERIES OF IRREGULARLY SPACED CONTOUR LINES. THE VALUES ARE ARRANGED
FROM LOWEST TO HIGHEST ON SUBSEQUENT CARDS. CON= NUMBER OF LINES.

```

```

*****
PURDUE UNIVERSITY VERSION / A. KEITH TURNER
JUNE 1967

```

```

*****
DIMENSION FORM(10), TITL(12), SYMTAB(21), PSYM(131), 7(100,100),
1 INCON(10), DRANG(25), TABE(25), ZPREV(131), SYM(131)
DIMENSION CUMH(27)
INTEGER ROWS,COLS,CON,TOUR,COLMAX,COL,PSYM,PS,GRID,TCUT,TLOW,
1 SYM,PLANK,PLUS,MINUS,STAR,SYMTAB
REAL MINZ,MAXZ,INCHES,INCON
DATA (SYMTAB(1),1=1,21)/1H0,1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,

```

```

1 1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,1HI,1HJ,1HK/,BLANK/1H /,PLUS/1H+/
2 /MINUS/1H-/ ,STAR/1H*/
C *****
C READ CONTROL AND TITLE CARDS
C *****
1 READ(5,1000) ROWS, COLS, CON, TOUR, LINES, LIST, INCHES, IHPRO
1000 FORMAT(3I2,3I1,F4.0,IX,I1)
1 READ(5,1010) TITLE
1010 FORMAT(12A6)
C *****
C ZERO COUNTERS AND ARRAYS USED IN FREQUENCY TABLE
C *****
      JU=0
      MV=0
      SUM=0.0
      TLOW=0
      TOUT=0
      DO 5 I=1,25
        TARE(I)=0.0
        N=ROWS*COLS
5 *****
C N = NUMBER OF DATA POINTS
C READ DATA FORMAT CARD AND DATA
C *****
1020 READ(5,1020) FORM
      FORMAT(10A6)
      DO 7 J=1,ROWS
7 READ(5,FORM) (Z(I,J),J=1, COLS)
C *****
C IF LIST =1 LIST INPUT DATA, OTHERWISE GO TO 20
C *****
      IF (LIST.NE.1) GO TO 20
1030 WRITE(6,1030) TITL
      FORMAT(1H/,12A6//)
      WRITE(6,1025)
1025 FORMAT(1H0,25X,22HLISTING OF INPUT DATA. )
      DO 10 J=1, ROWS
10 WRITE(6,1040) (7(I,J),J=1, COLS)
1040 FORMAT(1H0,10F10.3,(1X,10F10.0))
20 WRITE(6,1030) TITL
1050 WRITE(6,1050) N
      FORMAT(1H ,14,13H OBSERVATIONS //)
      CALL STATS(ROWS, COLS, 100, 100, Z, ZBAR, XP, ZSIG, MAXZ, MINZ)
C *****
C DETERMINE CONTOUR LINE ELEVATIONS
C TOUR VALUE DETERMINES METHOD USED IN DEFINING CONTOURS
C *****
      IF (TOUR .GT. 3 .OR. TOUR .LE. 0) GO TO 60
30 GO TO (30,40,50), TOUR
      WRITE(6,1060)
1060 FORMAT(25H CONTOUR LEVELS SPECIFIED)
1070 READ(5,1070) ZMIN, ZMAX
      FORMAT(2F10.0)
      GO TO 70
40 READ(5,1020) INCON
      WRITE(6,1080)
1080 FORMAT(37H VARIABLE CONTOUR INTERVALS SPECIFIED)
      READ(5, INCON) (DRANG(I), I=1, CON)
      ZMIN=DRANG(1)
      ZMAX=DRANG(CON)
      GO TO 70
50 ZMIN=ZBAR-3.0*ZSIG
      ZMAX=ZBAR+3.0*ZSIG
      CON=13
      WRITE(6,1090)
1090 FORMAT(30H CONTOUR INTERVAL = U1/2 SIGMA)
      GO TO 70
60 WRITE(6,1100)
1100 FORMAT(26H CONTOUR LEVELS CALCULATED)
      ZMIN=MINZ
      ZMAX=MAXZ
      WRITE(6,1110) FORM, ROWS, COLS, ZBAR, ZSIG, MAXZ, MINZ
1110 FORMAT(13H GRIDDED DATA/, 42H LINEAR INTERPOLATION WITHIN GRID SQU
      IARES /, 17H OBSERVED VALUES /, 1H 10A6/, 8H ROWS = ,13,10H COLS = ,
      213/, 8H ZBAR = ,F10.3,10H ZSIG = ,F10.3,10H MAXZ = ,F10.3,10H
      3 MINZ = ,F10.3)
C *****
C CALCULATE MAP WIDTH IN CHARACTERS (COL)
C *****

```

```

      IF (INCHES.LE.0.0) COL=100
      IF (INCHES.GT.12.7) COL=127
      IF (INCHES.GT.0.0.AND.INCHES.LE.12.7) COL=INCHES*10.0
      PS=(COL-COLS)/(COLS-1)
      *****
      TEST GRID SIZE- IF GRID SMALLER THAN 2 CHARACTERS BETWEEN COLUMNS,
      AN ERROR STATEMENT IS PRINTED AND PLOT ABORTED
      *****
      IF (PS.GT.1) GO TO 8
      WRITE (6,1120)
1120  FORMAT (25H TOO MANY COLUMNS IN GRID)
      GO TO 1
      *****
      CALCULATE AND WRITE OUT REQUIRED CONSTANTS
      *****
      COLMAX=PS*(COLS-1)+COLS
      YINC=1.07/((FLOAT(PS+1))*0.6)
      GRID=PS+1
      XINC=1.0/FLOAT(GRID)
      WRITE (6,1130)
1130  FORMAT (1H 7,16H VALUES EMPLOYED)
      IF (CON.EQ.0.OR.CON.GT.19) CON=6
      RANGZ=7*MAX-ZMIN
      FCON=CON
      CI=RANGZ/FCON
      WRITE (6,1140) ZMIN,ZMAX,CI,GRID,XINC,YINC,CON,PS,COLMAX
      FORMAT (8H ZMIN = ,F10.3,10H ZMAX = ,F10.3,8H CI = ,F10.3/,8H
1140  1GRID = ,15.10H XINC = ,F10.3,10H YINC = ,F10.3/,17H CON = 15,
      2 8H PS = ,15.12H COLMAX = ,15)
      IF (TOUR.EQ.2) GO TO 100
      JJJ=CON+1
      DO 90 I=1,JJJ
90     DRANG(I)=ZMIN+FLOAT(I-1)*CI
100    RANG2=2.0*RANGZ
      RLOW=ZMAX-RANG2
      RHIGH=ZMIN+RANG2
      *****
      WRITE OUT CONTOUR SYMBOL TABLE
      *****
      WRITE (6,1150)
1150  FORMAT (15H CONTOUR SYMBOL TABLE IS AS FOLLOWS)
      IF (LINES.EQ.1) WRITE (6,1160)
1160  FORMAT (43H (ONLY EVEN SYMBOLS PRINTED IN BODY OF MAP) )
      WRITE (6,1170)
1170  FORMAT (7H SYMBOL,11X,5HVALUE)
      IF (LINES.NE.0) GO TO 110
      WRITE (6,1180)
1180  FORMAT (5H0 ,*,6X,7HNO DATA,/,5H -,4X,10HBELOW LOW)
      WRITE (6,1190) (SYMTAB(I),DRANG(I),I=1,CON)
1190  FORMAT (4X,A1,2X,F12.4)
      WRITE (6,1200)
1200  FORMAT (4X,1H+,4X,10HASOVE HIGH)
      GO TO 120
110  WRITE (6,1210)
1210  FORMAT (5H0 ,*,25X,7HNO DATA,/,5H -,12X,10HBELOW LOW)
      WRITE (6,1220) (SYMTAB(I),DRANG(I),DRANG(I+1),I=1,CON)
1220  FORMAT (4X,A1,2X,F12.4,6H TO ,F12.4)
      WRITE (6,1230) DRANG(CON+1)
1230  FORMAT (4X,1H+,2X,F12.4,10H OR OVER)
120  WRITE (6,1030) TITL
      VAL=1.0-YINC
      GRID=COLS-1
      COL=3
      N=PS+1
      DO 140 J=1,GRID
      DO 130 I=2,N
130    SYM(COL)=BLANK
      COL=COL+1
      SYM(COL)=PLUS
140    COL=COL+1
      N=COLMAX+2
      SYM(2)=PLUS
      SYM(1)=BLANK
      SYM(N)=BLANK
      XSTOP=1.0-XINC
      IF (LINES.EQ.2) LIST=1
      YSTOP=1.0-YINC
      WRITE (6,1240) (SYM(I),I=1,N)
1240  FORMAT (1H0,129A1)

```



```

C *****
C ESTIMATE VALUE OF ALL PRINTING POSITIONS ON MAP
C *****
C LOOP THROUGH MAP LENGTH, ROW BY ROW
C *****
145 DO 340 MM=2,ROWS
150   MM=MM-1
      IF (MM.GE.ROWS) YSTOP=1.0
      YP=0.0
      COL=1
      K=1
      IF (YP.NE.0.0) GO TO 160
      PSYM(1)=PLUS
      PSYM(N)=PLUS
      GO TO 170
160   PSYM(1)=BLANK
      PSYM(N)=BLANK
170   IF ((M.EQ.1).AND.(YP.FQ.0.0)) GO TO 180
      IF ((MM.GE.ROWS).AND.(YP.GT.VAL1)) GO TO 180
      INDEX=0
      GO TO 190
180   INDEX=1
      PSYM(1)=PLUS
      PSYM(N)=PLUS
C *****
C LOOP THROUGH MAP WIDTH, COLUMN BY COLUMN
C *****
190   II=COL-1
      DO 330 J=1,II
      JJ=J+1
      IF (JJ.GE.COLS) XSTOP=1.0
      IF (J.LE.1) Z1=Z2
      IF (J.LE.1) Z1=YP*(Z(MM,J)-Z(M,J))+Z(M,J)
      Z2=YP*(Z(MM,JJ)-Z(M,JJ))+Z(M,JJ)
      ZDELTA=Z2-Z1
      XP=0.0
195   COL=COL+1
C *****
C CHECK FOR EDGE OF MAP
C *****
      IF (LINES.EQ.2) GO TO 200
      LIST=1
      IF (COL.NE.2.AND.COL.LE.COLMAX.AND.INDEX.NE.1) LIST=0
200   ZEST=XP*ZDELTA+Z1
      IF (COL.GT.2) K=0
C *****
C ELIMINATE OUT OF RANGE VALUES
C *****
      IF (ZEST.LT. RHIGH .AND. ZEST .GT. RLOW) GO TO 210
      TOUT=TOUT+1
      IF (LIST.EQ.0) PSYM(COL)=BLANK
      IF (LIST.NE.0) PSYM(COL)=STAR
      GO TO 220
C *****
C ASSIGN ELEVATION ESTIMATE TO APPROPRIATE CONTOUR INTERVAL
C *****
210   SUM=SUM+1.0
      IF (ZEST.GE.ZMIN) GO TO 220
      I=-1
      TLOW=TLOW+1
      GO TO 270
220   IF (ZEST.LE.ZMAX) GO TO 230
      I=CON+1
      TABE(I)=TABE(I)+1.
      GO TO 270
230   IF (TOUR.EQ.2) GO TO 240
      I=((ZEST-ZMIN)/CI)+1.0
      GO TO 265
240   DO 250 I=1,CON
      IF (ZEST.LT.DRANG(I)) GO TO 260
250   CONTINUE
260   CONTINUE
265   TABE(I)=TABE(I)+1.
C *****
C ASSIGN PRINTING CHARACTER TO EACH PRINTING POSITION
C *****
270   IF (LIST.EQ.0) GO TO 280
      IF (I.LT.C) PSYM(COL)=MINUS
      IF (I.GT.CON) PSYM(COL)=PLUS

```

```

      IF (I.GE.0.OR.I.LE.CON) PSYM(COL)=SYMTAB(I)
      GO TO 320
C *****
C PRINT MAP ACCORDING TO LINES SPECIFICATION
C *****
C IF (LINES.EQ.0) GO TO 200
C *****
C PRINT EVEN SYMBOLS
C *****
      K=1/2
      IF ((K*2).NE.1.AND.ZEST.LT.ZMAX) PSYM(COL)=SYMTAB(I)
      IF ((K*2).EQ.1.OR.ZEST.GE.ZMAX) PSYM(COL)=BLANK
      GO TO 320
C *****
C PRINT CONTOUR LINES
C *****
290 IF (K.EQ.0) GO TO 30
      PSYM(COL)=SYMTAB(I)
      GO TO 320
C *****
C WHICH CONTOUR PASSES THROUGH PRINTING AREA
C *****
300 DO 310 I=1,CON
      ZSTEP=DRANG(I)
      SW1=1.
      SW2=1.
      SW3=1.
      SW4=1.
      IF (ZSTEP.GE.ZLAST.OR.ZSTEP.GE.ZPREV(COL)) SW1=0.
      IF (ZSTEP.LE.ZEST) SW2=0.
      IF (ZSTEP.LT.ZLAST.OR.ZSTEP.LT.ZPREV(COL)) SW3=0.
      IF (ZSTEP.GE.ZEST) SW4=0.
      IF (SW1.EQ.0..AND.SW2.EQ.0.)OR.(SW3.EQ.0..AND.SW4.EQ.0.) GO TO 310
      PSYM(COL)=BLANK
      GO TO 320
310 PSYM(COL)=SYMTAB(I)
320 ZLAST=ZEST
      ZPREV(COL)=ZEST
      XP=XP+XINC
      IF (XP.LE.XSTOP) GO TO 195
330 CONTINUE
      WRITE (6,1240) (PSYM(L),L=1,N)
      XSTOP=XSTOP+XINC
      JJ=0
      YP=YP+YINC
      IF (YP.LE.YSTOP) GO TO 150
340 CONTINUE
      WRITE (6,1240) (SYM(L),L=1,N)
C *****
C CALCULATE AND PRINT FREQUENCY TABLE
C *****
      WRITE (6,1250) TOUT
1250 FORMAT (16HIFREQUENCY TABLE,/,12X,8HINTERVAL,16X,5HUNITS,6X,10HP
1ERCENTAGE,14X,10HCUMULATIVE,/,16X,7HNO DATA,11X,18)
      PTAB=(FLOAT(TLOW)/SUM)*100.0
      CTAB=PTAB
      CUMH(1)=CTAB
      WRITE (6,1260) TLOW,PTAB,CTAB
1260 FORMAT (14X,9HBELOW LOW,11X,18,2(3X,F12.4))
      DO 350 I=1,CON
      VALUE=DRANG(I)
      VAL1=DRANG(I+1)
      PTAB=(TABE(I)/SUM)*1.0
      CTAB=CTAB+PTAB
      CUMH(I+1)=CTAB
350 WRITE (6,1270) VALUE,VAL1,TABE(I),PTAB,CTAB
1270 FORMAT (1X,F12.4,6H TO, F12.4,3X,F8.0,2(3X,F12.4))
      I=CON+1
      PTAB=(TARE(I)/SUM)*1.0
      CTAB=PTAB+CTAB
      CUMH(CON+2)=CTAB
      WRITE (6,1280) VAL1,TABE(I),PTAB,CTAB,SUM,CTAB,CTAB
1280 FORMAT (1X,F12.4,10H OR OVER,11X,F8.0,2(3X,F12.4),/,18X,5HTOTAL
1,11X,F8.0,2(3X,F12.4))
C *****
C IF IHYPSO = 1, PERFORM HYPSONETRIC ANALYSIS
C *****
450 IF (IHYPSO) 450,451,450
      CALL HYPSO(DRANG,ZMAX,ZMIN,CON,CUMH,TITL)

```

```

451 GO TO 1
END
SIBFTC STAT
SUBROUTINE STATS(ROWS,COLS,II,JJ,X,XPAR,XVAR,XSIG,XMAX,XMIN)
C*****
C PROGRAM TO FIND STATISTICAL MEASURES
C*****
INTEGER ROWS,COLS
DIMENSION X(II,JJ)
FNO=ROWS*COLS
XSOR=0.0
XSUM=0.0
XMAX=X(1,1)
XMIN=X(1,1)
DO 10 I=1,ROWS
DO 10 J=1,COLS
IF (X(I,J).GT.XMAX) XMAX=X(I,J)
IF (X(I,J).LT.XMIN) XMIN=X(I,J)
XSUM=XSUM+X(I,J)
10 XSOR=XSOR+X(I,J)*X(I,J)
XPAR=XSUM/FNO
XVAR=(XSOR-2.0*XPAR*XSUM+FNO*XPAR*XPAR)/FNO
XSIG=SQRT(XVAR)
RETURN
END
SIBFTC HYP5
SUBROUTINE HYP5O(DRANG,ZMAX,ZMIN,CON,CUMH,TITL)
C*****
C A PROGRAM TO PERFORM HYP5OMETRIC ANALYSIS.
C*****
REFERENCE=
A. N. STRAHLER-1952-HYP5OMETRIC (AREA-ALTITUDE) ANALYSIS
OF EROSIONAL TOPOGRAPHY-GEOL. SOC. AMERICA BULL. VOL.63
PAGES 1117-1142.
C*****
DIMENSION IROW(49,81),RELH(25),RELA(25)
DIMENSION TITL(12),CUMH(27),DRANG(27)
DATA DOT,PLANK,STAR,1H.,1H.,1H*/
REAL IROW
INTEGER CON
C*****
C MAKE PLOT ALL BLANKS,DRAW BORDERS WITH DOTS,AND PLOT A STAR AT TOP
C LEFT AND BOTTOM RIGHT CORNERS
C*****
DO 2 M=1,49
DO 2 N=1,81
IROW(M,N)=PLANK
IROW(1,1)=STAR
2 DO 3 N=2,81
IROW(1,N)=DOT
IROW(49,81)=STAR
3 DO 4 N=1,80
IROW(49,N)=DOT
4 DO 5 M=2,49
IROW(M,1)=DOT
5 IROW(M,81)=DOT
C*****
C DETERMINE POSITIONS OF STARS WITHIN THE PLOT
C*****
K=CON+1
DO 20 I=1,K
RELH(I)=(DRANG(I)-ZMIN)/(ZMAX-ZMIN)
RELA(I)=1.0-((CUMH(I)-CUMH(1))/(CUMH(CON+1)-CUMH(1)))
M=(49.0-(RELH(I)*49.)))+0.5
N=(RELA(I)*81.0)+0.5
20 IROW(M,N)=STAR
C*****
C PRINT OUT ALL THE PLOT SEQUENTIALLY
C*****
WRITE(6,1000) TITL
FORMAT(1H1,22H HYP5OMETRIC CURVE FOR ,12A6)
WRITE(6,1001)
1001 FORMAT(1H ,8HREL. HT./)
WRITE(6,1002)
1002 FORMAT(1H ,8X,3H0.0,37X,3H0.5,37X,3H1.0)
WRITE(6,1003)
1003 FORMAT(1H ,9X,1H+,39X,1H+,39X,1H+)
WRITE(6,1004) (IROW(I,N),N=1,81)
1004 FORMAT(1H ,4X,5H1.0 +,81A1,5H+ 1.0)

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CONTOUR MAP OF DRAINAGE BASIN IN VERDUGO HILLS, STRAHLER FIG 15 .

320 OBSERVATIONS

CONTOUR LEVELS SPECIFIED

GRIDDED DATA

LINEAR INTERPOLATION WITHIN GRID SQUARES

OBSERVED VALUES

(16F4.0)

ROWS = 20 COLS = 16

ZBAR = 6145.009 ZSIG = 4262.532 MAXZ = 9999.000 MINZ = 1080.000

VALUES EMPLOYED

ZMIN = 1080.000 ZMAX = 1880.000 CI = 50.000

GRID = 4 XINC = 0.167 YINC = 0.278

CON = 16 PS = 5 CULMAX = 91

CONTOUR SYMBOL TABLE IS AS FOLLOWS

(ONLY EVEN SYMBOLS PRINTED IN BODY OF MAP)

SYMBOL	VALUE
*	NO DATA
-	BELOW LOW
0	1080.0000 TO 1130.0000
1	1130.0000 TO 1180.0000
2	1180.0000 TO 1230.0000
3	1230.0000 TO 1280.0000
4	1280.0000 TO 1330.0000
5	1330.0000 TO 1380.0000
6	1380.0000 TO 1430.0000
7	1430.0000 TO 1480.0000
8	1480.0000 TO 1530.0000
9	1530.0000 TO 1580.0000
A	1580.0000 TO 1630.0000
B	1630.0000 TO 1680.0000
C	1680.0000 TO 1730.0000
D	1730.0000 TO 1780.0000
E	1780.0000 TO 1830.0000
F	1830.0000 TO 1880.0000
*	1880.0000 OR OVER

FREQUENCY TABLE

INTERVAL	UNITS	PERCENTAGE	CUMULATIVE
NO DATA	3081		
BELOW LOW	0	0.	0.
1080.0000 TO 1130.0000	39.	1.7751	1.7751
1130.0000 TO 1180.0000	98.	4.4606	6.2358
1180.0000 TO 1230.0000	171.	7.7833	14.0191
1230.0000 TO 1280.0000	184.	8.3751	22.3942
1280.0000 TO 1330.0000	223.	10.1502	32.5444
1330.0000 TO 1380.0000	230.	10.4688	43.0132
1380.0000 TO 1430.0000	230.	10.4688	53.4820
1430.0000 TO 1480.0000	213.	9.6950	63.1771
1480.0000 TO 1530.0000	182.	8.2840	71.4611
1530.0000 TO 1580.0000	146.	6.6454	78.1065
1580.0000 TO 1630.0000	136.	6.1903	84.2968
1630.0000 TO 1680.0000	88.	4.0055	88.3022
1680.0000 TO 1730.0000	84.	3.8234	92.1256
1730.0000 TO 1780.0000	67.	3.0496	95.1752
1780.0000 TO 1830.0000	34.	1.5476	96.7228
1830.0000 TO 1880.0000	17.	0.7738	97.4966
1880.0000 OR OVER	55.	2.5034	100.0000
TOTAL	2197.	100.0000	100.0000

CONTOUR MAP OF DRAINAGE BASIN IN VERDUGO HILLS, STRAMLER FIG 15.

HYPSONETRIC CURVE FOR CONTOUR MAP OF DRAINAGE BASIN IN VERDUGO HILLS, STRAMLER FIG 15.

THE HYPSONETRIC INTEGRAL FOR THE ABOVE CURVE (THE AREA BELOW THE CURVE) IS 0.4285