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A METHOD FOR THE PROCESSING AND ANALYSIS OF DIGITAL TERRAIN ELEVATION DATA

By Bobby G. Junkin*

SUMMARY

This report presents a method for the processing and analysis of digital topography data that can subsequently be entered in an interactive data base in the form of slope, slope length, elevation and aspect angle. Included are a discussion of the data source and specific descriptions of the data processing software programs. In addition, the mathematical considerations involved in the registration of raw digitized coordinate points to the UTM coordinate system are presented. Scale factor considerations are also included. Results of the processing and analysis are illustrated using the Shiprock and Gallup Quadrangle test data.

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ABBREVIATIONS

NCIC	National Cartographic Information Center
CCT	Computer Compatible Tapes
DMA	Defense Mapping Agency
DMATC	Defense Mapping Agency Topographic Center
ACS	Arbitrary Coordinate System
UTM	Universal Transverse Mercator
IDDP	Interactive Data Base Display Program
CM	Central Meridian
C.N.	Column Number
R.N.	Row Number
S.L.	Slope Length
RCC	Tape Nomenclature
SW	Southwest Sheet Corner of $1^{o} \times 1^{o}$ Area
SE	Southeast Sheet Corner of $1^{o} \times 1^{o}$ Area
NW	Northwest Sheet Corner of $1^{o} \times 1^{o}$ Area
NE	Northeast Sheet Corner of $1^{o} \times 1^{o}$ Area

INTRODUCTION

Land resource managers are becoming increasingly aware of the problem of converting disparate sources of data in map format into a form suitable for processing on a computer-oriented information system. This information, acquired from map sources or remote sensor data obtained from aircraft and satellites, is compiled into data bases which contain information on land use, topography, soil, rainfall, population density, etc. This report defines the procedures and techniques in use at the NASA/ERL for processing digital topography data that can subsequently be entered in a data base in the form of slope, slope length, elevation and aspect.

DIGITAL TERRAIN ELEVATION DATA

The National Cartographic Information Center (NCIC) of the U. S. Geological Survey, Department of the Interior, provides a national information service to make cartographic data of the United States available to the public and to various federal, state, and local agencies (reference 1). These cartographic data include standard 9-track 800 BPI or 1600 BPI computer-compatible tapes (CCT) which contain digital representations of terrain elevations. These tapes, which are produced by the Defense Mapping Agency Topographic Center (DMATC) from the 1:250,000-scale series of maps, are copied and distributed to users by the NCIC.

The DMATC utilizes a processing system which collects data from a 1:250,000-scale map using digital graphic recorders tied into a central processor with disk storage, magnetic tape output and verification plot capability. The function of this sytem is to generate a magnetic tape file containing a matrix of elevation readings extracted at 250 micrometer intervals. The 1:250,000-scale map generally covers one by two degrees of longitude and latitude. The DMATC prepares two one-degree by one-degree matrices for each quadrangle. Each block of data is stored on a 7-track UNIVAC 1108 computer tape by the DMATC and forwarded to the NCIC. The NCIC subsequently takes these data and stores up to eight one-degree quadrangles of longitude and latitude on each 9-track (1600 BPI) tape (four using 800 BPI tapes). This latter data format is generally used by the ERL as its source of topographic information.

General information concerning the source of data is given in Appendix D.

DATA PROCESSING SOFTWARE DEVELOPMENT

General Program Functions

The NASA/ERL software programs for geographical data analysis and display consist of four separate programs for processing digital terrain data tapes produced by the DMATC. These programs perform the following functions: (1) Transforms data in the local $(\tilde{x},\tilde{y})$ digitizer system to the (X_E, Y_N) UTM system, (2) translates the $1^o \times 1^o$ data set to an input origin, (3) adjusts the input data set to any desired output cell size, (4) computes slope, slope length, and aspect for each cell by use of the maximum gradient from a center cell to the surrounding eight cells, (5) generates output data files (elevation, slope, slope length, and aspect) which are in a form suitable for entering into the ERL Interactive Data Base Display Program (IDDP).

Specific Program Descriptions

The processing of digital terrain tapes requires the execution of four separate programs. These programs are described herein.

Program TOPREF. This program prints out pertinent information for each column of data as written to the reformatted output tape. The starting $\tilde{x}$-$\tilde{y}$ points, ending $\tilde{y}$-point, number of $\tilde{y}$-points, and the first three and last three elevation data values are printed for each $\tilde{x}$-column. Also, the minimum and maximum elevation values are printed. This program reads the NCIC data tapes of 15840-word records (16-bit words) and writes a tape file of 2005-word records in the following format:

word 1 = 0

word 2 = record number

word 3 = $\tilde{x}$ coordinate in .01 inches for this record

word 4 = starting $\tilde{y}$ coordinate in .01 inches

word 5 = N = number of elevation values in this record

words 6 through (6 + N) = elevation values of points

$(\tilde{x},\tilde{y}_1)$ through $(\tilde{x},\tilde{y}_N)$

words (6 + N + 1) through 2005 = zero fill

Program TOPTWO. This program prints out all input control parameters which define the area of interest to process, column and row bias's, etc. Also printed out is a table of computed easting and northing and elevations for the first and last data point for each row. The reformatted tape from TOPREF is read. Card input control parameters are used to extract only that data required for processing the selected area and writes out a file suitable for sorting. Output from this program consists of 7200-word records in 3-word groups of X_E and Y_N coordinate values for each cell and its elevation value.

Program TOPSRT. This program prints out check point row numbers for raw data that are sorted and output in reverse order. The data that are written in TOPTWO are sorted so that all elevation values corresponding to Y_N are written as the first record, those elevation values corresponding to Y_{N+1} as record 2, etc., continuing on until record N = all elevation values corresponding to Y_1. These data are written to an intermediate scratch disk file, and then output to tape.

Program TOPODB. This program prints input control parameters and input levels for elevation and slope. Optionally, a printer map is printed showing coded levels for each data element in row-column format for all four types of output. Output consists of four files of data to disk for input to the IDDP:

1. Elevation data
2. Slope data
3. Aspect data
4. Slope length data

MATHEMATICAL ANALYSIS

UTM Coordinate Equations

Consider the example of a 1:250,000-scale map as shown in figure 1. The UTM (X_E, Y_N) grid system on these type maps is not normally aligned with the $(\tilde{x}, \tilde{y})$ coordinate system of the digitizer system. Thus, an angle correction is required for each $1^o \times 1^o$ area or file of data. The sheet corners indicated by the arrows are translated into the origin of the data file by the following:

$$\left.\begin{aligned} \tilde{x}_i' &= \tilde{x}_i - \tilde{x}_{\theta RI} \\ \tilde{x}_i' &= \tilde{y}_i - \tilde{y}_{\theta RI} \end{aligned}\right\} \qquad I = 1,\ 2 \qquad (1)$$

where:

$(\tilde{x}_i, \tilde{y}_i)$ = plate coordinates of digitizer points, in inches

Figure 1 - Example of USGS 1:250,000 Scale Map

$(\tilde{x}_{\theta R1}, \tilde{y}_{\theta R1})$ = coordinates of SW sheet corner of file 1, in inches

$(\tilde{x}_{\theta R2}, \tilde{y}_{\theta R2})$ = coordinates of SE sheet corner of file 2, in inches

The $(\tilde{x}_i', \tilde{y}_i')$ data are corrected for the Δ angle between the polyconic coordinate system and the UTM coordinate system to yield corrected $(\tilde{x}_i'', \tilde{y}_i'')$ digitizer plate points.

The relationship between the corrected digitizer plate points and the corresponding UTM coordinates are given by the following transformation:

$$X_{Ei} = \tilde{x}_i'' \quad S_{Xi} + X_{\theta RJ} \tag{2}$$

$$Y_{Ni} = \tilde{y}_i'' \quad S_{Yi} + Y_{\theta RJ} \tag{3}$$

where J = 1, 2, and:

$(X_{\theta RJ}, Y_{\theta RJ})$ = UTM coordinates of SW or SE sheet corner

S_{Xi} = X scale factor, file 1 or 2

S_{Yi} = Y scale factor, file 1 or 2

It should be pointed out that the above equations, in effect, register the plate coordinates of the left side $1^o \times 1^o$ area of a quad map to the SE sheet corner and the subsequent UTM coordinates are merely determined with respect to the $(X_{\theta R2}, Y_{\theta R2})$ origin of the SE sheet corner.

Derivation of Equations for Data Registration

The $(\tilde{x},\tilde{y})$ digitizer plate coordinate points are registered to the UTM coordinate system through the utilization of the Δ angle between the polyconic coordinate system and the UTM coordinate system. Consider first the geometry in figures 2 and 3. These figures depect the location situations that are

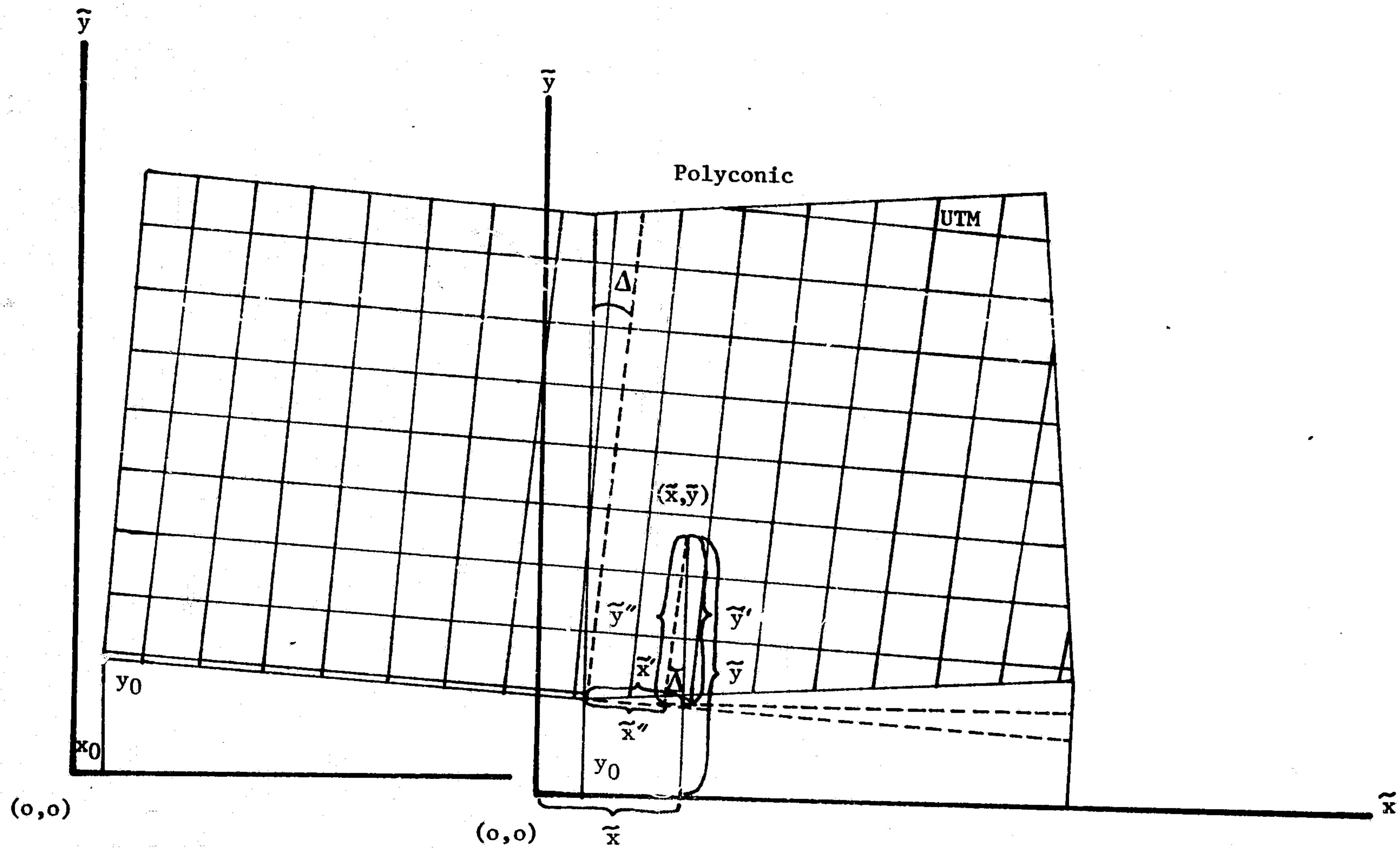


Figure 2. East of Zone CM

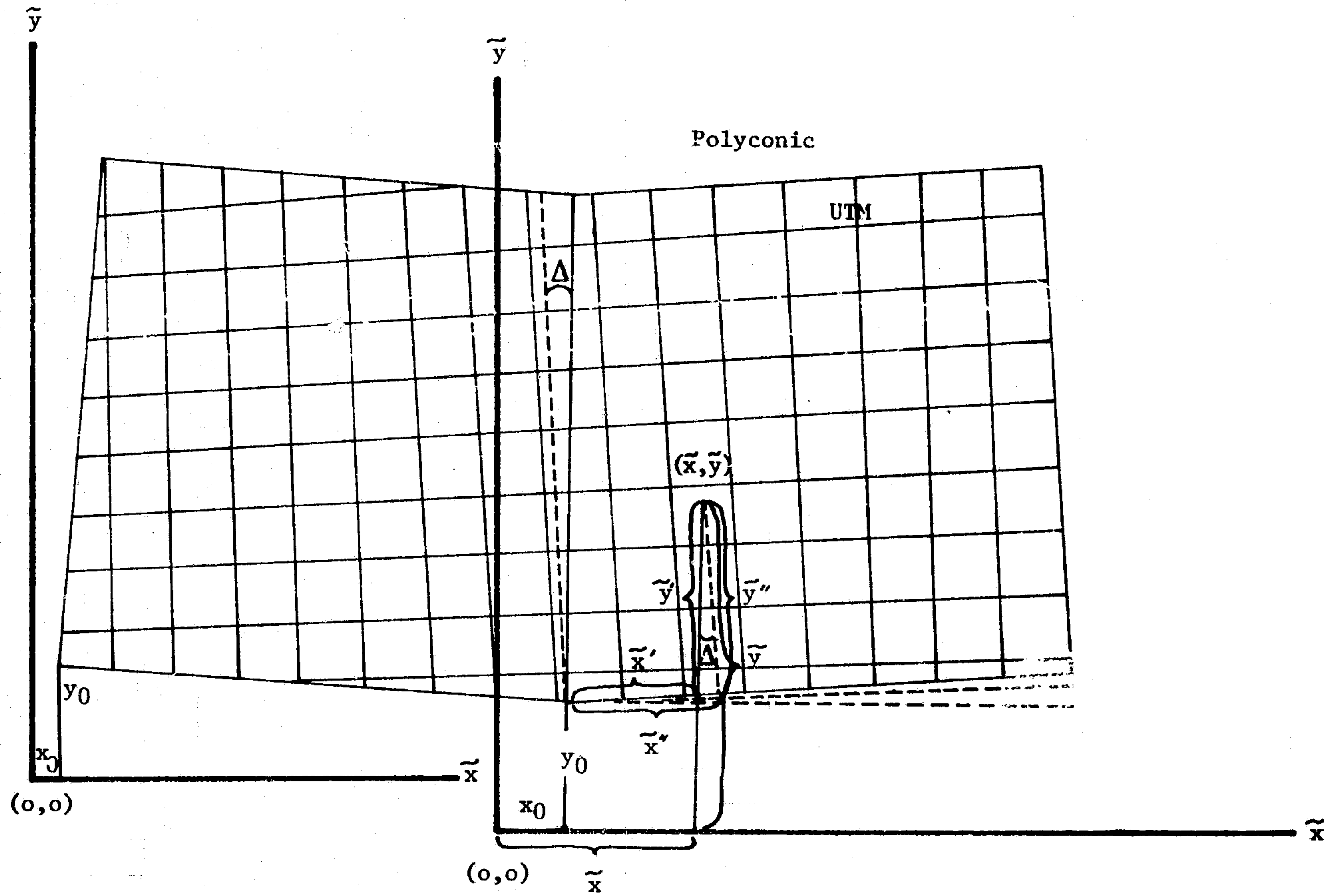


Figure 3. West of Zone CM

possible regarding a quad sheet relative to the central meridian of a zone. Figures 4, 5, 6, and 7 show the geometry between the $(\tilde{x},\tilde{y})$ coordinate system and the UTM coordinate system.

We first consider the geometry in figure 4 as relates to the right side of a quad located east of the zone CM. From this figure:

$$\tilde{y}'' = a_1 + b_1 \tag{4}$$

and:

$$\tilde{x}'' = a_4 \cos\Delta \tag{5}$$

$$a_1 = a_4 \sin\Delta \tag{6}$$

from $\overline{\Delta T_1}$:

$$\tilde{y}' = b_1 \cos\Delta \tag{7}$$

$$b_3 = b_1 \sin\Delta \tag{8}$$

solving (7) for b_1:

$$b_1 = \tilde{y}'/\cos\Delta \tag{9}$$

substituting (9) in (8):

$$b_3 = \frac{\tilde{y}' \sin\Delta}{\cos\Delta} \tag{10}$$

also:

$$a_4 = \tilde{x}' - b_3 \tag{11}$$

substituting (10) in (11):

$$a_4 = \tilde{x}' - \frac{\tilde{y}' \sin\Delta}{\cos\Delta} \tag{12}$$

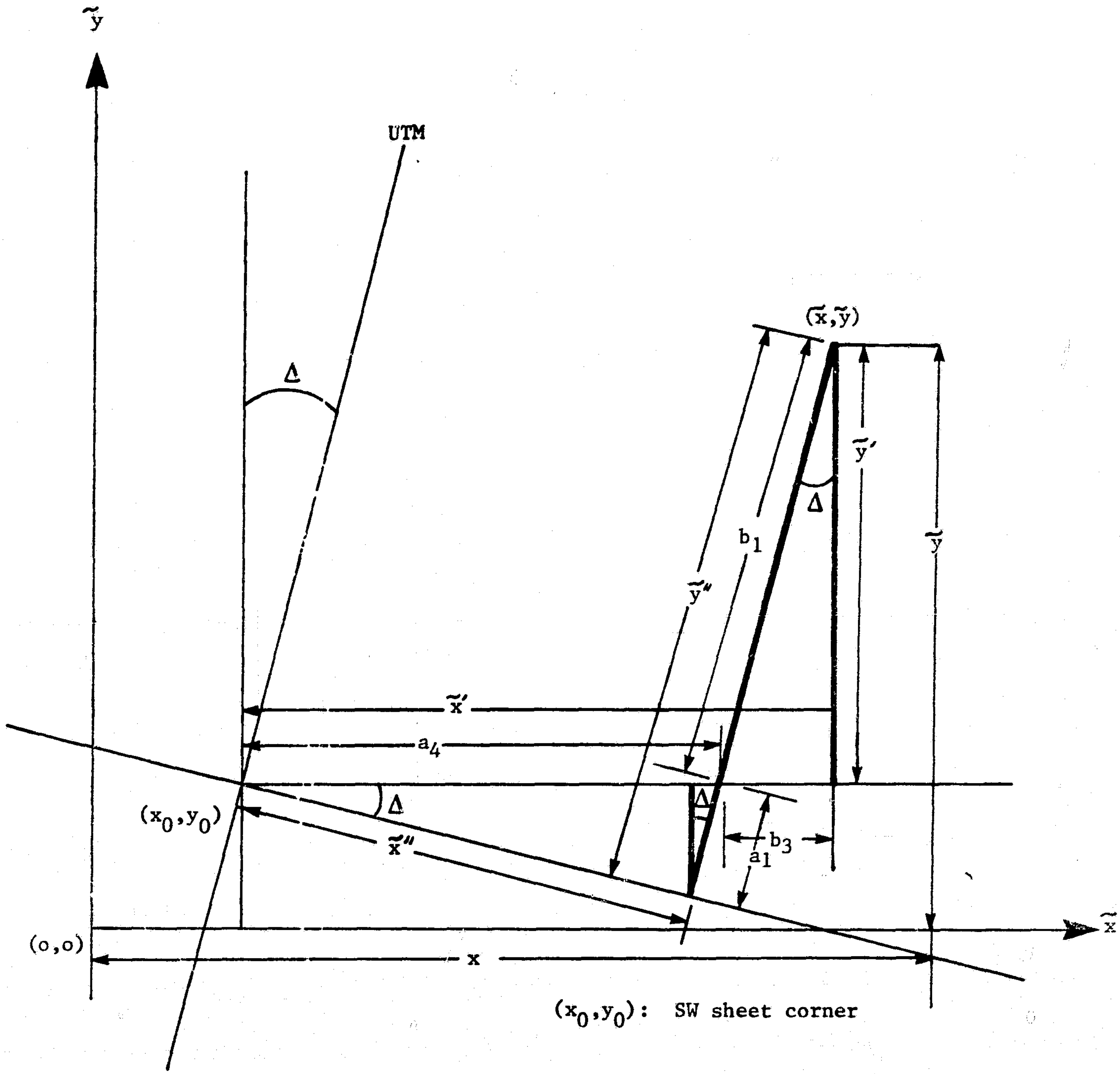


Figure 4. East of Zone CM, Right Side of Quad

and (12) in (5):

$$\tilde{x}'' = \tilde{x}' \cos\Delta - \tilde{y}' \sin\Delta \tag{13}$$

substituting (12) in (6) and the result in (4) and also (9) in (4) yields:

$$\tilde{y}'' = \tilde{x}' \sin \quad - \frac{\tilde{y}' \sin^2\Delta}{\cos\Delta} + \frac{\tilde{y}'}{\cos\Delta} \tag{14}$$

where the $(\tilde{x},\tilde{y})$ points are translated to the (x_o,y_o) origin point by:

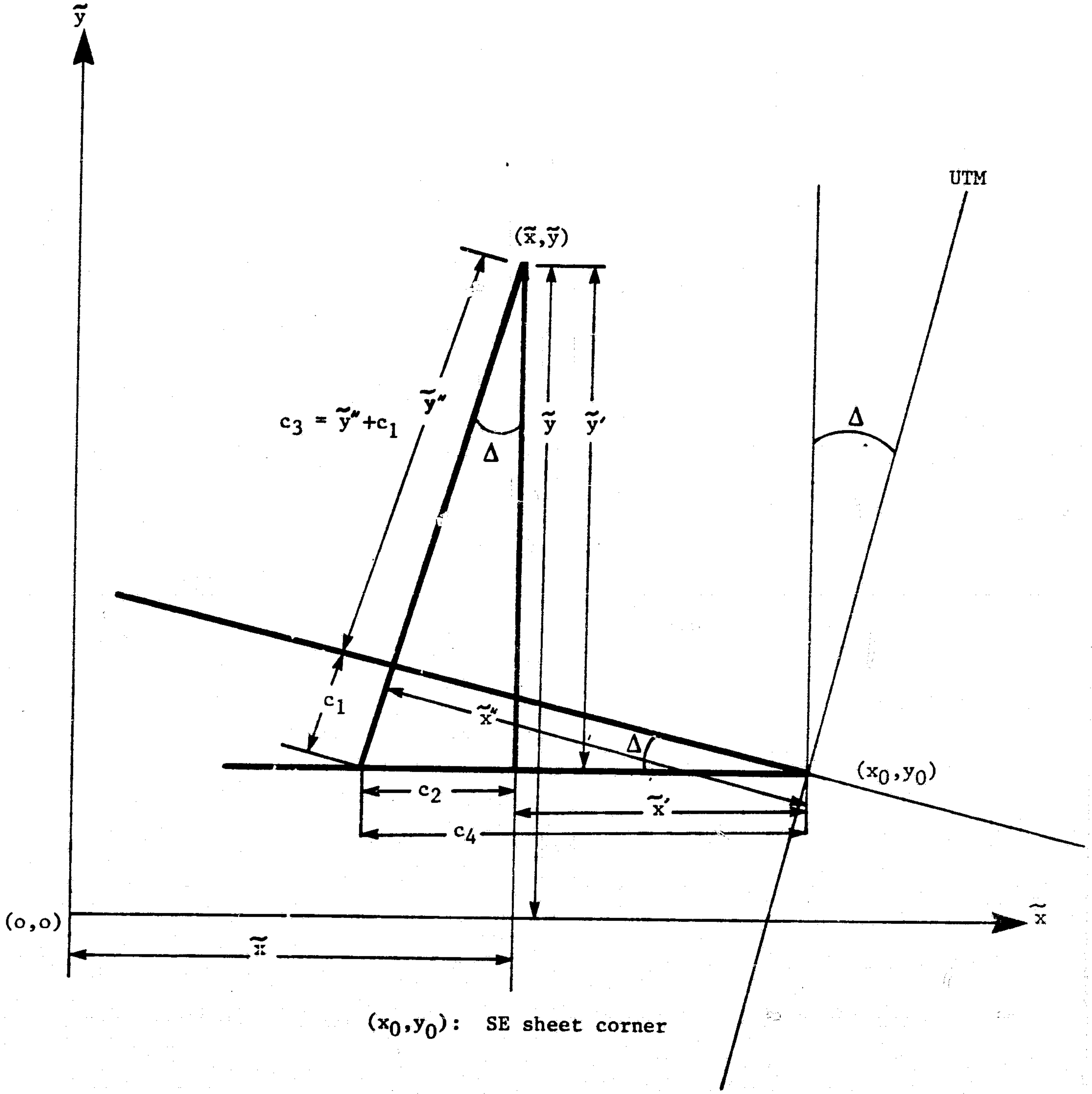
$$\left.\begin{aligned} \tilde{x}' &= \tilde{x} - x_o \\ \tilde{y}' &= \tilde{y} - y_o \end{aligned}\right\} \tag{15}$$

Thus, equations (13) and (14) give the registration of the $(\tilde{x},\tilde{y})$ plate coordinate point relative to its $(\tilde{x}'',\tilde{y}'')$ position in the UTM coordinate system. These equations are valid for the right side of a quad map and east of the zone CM.

Consideration of the geometry in figure 5 yields the following equations for the left side of a quad map, east of zone CM:

$$\left.\begin{aligned} \tilde{x}'' &= \tilde{x}' \cos\Delta + \tilde{y}' \sin\Delta \\ \tilde{y}'' &= -\tilde{x}' \sin\Delta - \frac{\tilde{y}' \sin^2\Delta}{\cos\Delta} + \frac{\tilde{y}'}{\cos\Delta} \end{aligned}\right\} \tag{16}$$

These equations are also valid for the right side of a quad, west of the zone CM. This can be verified by consideration of the geometry in figure 6. Consideration of the geometry in figure 7 also shows equations (13) and (14) to be valid for the left side of a quad map, west of the zone CM.



(x_0, y_0): SE sheet corner

Figure 5. East of Zone CM, Left side of Quad

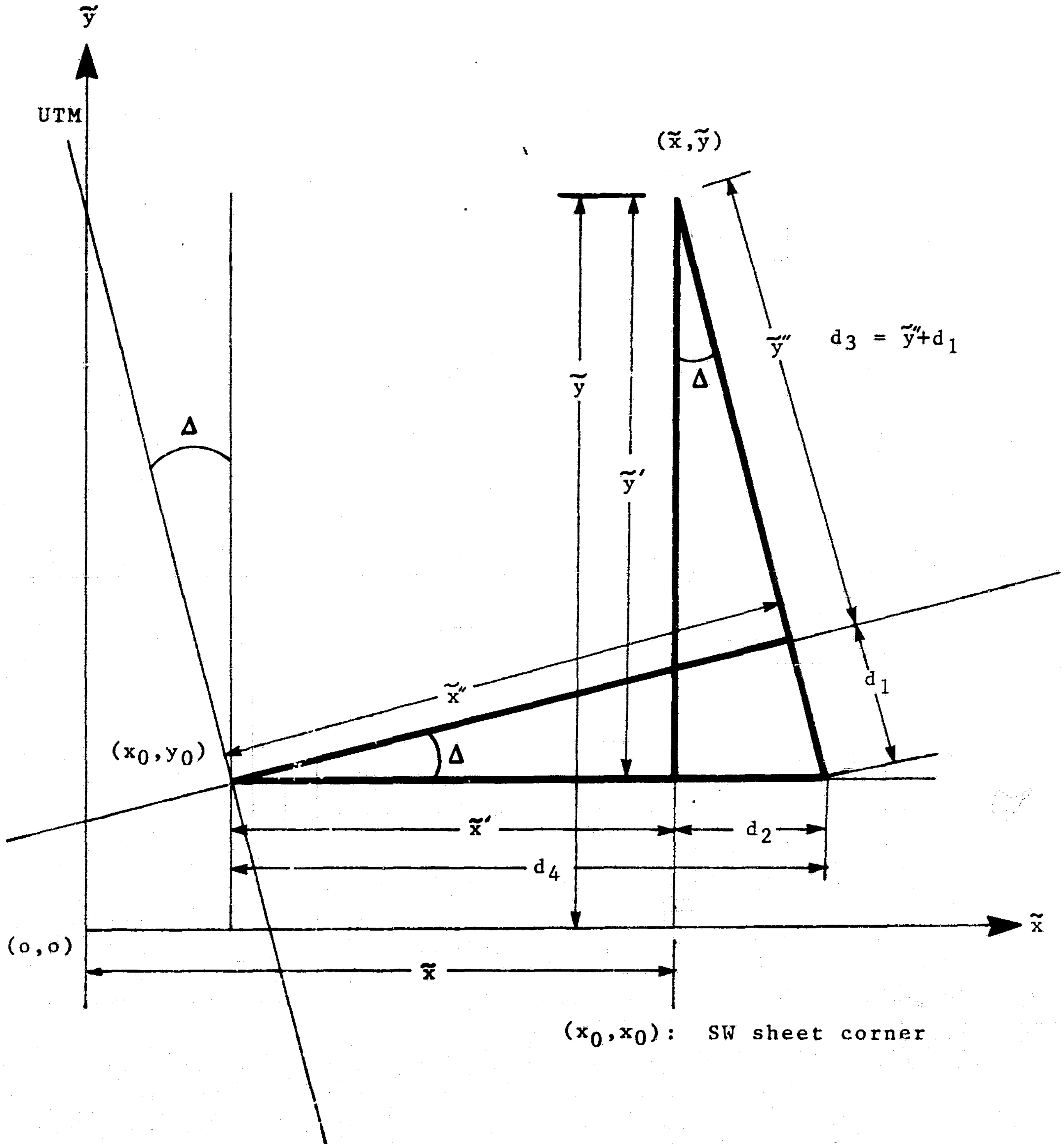


Figure 6. West of Zone CM, Right Side of Quad

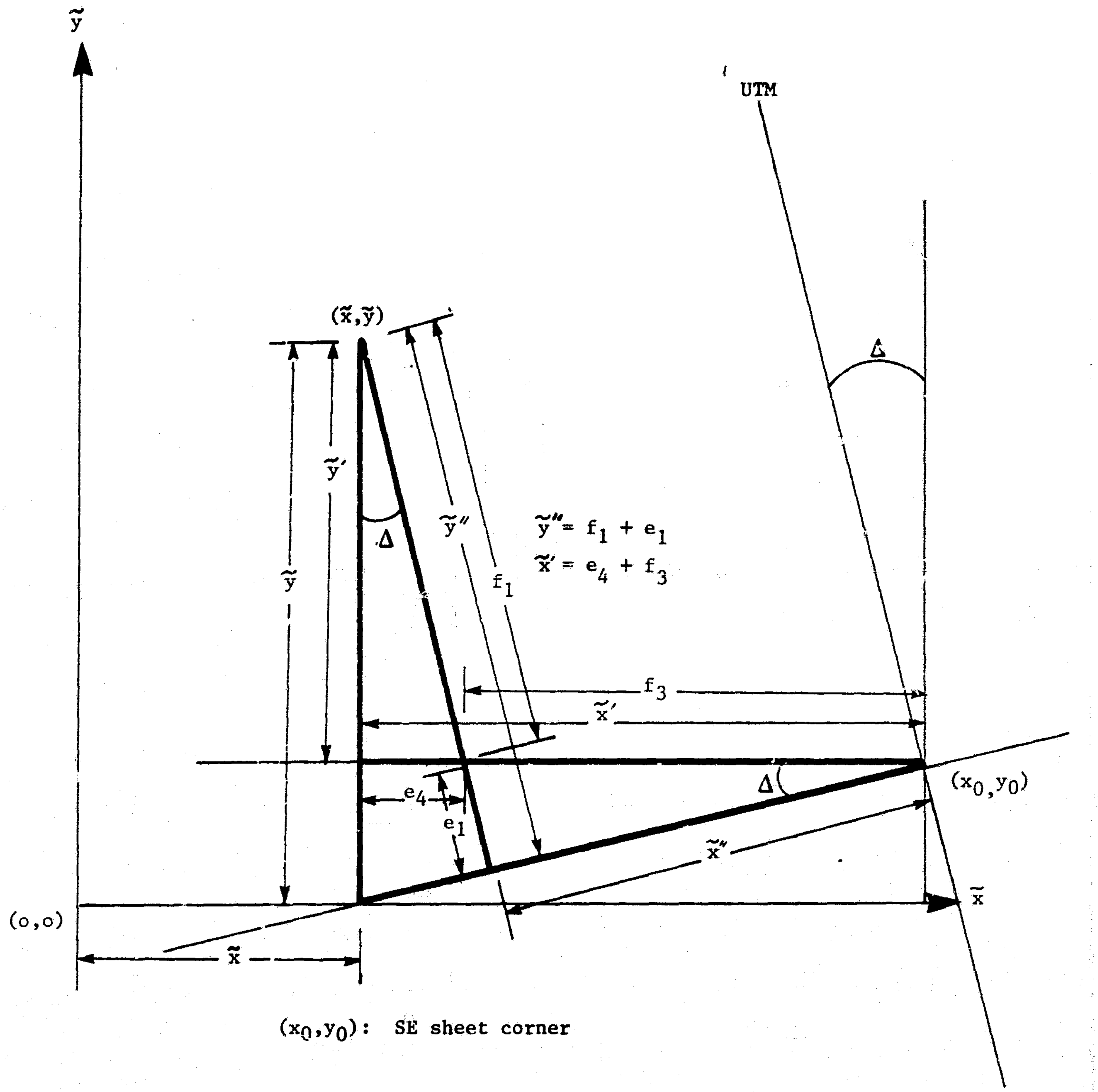


Figure 7. West of Zone CM, Left Side of Quad

Scale Factor Equations

The equations for the $\tilde{x}$ and $\tilde{y}$ scale factors S_{Xi} and S_{Yi}, respectively, are derived by assuming that the scale factor varies linearly from the bottom to the top for $\tilde{x}$ and from left to right for $\tilde{y}$. For example, we can compute from known data a $\tilde{y}$ scale factor on the left, S'_{YL}, and a $\tilde{y}$ scale factor on the right, S'_{YR}. The $\tilde{x}$ position of these scale factors are known data points $\tilde{x}'_L$ and $\tilde{x}'_R$. On the basis of the linearity assumption, we can write the general equation:

$$S_{Yi} = m_Y \tilde{x}''_i + b_Y \tag{17}$$

But the two end conditions yield:

$$m_Y = (S_{YR} - S_{YL})/(\tilde{x}'_R - \tilde{x}'_L) \tag{18}$$

$$b_Y = S_{YL} - m_Y \tilde{x}'_L \tag{19}$$

Similarly for S_{Xi}:

$$S_{Xi} = m_X \tilde{y}''_i + b_X \tag{20}$$

here the two end conditions yield:

$$m_X = (S_{XT} - S_{XB})/(\tilde{y}'_T - \tilde{y}'_B) \tag{21}$$

$$b_X = S_{XB} - m_X \tilde{y}'_B \tag{22}$$

Slope, Slope Length, and Aspect Determination

Thus, equations (2) and (3) yield an (X_{Ei}, Y_{Ni}, Z_i) type point for each plate coordinate point. If the output cell size is greater than the input cell of .01" x .01" (208' x 208'), then the average of all the Z's in the output cell domain is computed and used as the Z value for the cell size.

For purposes of output and for subsequent entry into the data base, a column and row number for each point is computed from:

$$\left.\begin{aligned} C.N. &= \frac{(X_E - X_\theta)}{C_\theta} + 1 \\ R.N. &= \frac{(Y_N - Y_\theta)}{C_\theta} + 1 \end{aligned}\right\} \qquad (23)$$

where:

C_θ = output cell size

(X_θ, Y_θ) = origin of output area, in meters

Consider the following figure 8:

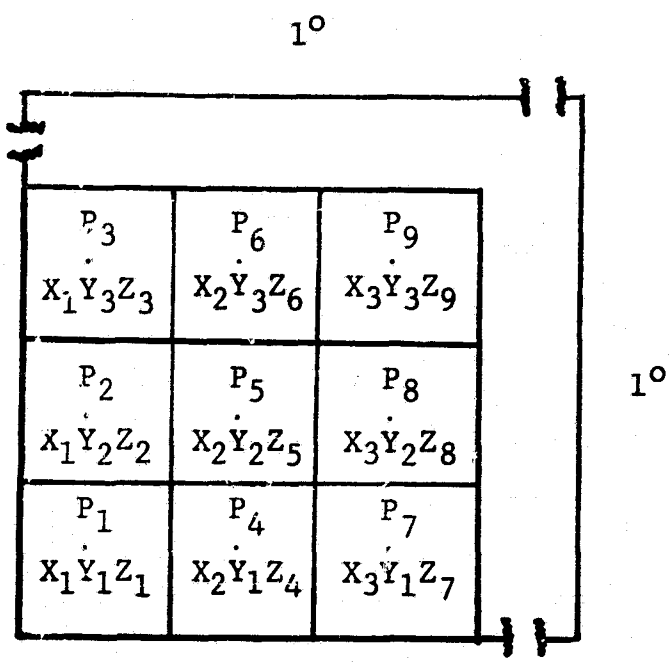


Figure 8.- Neighborhood cell approach.

Slope is defined as $|\Delta H| / \Delta D$, i.e.:

$$
\begin{aligned}
S_1(P_5P_1) &= (Z_5 - Z_1) \;/\; \sqrt{\Delta X^2 + \Delta Y^2} \\
S_2(P_5P_2) &= (Z_5 - Z_2) \;/\; (X_2 - X_1) \\
S_3(P_5P_3) &= (Z_5 - Z_3) \;/\; \sqrt{\Delta X^2 + \Delta Y^2} \\
S_4(P_5P_4) &= (Z_5 - Z_4) \;/\; (Y_2 - Y_1) \\
S_5(P_5P_6) &= (Z_5 - Z_6) \;/\; (Y_3 - Y_2) \\
S_6(P_5P_7) &= (Z_5 - Z_7) \;/\; \sqrt{\Delta X^2 + \Delta Y^2} \\
S_7(P_5P_8) &= (Z_5 - Z_8) \;/\; (X_3 - X_2) \\
S_8(P_5P_9) &= (Z_5 - Z_9) \;/\; \sqrt{\Delta X^2 + \Delta Y^2}
\end{aligned}
\tag{24}
$$

The largest S_i ($i = 1,2,..,8$) is selected as the slope of the cell containing P_5. The Z_5 value and the Z_i corresponding to the largest S_i are then compared. Then the aspect is defined as the direction from the smallest Z to the largest Z.

Slope length is given by the following equation:

$$
S.L. = \sqrt{2(C_\theta)^2 + \Delta Z^2} \tag{25}
$$

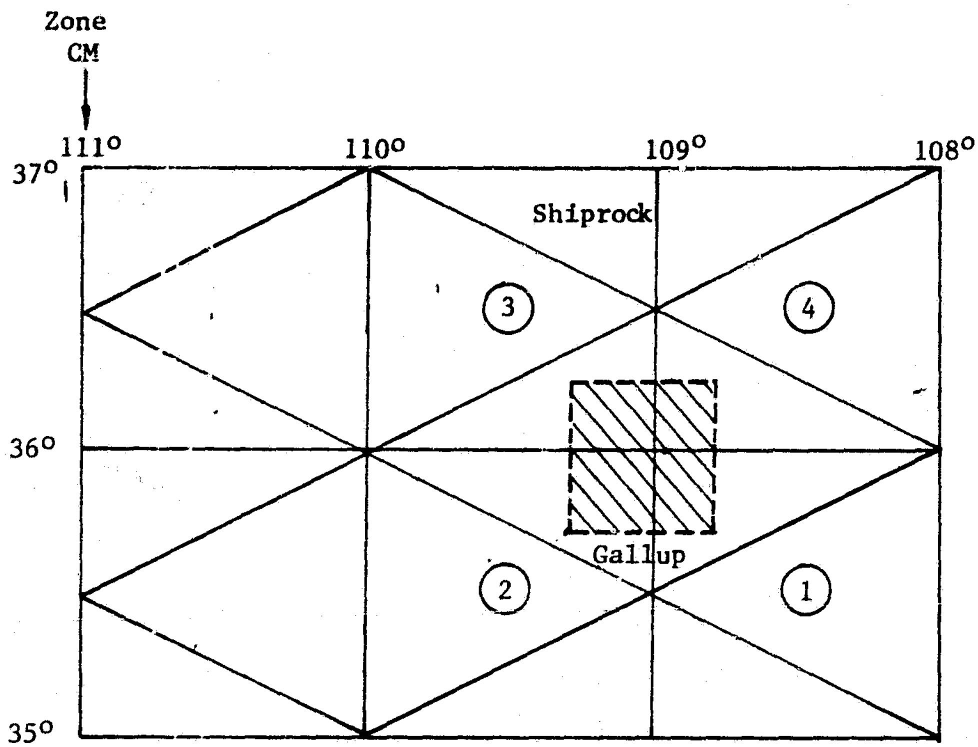
Since the slope and aspect determination are based on a neighboring approach, the perimeter cells for the adjacent files of a quad map are duplicated for use in the algorithm. This assures perimeter values for the slope and aspect of a $1^\circ \times 2^\circ$ area at the tape file interfaces.

RESULTS

Shiprock and Gallup Quad Data

The digital terrain data for the Shiprock and Gallup Quad, located as shown in figure 9, were selected for processing and for subsequent entry in the IDDP. The cross-hatched area in this figure represents the area of interest. Input parameters such as desired output origin, cell size, quantum levels for elevation, and slope were determined. Figure 10 shows a typical computer printout for one of the variables (topographic elevation) in the data base. The input data for the example shown in figure 10 is given in table I. The input indicates 241 rows and 354 columns of output, but only 62 rows and 120 columns are shown for the sake of brevity. Each letter represents a cell 100m x 100m in size. Each cell is identified by a row and column number and can be related back to the UTM coordinate system by equation (23). It should be pointed out that the (x_o,y_o) origin is referenced to the lower left-hand cell corner.

To determine the magnitude of agreement between the actual data and data produced from the TOPO program, the elevation data for these files were aligned with the corresponding Landsat scene data. Specific mountain peaks and/or features for the file 2 data were then identified from a 1:62,500-scale USGS map. A northing, easting, and elevation value were read from the map for three specific points. The northing and easting of each



1: File 1
2: File 2
3: File 3
4: File 4

Figure 9. Shiprock and Gallup Quad Data, RCC 135

```
ELEV.    DATA      COLUMNS    1 TO   120
  1 IIIIIJJJJJKKKKKKKKKJJJIFDDDDDDDFGIJJKLKLKKKKKKKKKLLLLLLMMMMMMMMNNMNNNMMNNNOOOOOOOOOOOOOOOOOPPPPPPOOPOOOPPPPPPONNNMMMM
  2 IIIIIJJJJKKKKKKLKKKJJJGDDDCCDFGIIJJKLKKKKKKKKKKKLLLLLLMMMMMMMMMNMNNNMMNNNOOOOOOOOOOOOOOOOOPPPPPPPPPPOOPPPPPPPONNMMMMM
  3 IIIIIJJJJKKKKKKLKKKJJIGDDDCCFHJIIJJKLKKKKKKKKKKKLLLLLLMMMMMMNMMNNNNNNMNNNOOOOOOOOOOOOOOOOOPPPPPPPPPPPPPPPPPPPONNNMMMMM
  4 IIIIIJJJJKKKKKKKLLKJJHFDDCCDEHIJIJJIKJJKKKKKKKKKLLLLLLMMMMMMNMMNNNNNNNNNNOOOOOOOOOOOOOOOOOPPPPPPPPPPPPPPPPPPOONNMMMMMM
  5 IIIIIJJJJJKKKKKKKLKKJHEDDCCDDFFGIGEEFIIIKKKKKKKKLLLLLLMMMMMMNMNNNNNNNNNNNOOOOOOOOOOOOPOPOPPPPPPPPPPPPPPPPPOONNMMMMMMM
  6 IIIIIJJJJJKKKKKKKKLKJHEDCCCCCCCDEDDDDHIIJLKKKKKKLLLLLMMMMMMNMNNNNNNNNNNNOOPOOOOOOOOOPPPPPPPPPPPPPPPPPPPPOONNMMMMMMMM
  7 JIIIIJJJJJJKKKKKKKLKJHEDCCCCCCCCDDDEHIIIJJKKKKKKLLLLLMMMMMMMMNNNNNNNNNNOOOOOOOPOOOOPPPPPPPPPPPPPPPPPPPPPOONNNMMMMMMMM
  8 JJIIIIJJJJJJJJJJJKKKJHECBBCCCDEEEDEFHIIIIJJKKLLKLLLLLLMMMMMMNMNNNNNNNNNNOOOOOOOOOOOOOPPPPPPPPPPPPPPPPPPPPOONNMMMMMMMM
  9 JJIIIIJJJJJJJJJIJJJKJJGEBBBCCEFGGGFGHIJJJIIJJKLLLLLLLLMMMMMMMMNNNNNNNNNNOOOOOOOOOOOOOPPPPPPPPPPPPPPPPPPPOONNMMMMMMMM
 10 JIIIIIJJJJJJJJJIIIJJJJHEDBBBCDFGIJIHHIJKLKJKKKKLLLLLLLMMMMMMMMMNNNNNNNNNOOOOOOOOOOPOPPPPPPPPPPPPPPPPPPPOONNMMMMMMMMM
 11 IIIIIIIIJJJJJJIHHIJJHFCBBBBDEGIJJJJIJJKLKLKLLLLLLLLLLMMMMMMMMMNNNNNNNNNOOOOOOOOOPOPPPPPPPPPPPPPPPPPPPPOONNMMMMMMMMMMM
 12 JIIIIIIIJJJJJJIGFGHHFDBBBBCDFHJKLLLLLKKKLLLLLLLLLLLLMMMMMMNMMNNNNNNNNNOOOOOOOPPPPPPPPPPPPPPPPPPPPPPPPONNMMMMMMMMMMMMM
 13 IIIIIIIIIIJJJJIEDEEEDBBBBBCEGIJKKLLLLKKKLLLLLLLLLLLMMMMMMMNMNNNNNNNNNOOOOOOOOOPPPPPPPPPPPPPPPPPPPPPPPOONNMMMMMMMMMMMM
 14 IIIIIIIIIIIJJJJGDBCCCBBBBBBCFHJJKKKLLLKKKKLLLLLLLLLLLMMMMMMMMMNNNNNNNOOOOOOOOOOOPPPPPPPPPPPPPPPPPPPPPPONNNMMMMMMMMMMN
 15 JIIIIIIIIIIIJIHECBBBBBBBBBBCCFHJJJKKLLLKKKLLLLLLLLLLLLMMMMMMMMMMNNNNNNNOOOOOOOOOOOOPPPPPPPPPPPPPPPPPPPPOONNMMMMMMMMMMM
 16 IIIIIIIIIIIIHGFCBBBBBBBBBBBCEGIJJJKKLKKKKLLLLLLLLLLLLMMMMMNNNMNNNNNNNOOOOOOOOPPPOPPPPPPPPPPPPPPPPPOOPNNMMMMMMMMMMMMMMM
 17 IIIIIIIIIIIGFEDBAABBBBBCBBBCDFEHIJKKLKKKKLLLLLLLLLLLMMMMMMNNNNNNNNNNOOOOOOOOPPPPPPPPPPPPPPPPPPPPPPPOONMMMMMMMLMMMMMMMMMM
 18 IIIIIIIIHHFEDBBBAAABBDDDCCCCCDDEHJKKKKKKKLLLLLLLLLLMMMMMMMMNNNNNNNNNNOOOOPOPPPPPPPPPPPPPPPPPPPPPPPPPPONMMMMMMMLLMMMMMMMMM
 19 IIIIIIIIGFDCCBBAAABBDEEEDCCCCCCEGIKKKKKKKLLLLLLLLLLMMMMMMNMMNNNNNNNNNOOOOOOPPPPPPPPPPPPPPPPPPPPPPPPONMMMMMMMLLLMMMMMMMMM
 20 IIIIIIIIFDBBBABABBCDEGGFDCCDDCCDFHJLLKKKKLLLLLLLLLLMMMMMMMNMNNNNNNNNNOOOOOOPPPPPPPPPPPPOPPPPPPPPPPPNNMMMMMMMLLLMMMMMMMMM
 21 IIIIIIIHFCBBAAAABCDEGIJHEDDDDDDCEHIKLLKKKLLLLLLLLLMMMMMMMMNMNNNNNNNNNOOOOOOPPPPPPPPPPPOOOOPPPPONNMMMMMMMMMLLLMMMMMMMMMN
 22 IIIIIIIHFBBAAAAACDEGHIIIFEDDEEEDCGIJLLLKKLLLLLLLLLMMMMMMMMMMNNNNNNNNNOOOOOOOPPPPPPPPPPPOOOOPPPONNMMMMMMMLLLLLLMMMMMMMMM
 23 IIIIIIIHGCBAAAABCEFHIIJJHFEEFGGEEHIIJKKKKLLLLLLLLLMMMMMMMNMMNNNNNNNNNOOOOOOOPPPPPPPPPPPOOOOOOPONMMMMMMMMLLLLLLMMMMMMMMMM
 24 IIIIIIIJIDBAAAABDEGIJJJJJHFGHHHGGIIIIJKKKLLLLLLLLMMMMMMMNMMNNNNNNNOOOOOOOOPPPPPPPPPPPOOOOOOONMMMMMMMLLLLLLLMMMMMMMMMMM
 25 IIIIIIIIJECAAAABDGIJKJJJJIHHIJIHHIIIIJKKLLLLLLLLLMMMMMMMNNMMNNNNNNOOOOPOOOOOPPPPPPPPPPOOOOOPNNMMMMMMMLLLLLLLLMMMMMMMMMM
 26 IIIIIIIIIFCAAAABDGJKKKKJJJIIIJJJJKKKKKKKKLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOOOOOOOPPPPPPPPFPOOOPOPNNMMMMMLLLLLLLLLMMMMMMMMMM
 27 IIIJIIIJGFCAAAABDGKKKKKKJJJIIIJKKKKKKKKKLLLLLLLLMMMMMMMMMMMNNNNNNNOOOOOOOOOOOOOOPPPPPPPONOOONMMMMMLLLLLLLLLLLMMMMMMMMMM
 28 IIIJIHGFEECBAAACDGJLLLLKKJJJIJJKKKKKKKKKLLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOOOOOOOOOOPPPPPPONNMNMMMMMMLLLLLLLLLLLMMMMMMMMMM
 29 JIIJHFEDCCCBAABCDGILKKKKKKJJJJKKKLKKKKKKLLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOOOOOOOOOOPPPPOONNMMMMMMMMLLLLLLLLLLLMMMMMMMMMMM
 30 IIIJGECBABBAAABCDGIKKKKKKKKKJJKKKKKKKKKKLLLLLLLLMMMMMMMMMMNMNNNNNNOOOOOOOOOOOOOOOOOPPPPOONNMMMMMMMLLLLLLLLLLLMMMMMMMMMMM
 31 IIIJGDBAAAAAAAABDFGIKKKKKKKKKKKKKKKKKKKKLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOOOOOOOOPOPPPPPPOONNMMMMMMLLLLLLLLLLLMMMMMMMMMMMM
 32 IHIIHDBAAAAAAACEGHIKKKKKKKLKKKKLKKKKKKKLLLLLLLLMMMMMMMMMMMMNNNNNNNOOOOOOOOOOOOOPPPPPPONNMMMMMMLLLLLLLLLLLMMMMMMMMMMMMM
 33 FEFHGDBAAAAAABDGHIJLKKKKKKLLKKKLKKKKKKKKLLLLLLLLMMMMMNMMMMNNNNNNNNOOOOOPOOOPOOOOOPPPPPONNMMMMMMLLLLLLLLLLLMMMMMMMMMMMMM
 34 CBCEDCBAAAAABDEIJKKKKKKKKKLLKLKLKKKKKKKLLLLLLLMMMMMMMMMMMMMNNNNNNNOOOOOPOOOPOOOOOOOOPPONNMMMMMLLLLLLLLLLLMMMMMMMMMMMMMM
 35 BBBBBAAAAAABCEFLKKKKKKKKKKLLLKKKKKKKKKKLLLLLLLMMMMMMNMMMMMMNNNNNNNOOOOOPOOOOOOOOOOOOOPPNMMMMMMLLLLLLLLLLLMMMMMMMMMMMMMM
 36 BBAAAAAAAAABBDFIJKKKKKKKKKKKLLKKKKKKKKKKLLLLLLMMMMMMMMMMMMMNNNNNNOOOOOPOOOOOOOOOOOOOOONMMMMLLLLLLLLLLLLMMMMMMMMMMMMMM
 37 BBAAAAAAAAABBDFIIKLKKKKKLKKKKLKKKKKKKKKKLLLLLLLMMMMMMMMMMMMNNNNNNOOOOOOOOOOOOOOOOOOOOOONMMMMLLLLLLLLLLLLLMMMMMMMMMMMMM
 38 BBAAAAAAAAABBDEGGIKKKKKKKLKKKLKKKKKKKKKKLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOOOOOOOOOOOOOOOOONMMMLLLLLLLLLLLLLLMMMMMMMMMMMMM
 39 BAAAAAAAAABBCDEEHJJKJKKKKLKKKKKKKKKKKKKLLLLLLLMMMMMMMMMMNNNNNNNNOOOOOOPOOOOOOOOOOOOONMMMLLLLLLLLLLLLLLMMMMMMMMMMMMMMM
 40 BAAAAAAAAAABBBCDGIJJJJKKKKLKKKKKKLKKKKKLLLLLLLMMMMMMMNNNNNNNNOOOOOOOOOOOOOOOOOOOOOONMMMLLLLLLLLLLLLLLLLMMMMMMMMMMMMMM
 41 AAAAAAAAAAAAAABCFHJJJJJJKKKLKKKLKLKKKKKLLLLLLLMMMMMMNNNNNNNNNOOOOOOOOOPOOOOOOOOOOONMMMLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMM
 42 AAAAAABBCAAAAABCEGJJJJJJJKKLKKKKLKKKKKKKKLLLLLMMMMMNNNNNNNNOOOOOOOOOOPOOOOOOOOONMMMLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMMM
 43 AABAABDEEBAAAABBCFGHHIJJJJJKLLKKKKKKKLKKKLLLLMMMMMMNNNNNNNNOOOOOOOPOOOPPOOOOOOOOONMMLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMM
 44 ADDCDEFHGCBAAAAABCEFGHIHIIIJKKKKKLKKKKKKKKLLLMMMMNNNNNNNNNOOOOOOOOOOOOOPOOOOOOPNNMMLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMMMM
 45 DFFFGGGHHECAAAAAAACDEGGGHIJJJKKKKLLKKKKKKLLLLLMMMMNNNNNNNNNOOOOOOOOOOOOOOOOOOOOOOOOMMMLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMM
 46 GGGHHGHHHGDBBAAAAAABCDEEGHIJJJJJJKKJJKKLLLLLMMMMMMNNNNNNNOOOOOOOPPOPPOOOOOOOOONMMMLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMM
 47 GGGHHHHHHHFDBAABBAAABCCDFGHJJJHHIIIIJJKKLLLLMMMMMMNNNNNNNOOOOOOOOPPOOPPOOOOOOOONMMMLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMMMN
 48 GGGHHHHHHHHGDDCEEDCBAABCEFGIIHFGHIIIJKKLLLLMMMMMMMNNNNNNNOOOOOPOOOPPOOOPOOOOONNMMLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMNNNNN
 49 GGGHHHHHHHHHGFEHGHGDBAABCDEFEDDFGHIJKKKLLLMMMNMMMMNNNNNNOOOOOOOOOOOOPOOPOOOONNMMMLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMNNNNN
 50 GGGHHHHHHHHHHGGHHHHGDBAABCBCBBCEGHIKKKKLLLMMNMMMMMNNNNNNOOOOOPOOOOOPPPOPPOONMMMLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMNNNNNNN
 51 GGGHHHHHHIIIIHHHHHHHFCBAABBBBBCEGHJKLKKLLLMMMNMNMMMMNNNNNOOOOPOPOOOOOOPOOPNNMMMLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMNNNNOO
 52 GGGHHHHHIIIIIIIIIIIIHECBBCCBBBDEGIIKLKKLLLMMMMMMMNNNNNNNOOOOOOPOOOOOOPOOONMMMLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMMNNOOO
 53 GGGHHHHHIIIIJIIIIIIIIFDCCDDCBCEFHIJKKKLLLMMMMMMMMNNNNNNNOOOOOOOOOOOOOPOONNMMLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMMNNOOOO
 54 GGGHHHHHIIIIJIIIIIJIIGEEEFFEDEGIIIJKKKKLLLMMMMMMNNNNNNNNNOOOOOOOOOOOOPONNMMMLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMMNNOOOPP
 55 HGGHHHHHIIIIIIIIIIIIIHFGFGGGFGHJIJJKLLKLLLLMMMMMMMMNNNNNNNNOOOPOOOOOOOOOPONNMLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMNNOOOPPP
 56 GGGHHHHHIIIIJIIIIIIIIIHHHHIIIIIIJJKKKKKKLLLLMMMMMNMMMNNNNNNNOOPPPOOOOOOPONMLLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMNNOPOPPP
 57 GGGHHHHHIIIIJIIIIIIIIIIIIIJJJJJJJJKKKKKKKLLLLMMMMMNNMMMMMMNNNNOOPPPOPOOOOPONMLLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMMMNNOOOPPPP
 58 GGGHHHHHHIIIIIIIIIIIIIJIIJJJJJKKKKKKKKKLKLLLLMMMMNNNNMMMMMMNNOOOPPPOPPPOONNMLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMNNNOOOPPPPPP
 59 GGGGHHHHHIIIIIIIIIIIIJJJJJJJKKLKKKKKKKKKLLLLLMMMMNNNNMMMMMNNNOOOPOPPPPPOONMMLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMNNNOOPPPPPPP
 60 GGGHHHHHHIIIIIIIIIIIIIJJJJJKKKKKKKKKKKKKLLLLLLLLMMMNMMMMMNNOOPOOPPPPPNNNMLLLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMNNNOOOOOPPPPP
 61 GGHHHHHHHIIIIIJIIIIIIIJJJJJKKKKKKKKKKKKKKLLLLLLLLMMMMMMMMMNNNOOOOOOOPONNNNLLLLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMNNNOOOPOOPPPP
 62 GGHHHHHHHIIIIIJJIIIIIIJJJJJKKLKKKKKKKKKKKLLLLLLLLMMMMMMMMMNNNNOOOOOOOONNNMLLLLLLLLLLLLLLLLLLLLLLLLLMMMMMMMMMNNNNOOOOOPPPPP
```

Figure 10 - Example of Output from TOPO Program for RCC 135 File 3 Terrain Data

TABLE I.- INPUT DATA FOR EXAMPLE SHOWN IN FIGURE 10

```
INPUT COLUMNS TO PROCESS =        1    354
INPUT STARTING ROW =      1
CELL SIZE =    100.00

NUMBER OF ROWS OUTPUT =    241    FROM     1  TO  241
354 COLUMNS OUTPUT NUMBERED FROM     1  TO  354

ELEVATION LEVELS COMPUTED IN INCREMENTS OF  100.0  FROM  6000.0 TO 8400.0
 LEVEL                    ST. EL.                  END EL.
```

LEVEL		ST. EL.	END EL.
1	A	0.0	6000.0
2	B	6000.0	6100.0
3	C	6100.0	6200.0
4	D	6200.0	6300.0
5	E	6300.0	6400.0
6	F	6400.0	6500.0
7	G	6500.0	6600.0
8	H	6600.0	6700.0
9	I	6700.0	6800.0
10	J	6800.0	6900.0
11	K	6900.0	7000.0
12	L	7000.0	7100.0
13	M	7100.0	7200.0
14	N	7200.0	7300.0
15	O	7300.0	7400.0
16	P	7400.0	7500.0
17	Q	7500.0	7600.0
18	R	7600.0	7700.0
19	S	7700.0	7800.0
20	T	7800.0	7900.0
21	U	7900.0	8000.0
22	V	8000.0	8100.0
23	W	8100.0	8200.0
24	X	8200.0	8300.0
25	Y	8300.0	8400.0
26	Z	8400.0	99999.0

point were then used to compute a row and column number and the corresponding elevation interval was determined from the TOPO output data. This comparison is shown in table II and shows close agreement between the actual data and the data produced as output from the TOPO programs.

As a further accuracy evaluation, the four known sheet corners for files 3 and 4 of the RCC 135 data and file 3 of the RCC 136 data were translated and registered to the UTM coordinate system using equations (2) and (3). These UTM values were then compared with the known UTM values and the differences recorded as shown in table III.

CONCLUDING REMARKS

The NASA/ERL has developed a method for processing digital topography data that can subsequently be entered in a data base to include slope, slope length, elevation, and aspect. It is expected that this information, and subsequent second and third level interpretive information derived from the original source data, can be used by land resource managers.

The current software programs have been written for an input data tape formatted as per the DMA Planar map data file format. Another tape format from the DMA is available to users whereby the data are referenced to the latitude, longitude coordinate system in terms of 3, 1, or .5 arc sec cell sizes. The former data format is used at the ERL since the majority

TABLE II.- COMPARISON OF ELEVATION VALUES FROM MAP AND TOPO PROGRAM

Point Number	Elevation from 1:62,500 map, ft.	Elevation from TOPO Program, ft.
1	7000	7000 - 7100
2	8171	8000 - 8100
3	8304	8100 - 8300

TABLE III.- UTM DIFFERENCES FOR KNOWN POSITIONS

TAPE ID	FILE	UTM Δ, meters Sheet Corner							
		SW		SE		NW		NE	
		X	Y	X	Y	X	Y	X	Y
RCC-135	3	18	61	0	0	127	9	58	27
RCC-135	4	0	0	31	86	48	7	42	33
RCC-136	3	0	0	1	103	22	1	17	1

of the Laboratory applications are concerned with the utilization of map data that are based on the UTM reference grid system.

REFERENCES

1. "National Cartographic Information Center (NCIC) User Guide," U. S. Department of the Interior, Geological Survey: INF-74-47.

APPENDIX A

NASA/ERL DIGITAL TERRAIN TOPOGRAPHIC PROGRAMS

This appendix defines the procedures and technique involved in processing digital terrain data tapes produced by the DMATC.

This processing necessitates the execution of four separate programs from which is output four data files (elevation, slope, aspect and slope length) which are in a form suitable for entering in the Gridded Data Base. Additional information can be obtained in the DMA TOPO Program Documentation manual on file with the NASA/ERL. The hardware required is a Varian V70 series mini-computer with the following program memory requirements:

Program 1 - 51100_8

Program 2 - 63600_8

Program 3 - 47122_8

Program 4 - 47373_8

One card reader, a line printer, and two tapes or disk files are required. The individual programs are run in the sequence as defined in this appendix.

PROGRAM 1 - TOPREF

DECK SETUP FOR PROGRAM Program 1 -- TOPO REFORMAT PAGE NO. 1 OF 1

(Back of deck)

/ENDJOB.

/EXEC, TØPREF.

/ACCESS, CDMØUT, MT,,REFORMATTED OUTPUT TAPE.

* /COPYF, CDMAIN,,F1. SKIP FILE(S) TO DATA FILE.

/ACCESS, CDMAIN, MT, REELNØ. NCIC INPUT TAPE.

/JOB,----STANDARD JOB CARD.

(Front of deck)

* Data is contained in the second tape file of each group of 3 files for each area. For a four area tape, skip 1, 4, 7, or 10 files to be positioned at the desired data file.

CARD
NO. ____________
JOB TOPO REFORMAT

NAME TOPREF

LEAD CARD SET UP PAGE NO. 1 OF 1

PROGRAMMER J. Forbes DATE 5/25/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
				No card input to this program.

COMMENTS ____________

PROGRAM 2 - TOPTWO

DECK SETUP FOR PROGRAM TOPO - PROGRAM 2 PAGE NO. 1 OF 1

(Back of deck)

/ENDJOB.

/REWIND, CDMØUT.

.
.

DATA CARDS.

.
.

/EXEC, TØPTWØ.

/ACCESS, CDMAIN, MT, L9XXXX, REFORMATTED INPUT.

/ACCESS, CDMØUT, DD.

/CREATE, CDMØUT*XXXXXX, 7200,200/s.

/JOB, --- STANDARD JOB CARD.

(Front of deck)

CARD NO. 1

JOB TOPO - PROGRAM 2

NAME TOPTWØ

LEAD CARD SET UP

PAGE NO. 1 OF 6

PROGRAMMER J. Forbes DATE 6/23/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-12	D12.2	XØ	Easting output origin in meters, minus 1/2 output cell size.
2	13-24	D12.2	YØ	Northing output origin in meters, minus 1/2 output cell size.
3	25-36	D12.2	XE	Easting output limit, plus 1/2 output cell size.
4	37-48	D12.2	YE	Northing output limit, plus 1/2 output cell size.
5	49-60	D12.2	XØRG	Map sheet corner, easting[1]
6	61-72	D12.2	YØRG	Map sheet corner, northing[1]
ORIGINAL PAGE IS OF POOR QUALITY				** Field input example **
				649950. Input as 649950D2
				3985597.81 Input as 398559781D0

COMMENTS [1] Map sheet corner = SW corner for east file and SE corner for west file of quad map.

CARD NO. 2

JOB TOPO - PROGRAM 2

NAME TØPTWØ

LEAD CARD SET UP

PAGE NO. 2 OF 6

PROGRAMMER J. Forbes DATE 5/25/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 5	I5	ISTART	Record number on input file to start processing.
				Deafult = 1.
2	6-15	F10.0	CELL	Output cell size in meters.
3	16-25	F10.0	CB	Column bias in meters.
4	26-35	F10.0	RB	Row bias in meters.

COMMENTS

Errata 5-1-79 [illegible]

CARD NO. 3

JOB NAME TOPO-PROGRAM TOPTWO

LEAD CARD SET UP

PROGRAMMER J. Forbes DATE 5/25/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	D20.10	DELTA	Rotation angle for easting bias (degrees).[1]
2	21-40	D20.10	THETA	Rotation angle for map misalignment (degrees).[2]
3	41	I1	LQ	=1 for processing left quadrant, otherwise blank.
				[1] The DELTA angle is determined from:
				$\tan \Delta = \vert E_2 - E_1 \vert / (N_2 - N_1)$ where the
				subscript 2 refers to the top sheet coordinates
				and the subscript 1 refers to the bottom sheet
				coordinates of the Quad map centerline. For an
				input data file relative to the Zone CM, the
				"sign" of the DELTA angle is as follows:
				—Negative: East of Zone CM, left half of Quad
				—Positive: East of Zone CM, right half of Quad
				—Positive: West of Zone CM, left half of Quad
				—Negative: West of Zone CM, right half of Quad
				[2] THETA is normally zero, but should be
				verified by checking the X sheet corners
				of the central meridian of the Quad map.

COMMENTS

CARD
NO. 4
JOB TOPO - PROGRAM 2

NAME TOPTWO

LEAD CARD SET UP

PAGE NO. 4 OF 6

PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-10	F10.0	XORI	X (.01 inches) of pivot point.*
2	11-20	F10.0	YØRI	Y (.01 inches) of pivot point.
				*1: Pivot point is SW corner for east file and
				SE corner for west file of Quad map.

COMMENTS

CARD
NO. 5
JOB TOPO - PROGRAM 2
NAME TOPTWØ

LEAD CARD SET UP

PAGE NO. 5 OF 6
PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-20	D20.10	SYL	Scale factor, y-left.
2	21-40	D20.10	SYR	Scale factor, y-right.
3	41-60	D20.10	SXB	Scale factor, x-bottom.
4	61-80	D20.10	SXT	Scale factor, x-top.

COMMENTS

CARD
NO. 6
JOB TOPO - PROGRAM 2
NAME TOPTWO

LEAD CARD SET UP

PAGE NO. 6 OF 6
PROGRAMMER J. Forbes
DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1-10	F10.0	XL	X (.01 inches) of SW corner of map.
2	11-20	F10.0	XR	X (.01 inches) of SE corner.
3	21-30	F10.0	YB	Y (.01 inches) of SW corner.
4	31-40	F10.0	YT	Y (.01 inches) of NW corner.

COMMENTS

PROGRAM 3 - TOPSRT

DECK SETUP FOR PROGRAM TOPO - PROGRAM 3 PAGE NO. 1 OF 1

(Back of deck)

/ENDJOB.

DATA CARD

/EXEC, TØPSRT.

/ACCESS, SRTTAP, MT,,SORTED DATA TAPE OUTPUT.

** /ACCESS, CDMØUT*XXXXXX, DD.

/ACCESS, CDMSRT, DD.

* /CREATE, CDMSRT, 7200, NRECS*. SCRATCH FILE.

/JOB,...STANDARD JOB CARD

(Front of deck)

* Number of records required for scratch file is determined by number of records output to file 'CDMØUT' from previous PROGRAM-2.

** File 'CDMOUT' output from previous PROGRAM-2.

CARD NO. 1

JOB NAME TOPO - PROGRAM 3 TOPSRT

LEAD CARD SET UP

PAGE NO 1 OF 1

PROGRAMMER J. Forbes DATE 5/28/78

FIELD I D	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 5	I5	NREC	Number of records on input file 'CDMØUT'.
2	6-10	I5	IRØW	Starting row number.
3	11-15	I5	LROW	Last row number.
4	16-20	I5	NTROWS	Total rows (calculated in program 2).
5	21-25	I5	NCOL	Number of columns.

COMMENTS This input is determined from printed output from previous PROGRAM-2.

PROGRAM 4 - TOPODB

DECK SETUP FOR PROGRAM TOPO - PROGRAM 4 PAGE NO. 1 OF 1

(Back of deck)

/ENDJOB

.
.

DATA CARDS

.
.

/EXEC, TØPØDB.

/ACCESS, LNDATA, DD.[2]

/ACCESS, ASDATA, DD.[2]

/ACCESS, SLDATA, DD.[2]

/ACCESS, ELDATA, DD.[1]

* /CREATE, LNDATA, 1080, NRECS/S. SLOPE LENGTH DATA.[2]

* /CREATE, ASDATA, 1080, NRECS/S. ASPECT DATA.[2]

* /CREATE, SLDATA, 1080, NRECS/S. SLOPE DATA.[2]

* /CREATE, ELDATA, 1080, NRECS/S. ELEVATION DATA.[1]

/ACCESS, SRTTAP, MT, L9XXXX, OUTPUT FROM PGM-3.

/JOB, --- STANDARD JOB CARD.

(Front of deck)

* Number of records output is determined by number of rows processed (see Lead Cards).

1 Omit this file if IØPT = 2 (lead card #1)

2 Omit these files if IØPT = 1

CARD NO. 1

JOB TOPO - PROGRAM 4

NAME TOPODB

LEAD CARD SET UP

PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 5	I5	ISR	Record number (row) on input file to start processing. Default = 1.
2	6-10	I5	ICOL	Starting column number to process.
3	11-15	I5	LCOL	Stop column number.
4	16-25	F10.2	CELL	Cell size in meters.
5	30	I1	IØPT	Processing option: 0 = Process all. 1 = Process elevation data only. 2 = Process slope, aspect and slope length only.

COMMENTS

CARD
NO. 2
JOB TOPO - PROGRAM 4
NAME TOPODB

LEAD CARD SET UP

PAGE NO. 2 OF 7

PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 5	I5	IROW	First row number for output file (input to
				database).
2	6-10	I5	LROW	Ending row number for output.
3	11-15	I5	ICBIAS	Column bias for shifting output.

COMMENTS

CARD
NO. 3
JOB TOPO - PROGRAM 4
NAME TOPODB

LEAD CARD SET UP

PAGE NO. 3 OF 7
PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 8	F8.0	STELV	Starting elevation level.
2	9-16	F8.0	ENDELV	End elevation level.
3	17-24	F8.0	ENCR	Increment for setting elevation levels from 'STELV' to 'ENDELV'.

COMMENTS Omit this card if IØPT (card 1) = 2

CARD
NO. 4
JOB TOPO - PROGRAM 4
NAME TOPODB

LEAD CARD SET UP

PROGRAMMER J. Forbes

DATE 5/28/78

FIELD I.D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 5	I5	NSL	Number of slope levels to read (following).
				MAX = 20.

COMMENTS Omit this card if IØPT = 1

CARD NO. 5

JOB TOPO - PROGRAM 4

NAME TOPODB

LEAD CARD SET UP

PROGRAMMER J. Forbes

PAGE NO. 5 OF 7

DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 8	F8.0	XSSL(I)	Starting slope level (1).
2	9-16	F8.0	XSSL(2)	Starting slope level (2).
3	17-24	F8.0	XSSL(3)	Starting slope level (3).
4	25-32	F8.0	XSSL(4)	Starting slope level (4).
5	33-40	F8.0	XSSL(5)	Starting slope level (5).
6	41-48	F8.0	XSSL(6)	Starting slope level (6).
7	49-56	F8.0	XSSL(7)	Starting slope level (7).
8	57-64	F8.0	XSSL(8)	Starting slope level (8).
9	65-72	F8.0	XSSL(9)	Starting slope level (9).
10	73-80	F8.0	XSSL(10)	Starting slope level (10).
				Input 'NSL' values (card number 4).

COMMENTS Input 2 of these cards if more than 10 slope levels.

CARD
NO. 6

JOB TOPO - PROGRAM 4

NAME TOPODB

LEAD CARD SET UP

PAGE NO. 6 OF 7

PROGRAMMER J. Forbes DATE 5/28/78

FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
1	1- 2	I2	IASP(1)	Aspect number code for undetermined.
2	3- 4	I2	IASP(2)	Aspect number code for NORTH.
3	5- 6	I2	IASP(3)	Aspect number code for NE.
4	7- 8	I2	IASP(4)	Aspect number code for E.
5	9-10	I2	IASP(5)	Aspect number code for SE.
6	11-12	I2	IASP(6)	Aspect number code for S.
7	13-14	I2	IASP(7)	Aspect number code for SW.
8	15-16	I2	IASP(8)	Aspect number code for W.
9	17-18	I2	IASP(9)	Aspect number code for NW.

COMMENTS Omit this card if IØPT = 1

CARD
NO. 7
JOB TOPO - PROGRAM 4
NAME TOPODB

LEAD CARD SET UP

PAGE NO. 7 OF 7
PROGRAMMER J. Forbes DATE 5/28/78

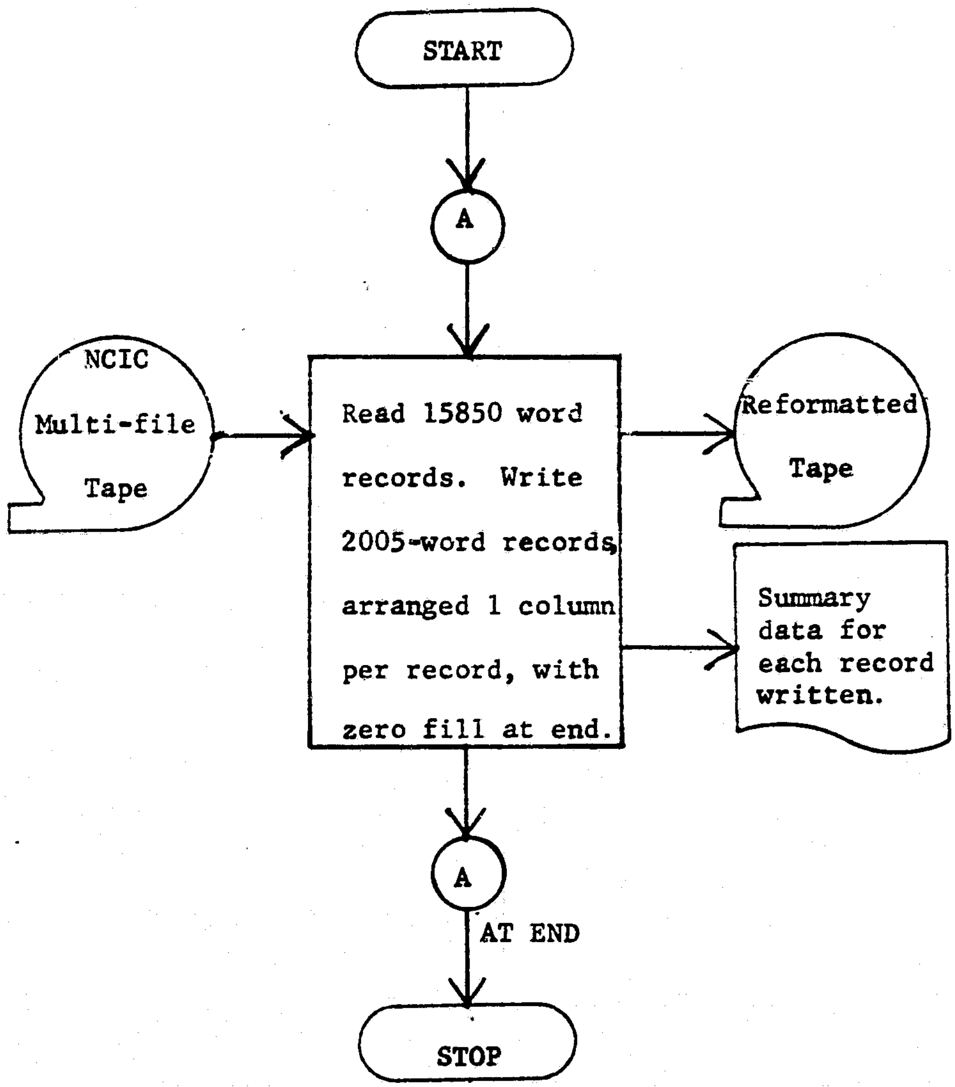
FIELD I. D.	CARD COLUMNS	FORMAT	SYMBOLIC NAME	IDENTIFICATION
	1	1X		Blank.
1	2	I1	IPØ	1 = yes, 0 = no
				Print elevation, slope and aspect printer maps.
	3	1X		Blank.
2	4	I1	ISLØP	Print slope lengths for each cell.
				1 = yes, 0 = no

COMMENTS Card required.

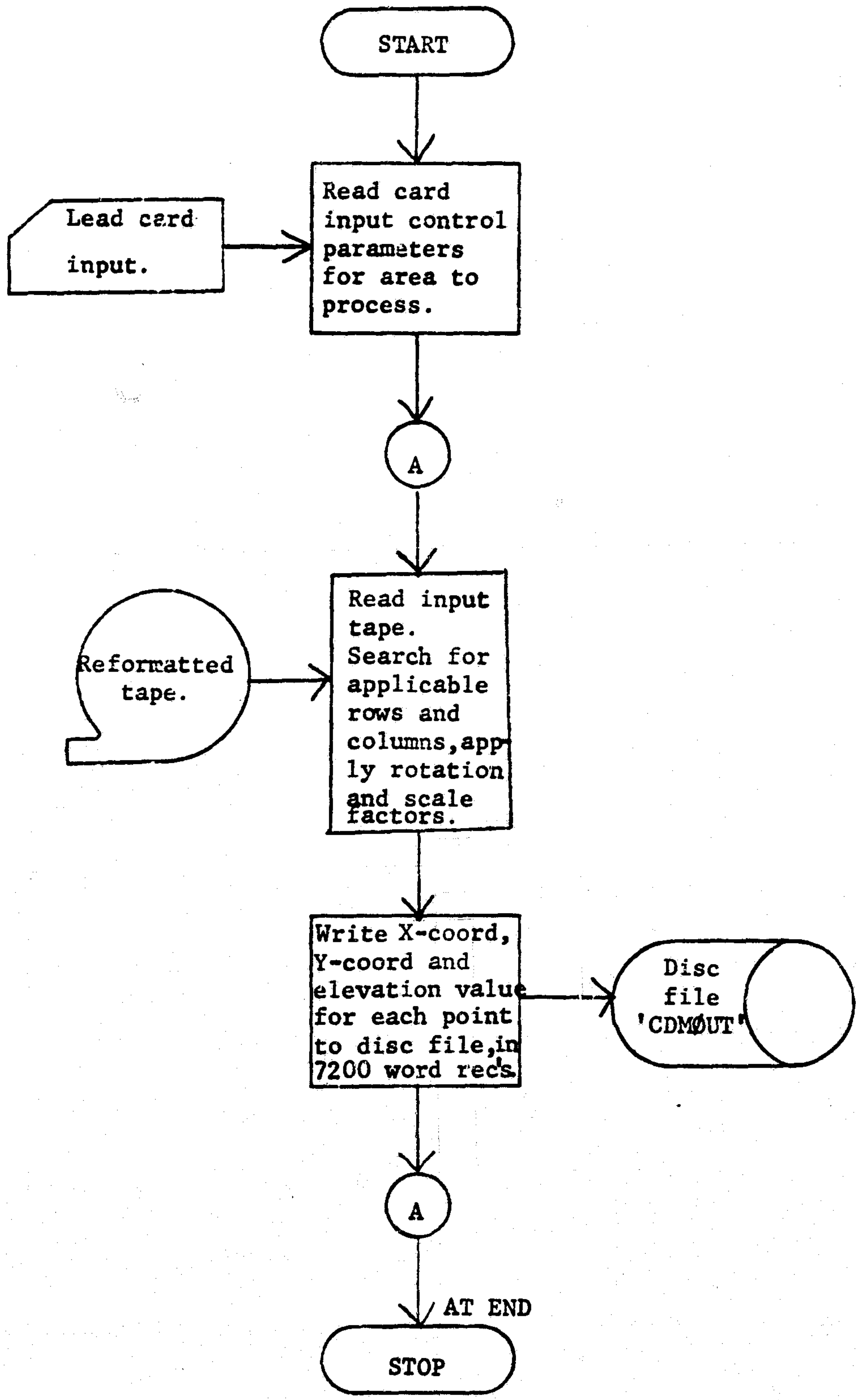
APPENDIX B

PROGRAM FLOW CHARTS

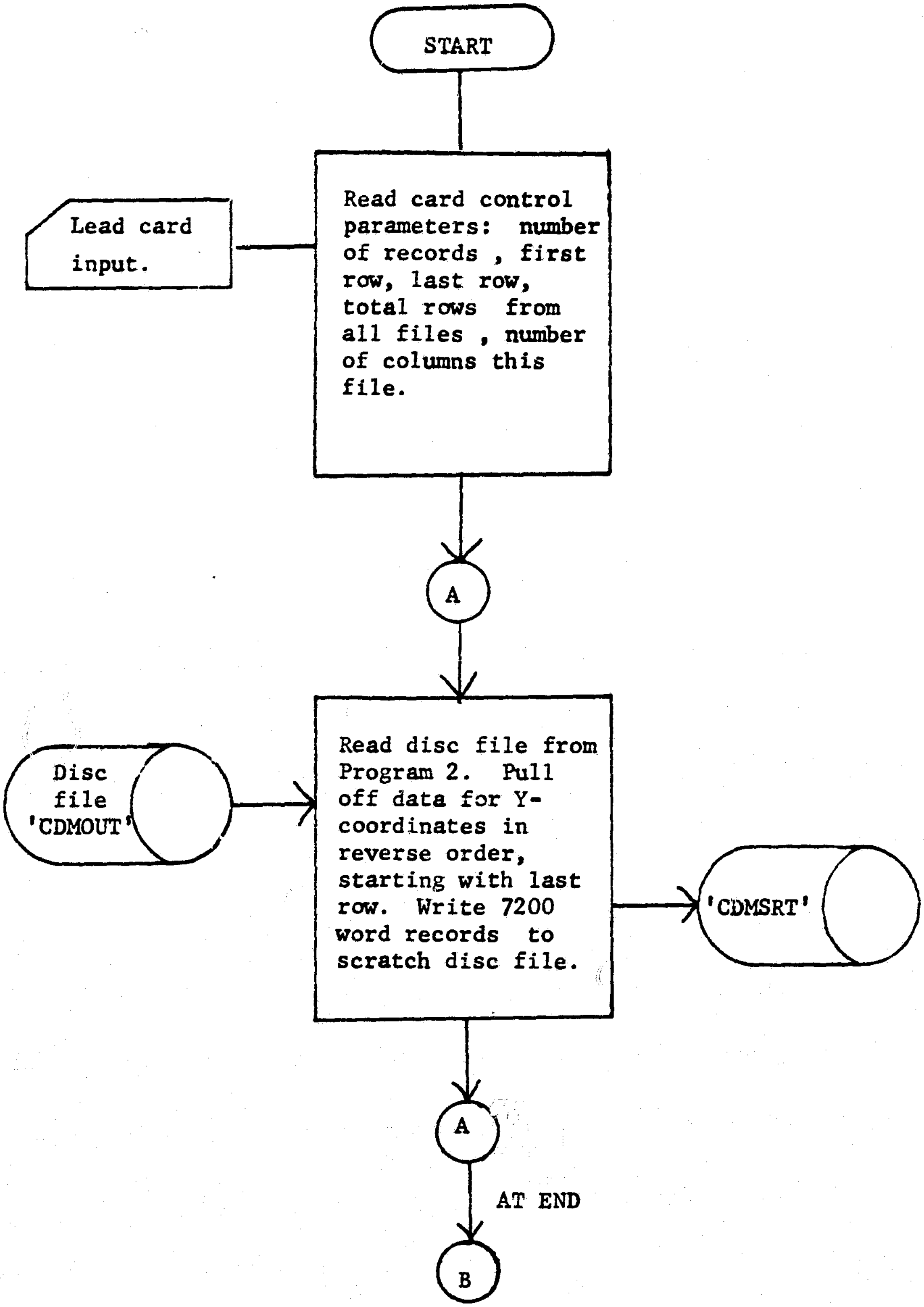
Program 1 - TOPREF



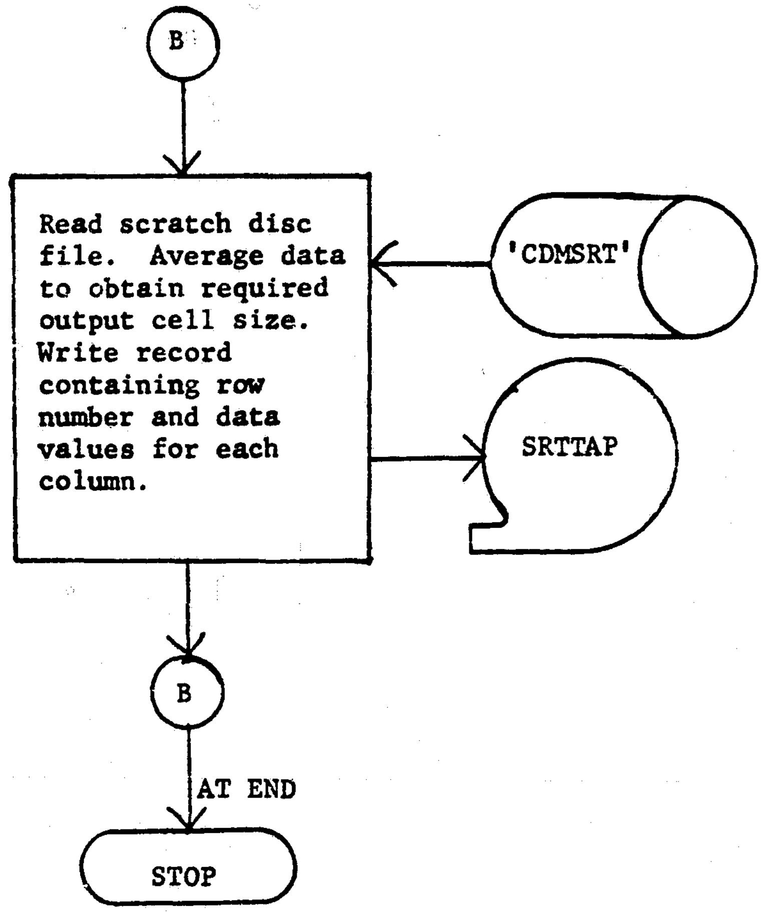
Program 2 - TOPTWO

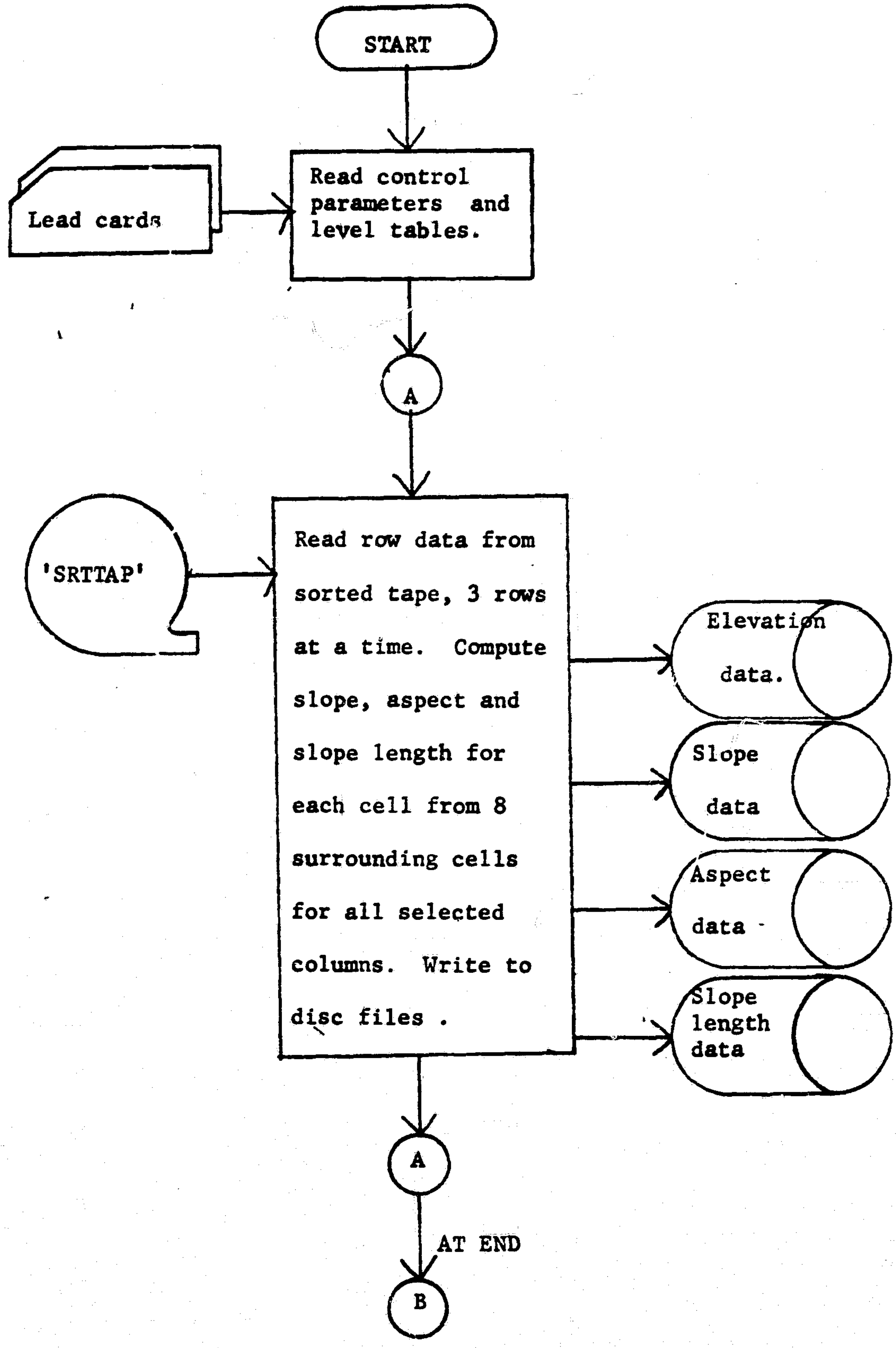


PROGRAM 3 - TOPSRT

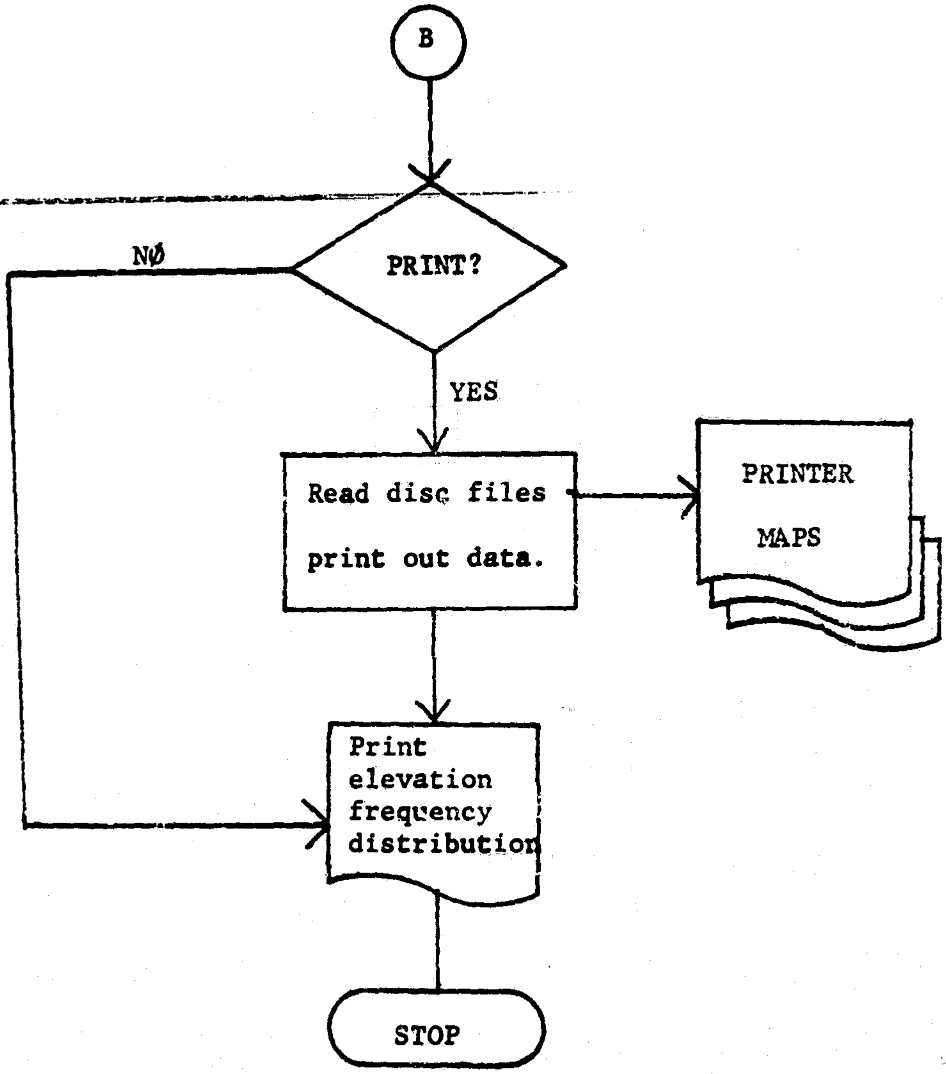


(continued)


B
Read scratch disc file. Average data to obtain required output cell size. Write record containing row number and data values for each column.
'CDMSRT'
SRTTAP
B
AT END
STOP


START
Lead cards
Read control parameters and level tables.
A
'SRTTAP'
Read row data from sorted tape, 3 rows at a time. Compute slope, aspect and slope length for each cell from 8 surrounding cells for all selected columns. Write to disc files .
Elevation data.
Slope data
Aspect data
Slope length data
A
AT END
B

(continued)


B
PRINT?
NØ
YES
Read disc files
print out data.
PRINTER
MAPS
Print
elevation
frequency
distribution
STOP

APPENDIX C

PROGRAM LISTINGS

```
      NAME TOPREF
      TITLE A148A1
      DIMENSION IN(15840),IA(2005),IFN(3)
C
      INTEGER OFN(3)
C
      DATA IFN,OFN/'CD','MA','IN','CD','MO','UT'/
      DATA IBLK/'      '/
 1000 FORMAT(2I6,3I5,9X3I6,' ..(',I5,' )..',3I6)
 1001 FORMAT('  FLAG   REC    X',4X'Y1    YN',13X'Z1     Z2     Z3',
     X 7X'N',7X'ZN-2  ZN-1   ZN')
 1005 FORMAT(1H1)
 1006 FORMAT(//,'   MIN-MAX ELEVATIONS, ',2I10)
      CALL CSINIT
      CALL PAGES
      WRITE(5,1001)
      MIN = 32000
      MAX = -9999
      KR = 0
      IA(2) = 0
      IFL = 0
      IA(1) = IFL
   90 CONTINUE
      DO 95 I = 1,15840
   95 IN(I) = 0
      CALL VSRD(IFN,15840,IN,L)
      IF(L .GT. 0) GO TO 98
      IF(L .EQ. -3) GO TO 900
   98 CONTINUE
      LC = IN(9)
      NWDS = L
      KR = KR + 1
      IF(KR .EQ. 1) GO TO 115
      K = 5
      GO TO 120
  115 K = 46
  120 CONTINUE
C
 130  CONTINUE
      IF (IN(K) .EQ. -1) GO TO 90
      DO 155 L = 6,2005
  155 IA(L) = 0
      I = IN(K+4)
      IA(2) = IA(2) + 1
      IA(3) = IN(K)
      IA(4) = IN(K+1)
      IA(5) = I
      IYN = IA(4) + I - 1
      NL = K+5
      NU = K+I+4
      N = 5
      DO 160 L=NL,NU
      N = N + 1
      IA(N) = IN(L)
      IF (IA(N).GT.MAX) MAX=IA(N)
      IF (IA(N).LT.MIN) MIN=IA(N)
  160 CONTINUE
      WRITE(5,1000) (IA(L),L=1,4),IYN,(IA(L),L=6,8),I,IA(N-2),IA(N-1)
     X ,IA(N)
```


ORIGINAL PAGE IS
OF POOR QUALITY

```
  165 CALL V$WR(OFN,2005,IA,L)
      IF(L .EQ. -2) GO TO 165
      K = K+(IN(K-2)/2)
      IF(K .GT. NWDS) GO TO 90
      GO TO 130
C
  900 CONTINUE
      WRITE(5,1006) MIN,MAX
      WRITE(5,1005)
      CALL V$EF(OFN)
      CALL V$EF(OFN)
      CALL V$RE(IFN)
      CALL V$RE(OFN)
      STOP
      END
```

```
      NAME TOPTWO
      TITLE B148A1
      INTEGER OFN
      DOUBLE PRECISION XO,YO,XE,YE,XORG,YORG,X1,Y
      DOUBLE PRECISION YM,BY,XM,BX,CON,DBL1,DBL2
      DOUBLE PRECISION XC,YC,XP,YP,SX,SY,XPP,YPP
      DOUBLE PRECISION SYL,SYR,SXB,SXT,XOR,YOR,XCELL
      DOUBLE PRECISION DELTA, THETA, YC1
      DIMENSION IFN(3),OFN(3),Y(2000),YA(2000),IA(2005),IB(7200)
      EQUIVALENCE (IFLAG,IA(1)),(IR,IA(2)),(LX,IA(3))
     X           ,(LY,IA(4)),(N,IA(5))
      DATA CON/0.017453292D0/
      DATA IFN,OFN/'CD','MA','IN','CD','MO','UT'/
 1000 FORMAT(' OUTPUT UTM ORIGIN ',2D15.9/
     X       ' UPPER RIGHT LIMITS',2D15.9,/
     X       ' DMAATC UTM ORIGIN ',2D15.9/)
 1001 FORMAT(6D12.2)
 1002 FORMAT(I5,3F10.0)
 1003 FORMAT(/' RUN COMPLETE - WROTE',I5,' RECORDS'/,
     X' FIRST ROW =    ',I5,'   LAST ROW =    ',I5/,
     X' FIRST COLUMN =',I5,'   LAST COLUMN =',I5/)
 1005 FORMAT(/' FIRST X',I6,'   FIRST Y',I6/)
 1006 FORMAT(4I5,5F15.2)
 1007 FORMAT(3X'IN  OUT  COL   J',12X'X',13X'Y(1)',11X'Z(1)',11X'Y(J)',
     X 11X'Z(J)'/)
 1010 FORMAT(2D20.10,I1)
 1011 FORMAT(2F10.0)
 1012 FORMAT(4D20.10)
 1013 FORMAT(4F10.0)
 1100 FORMAT(1X,'CALCULATED TOTAL NUMBER OF ROWS OUTPUT =',I5,/,
     *          1X,'CALCILATED NUMBER OF COLUMNS OUTPUT =',I5,/,
     *          1X,'ROW TO START PROCESSING ',I5,/,
     *          1X,'OUTPUT CELL SIZE ',F6.2,' METERS',/,
     *          1X,'COLUMN BIAS ',F10.2,/,
     *          1X,'ROW BIAS ',F10.2,' METERS')
 1102 FORMAT('      DELTA =    ',D20.7,/,
     *       '      THETA =    ',D20.7,/,
     *       '      QUAD FLAG = ',I1,/,
     *       '      XORI =     ',F12.2,/,
     *       '      YORI =     ',F12.2)
 1103 FORMAT('      SYL =      ',D20.10,/,
     *       '      SYR =      ',D20.10,/,
     *       '      SXB =      ',D20.10,/,
     *       '      SXT =      ',D20.10,/,
     *       '      XL  =      ',F12.2,/,
     *       '      XR  =      ',F12.2,/,
     *       '      YB  =      ',F12.2,/,
     *       '      YT  =      ',F12.2)
      CALL CSINIT
      CALL PAGE8
      READ(4,1001)XO,YO,XE,YE,XORG,YORG
      READ(4,1002) ISTART,CELL,CB,RB
      READ(4,1010) DELTA,THETA,LQ
      READ(4,1011) XORI,YORI
      READ (4,1012) SYL,SYR,SXB,SXT
      READ (4,1013) XL,XR,YB,YT
      IF (ISTART.EQ.0) ISTART=1
      NROW = ((YE-YO)/CELL)+1.
      NCOL =  (XE-XO)/CELL
```

```
      WRITE(5,1000) XO,YO,XE,YE,XORG,YORG
      WRITE(5,1100) NROW,NCOL,ISTART,CELL,CB,RB
      WRITE(5,1102) DELTA,THETA,LO,XORI,YORI
      WRITE(5,1103) SYL,SYR,SXB,SXT,XL,XR,YB,YT
C
      LROW = NROW
      KROW = 0
      XCELL = CELL
      THETA = THETA*CON
      DELTA = DELTA*CON
      DBL1 = CB
      XO = XO+DBL1
      XE = XE+DBL1
      DBL1 = RB
      YO = YO+DBL1
      YE = YE+DBL1
      DBL1 = XR
      DBL2 = XL
      YM = (SYR-SYL)/(DBL1-DBL2)
      BY = SYL-YM*DBL2
      DBL1 = YT
      DBL2 = YB
      XM = (SXT-SXB)/(DBL1-DBL2)
      BX = SXB-XM*DBL2
      ICN = 0
      IVL = 0
      NRO = 0
      IXC = 1
      A = 0.0
      YCI = 0.0D0
      IYP = 0
      IYL = 1
      NLIN = 65
      DBL1 = DSIN(DELTA)
      DBL2 = DCOS(DELTA)
  200 CONTINUE
      CALL V$RD(IFN,2005,IA,IST)
      IF(IST .GT. 0) GO TO 205
      IF(IST .EQ. -3) GO TO 200
  205 CONTINUE
      IF(LX .LT. 1) GO TO 200
      ICN = ICN + 1
      IF(ICN .LT. ISTART) GO TO 200
      IF(ICN .GT. ISTART) GO TO 220
      XC = LX
      YC = LY
      WRITE(5,1005) LX,LY
      CALL PAGE$
  220 CONTINUE
      XP = LX
      YP = YC
      XOR = XORI
      YOR = YORI
      XP = XP-XOR
      YP = YP-YOR
      IF (LO) 230,225,230
  225 YPP = (XP*DBL1) - (YP*(DBL1*DBL1)/DBL2) + (YP/DBL2)
      XPP = (XP*DBL2)-(YP*DBL1)
```

```
      GO TO 235
C
  230 YPP = (-XP*DBL1) - (YP*(DBL1*DBL1)/DBL2) + (YP/DBL2)
      XPP = (XP*DBL2)+(YP*DBL1)
  235 CONTINUE
      SX = XM*YPP+BX
      SY = YM*XPP+BY
      X1 = XPP*SX+XORG
      IF (X1.LT.XO) GO TO 200
      IF (X1.GT.XE) GO TO 280
      Y(1) = YPP*SY+YORG
      YA(1) = IA(6)
      N1 = 7
      DO 240 I = 2,N
      Y(I) = Y(I-1)+SY
      YA(I) = IA(N1)
      N1 = N1 + 1
  240 CONTINUE
      IVL = IVL+1
      J = 0
      DO 252 I = 1,N
      IF(Y(I) .LT. YO) GO TO 252
      IF(Y(I) .GT. YE) GO TO 255
      J = J + 1
      Y(J) = Y(I)
      YA(J) = YA(I)
  252 CONTINUE
  255 CONTINUE
      IX = (X1-XO)/CELL + 1.
      IF (IX.LE.0) GO TO 200
      IF (IX.GT.NCOL) GO TO 280
      IF(NLIN .LT. 55) GO TO 261
      CALL PAGES
      WRITE(5,1007)
      NLIN = 0
  261 CONTINUE
      XX = X1
      Y11 = Y(1)
      Y12 = YA(1)
      YJ1 = Y(J)
      YJ2 = YA(J)
      NLIN = NLIN + 1
      WRITE(5,1006) IR,IVL,IX,J,XX,Y11,Y12,YJ1,YJ2
      IF(IVL .EQ. 1) ICOL = IX
      DO 270 I = 1,J
      IY = (Y(I) - YO)/XCELL + 1.
      IF(IY .LE. 0) GO TO 270
      IF(IY .GT. NROW) GO TO 200
      IF(IYL .EQ. 1) IROW = IY
      IF(IYL.EQ.1 .OR. IYL.EQ.2) GO TO 262
      IF(IY .NE. IYP) GO TO 265
  262 CONTINUE
      A = A + ABS(YA(I)) + .1
      IYL = 3
      IXP = IX
      IYP = IY
      IC1 = IC1 + 1.D0
      GO TO 270
```

```
 265  YCS = YC1
      IF (IYP.GT.KROW) KROW=IYP
      IB(IXC+2) = A/YCS
      IB(IXC+1) = IYP
      IB(IXC) = IXP
      A = 0.0
      YC1 = 0.0D0
      IXC = IXC + 3
      IF(IXC .LE. 7200) GO TO 262
      CALL VSWR(OFN,7200,IB,IST)
      IXC = 1
      IF(IST .EQ. -4) GO TO 280
      NRO = NRO + 1
      GO TO 262
  270 CONTINUE
      IYL = 2
C
      IF (IYP.GE.LROW) GO TO 200
      NXTP = IYP
      DO 275 K = NXTP,LROW
      IB(IXC) = IXP
      IB(IXC+1) = K
      IB(IXC+2) = 0
      IXC = IXC+3
      IF (IXC.LE.7200) GO TO 275
      CALL VSWR(OFN,7200,IB,IST)
      IXC = 1
      IF (IST.EQ.-4) GO TO 280
      NRO = NRO+1
  275 CONTINUE
      GO TO 200
  280 CONTINUE
      IF (IX.GT.NCOL) IX = IX-1
      LCOL = IX
      IF(IXC .EQ. 1) GO TO 290
      DO 285 I = IXC,7200
  285 IB(I) = 0
      CALL VSWR(OFN,7200,IB,IST)
      NRO = NRO + 1
  290 CONTINUE
      CALL VSEF(OFN)
      WRITE(5,1003) NRO,IROW,KROW,ICOL,LCOL
      STOP
      END
```

```
      NAME TOPSRT
      TITLE C148A1
      INTEGER ODAT,OFN,OST
      DIMENSION IDAT(7200),ODAT(7200),IFN(3),OFN(3)
      DIMENSION AR(1080),IFAR(3)
      DATA IFN,OFN/'CD','MO','UT','CD','MS','RT'/
      DATA IFAR/'SR','TT','AP'/
 1000 FORMAT(5I5)
 1001 FORMAT(/' NO. RCDS. ON O/P DISC FILE',I5/)
 1002 FORMAT(20X,I6)
 1003 FORMAT(/' NO. RCDS. ON O/P TAPE FILE',I5/)
 1004 FORMAT('1   EXIT - SEARCHING FOR ROW VALUE ',I4,' ON INPUT RECORD
     *',I4,'   N = ',I5,/)
 1100 FORMAT('0  NUMBER OF RECORDS OUTPUT, IN ERROR.  NO TAPE OUT.')
 1006 FORMAT('1  INPUT PARAMETERS -',/,
     *      '      NRECS      ',I5,/,
     *      '      FIRST ROW ',I5,/,
     *      '      LAST ROW  ',I5,/,
     *      '      OF TOTAL ROWS ',I5,/,
     *      '      NCOLS     ',I5,/)
 1007 FORMAT(10X,'MOD 10 ROWS WRITTEN TO SRTTAP -')
 1008 FORMAT('0   NORMAL EXIT, PART 1, SEARCHING FOR ROW VALUE (',I4,')
     * ON INPUT RECORD ',I4,/)
 1009 FORMAT('   WRITE CDMSRT REC ',I4,'   LAST INPUT ROW = ',I6)
C
      CALL C$INIT
      READ (4,1000) NREC,IROW,LROW,NTROWS,NCOL
      WRITE(5,1006) NREC,IROW,LROW,NTROWS,NCOL
      ISKP = (NTROWS-LROW)*3
      NRO = 0
      IQUIT = 0
      NROW = LROW-IROW+1
      NSK = NROW * 3
      KK = LROW + 1
      M = 1
C
C
      DO 300 K = IROW,LROW
      K = K
      KK = KK - 1
      N = (NROW+IROW-K)*3 - 1
      IF(N .GT. 7200) GO TO 95
      NRRD = 0
      CALL V$FC(IFN,0,1)
      CALL V$RD(IFN,7200,IDAT,IST)
      NRRD = NRRD + 1
      IF(IDAT(N) .NE. KK) GO TO 93
   70 CONTINUE
      ODAT(M) = IDAT(N-1)
      ODAT(M+1) = IDAT(N)
      ODAT(M+2) = IDAT(N+1)
      M = M+3
      IF(M .LT. 7200) GO TO 90
   80 CALL V$WR(OFN,7200,ODAT,OST)
      IF(OST .EQ. -4) GO TO 350
      IF(OST .EQ. -2) GO TO 80
      NRO = NRO + 1
      WRITE(5,1009) NRO,K
      IF (IQUIT.EQ.1) GO TO 350
```

```
      M = 1
      DO 85 I = 1,7200
   85 ODAT(I) = 0
   90 CONTINUE
      N=N+NSK+ISKP
      IF (N.LT.7200) GO TO 91
      IF (N.GT.7202) GO TO 95
      N = N-3
   91 CONTINUE
      IF(IDAT(N)    .EQ. KK) GO TO 70
   93 CONTINUE
      LL = N - 30
      IF(LL .LT. 2) LL = 2
      LU = N + 30
      IF(LU .GT. 7199) LU = 7199
      DO 92 I = LL,LU,3
      IF(IDAT(I) .NE. KK) GO TO 92
      IDIF = I-N
      NSK = NSK+IDIF
      N = I
      GO TO 70
   92 CONTINUE
      IF(LU .EQ. 7199) GO TO 94
      IF (KK.NE.IROW) GO TO 96
      WRITE(5,1008) KK,NRRD
  97  IQUIT = 1
      IF (M-1) 350,350,80
  96  CONTINUE
      IF (NRRD.EQ.NREC) GO TO 295
      WRITE(5,1004) KK,NRRD,N
      GO TO 97
C
   94 CONTINUE
      N = 7202
   95 CONTINUE
      NRRD = NRRD + 1
      IF(NRRD .GT. NREC) GO TO 295
      N = N-7200
      CALL V$RD(IFN,7200,IDAT,IST)
      GO TO 91
  295 CONTINUE
  300 CONTINUE
  350 CONTINUE
      CALL V$EF(OFN)
      WRITE(5,1001) NRO
      NRM5 = NREC-5
      IF (NRO.GE.NRM5) GO TO 375
      WRITE(5,1100)
      GO TO 800
C
  375 WRITE(5,1007)
      CALL V$FC(OFN,0,1)
      NRT = 0
      IC = 0
  400 CONTINUE
      CALL V$RD(OFN,7200,ODAT,OST)
      IF(OST.EQ.-3 .OR. OST.EQ.-8) GO TO 800
      DO 500 I = 1,7200,3
```

```
      IC = IC + 1
      IF(IC .GT. 1) GO TO 410
  403 CONTINUE
      IY = ODAT(I+1)
      IF(IY .EQ. 0) GO TO 500
  405 CONTINUE
      IX = ODAT(I)
      SUM = 0.
      XN = 0.
  410 CONTINUE
      IF(ODAT(I+1) .EQ. 0) GO TO 500
      IF(IY .NE. ODAT(I+1)) GO TO 450
      IF(IX .NE. ODAT(I)) GO TO 420
      XN = XN+1.0
      SUM = SUM + ODAT(I+2)
      GO TO 500
  420 CONTINUE
      AR(IX+1) = SUM/XN
      GO TO 405
  450 CONTINUE
      AR(IX+1) = SUM/XN
      AR(1) = IY
      MO = MOD(IY,10)
      IF (MO.EQ.0) WRITE(5,1002) IY
      CALL VSWR(IFAR,2160,AR,IST)
      NRT = NRT + 1
      DO 480 J = 1,NCOL
      AR(J) = 0.0
  480 CONTINUE
      GO TO 403
  500 CONTINUE
      IC = 1
      GO TO 400
  600 CONTINUE
      AR(IX+1) = SUM/XN
      AR(1) = IY
      WRITE(5,1002) IY
      CALL VSWR(IFAR,2160,AR,IST)
      NRT = NRT + 1
      WRITE(5,1003) NRT
      CALL VSEF(IFAR)
      CALL VSEF(IFAR)
  800 CONTINUE
      STOP
      END
```

```
      NAME TOPODB
      TITLE D148A1
      INTEGER EFN,SFN,AFN
      DIMENSION AR(1080),IXELV(1080),IXSLP(1080),IXASP(1080)
      DIMENSION ELEC(1000,3),AP(8),DIFF(8),DIST(8),ICH(20),IASP(9)
      DIMENSION PARM(2),ELE(2),SLO(2),ASP(2),IFN(3),EFN(3),SFN(3),AFN(3)
      DIMENSION XSSL(20),XESL(20),XSEL(254),XEEL(254)
      DIMENSION IXLEN(1080),LFN(3),SLEN(2)
      DIMENSION ELF(254)
      DATA ELF/254*0.0/
      DATA LFN/'LN','DA','TA'/
      DATA SLEN/'S.LE','NGTH'/
      DATA ELE,SLO,ASP/'ELEV','.','SLOP','E','ASPE','CT'/
      DATA IFN,EFN,SFN,AFN/'SR','TT','AP','EL','DA','TA','SL','DA','TA'
     X ,'AS','DA','TA'/
  510 FORMAT(1H ,2A4,' DATA      COLUMNS',I5,' TO ',I5)
  511 FORMAT(' (DIVIDED BY 10)')
  530 FORMAT(1XI4,1X120A1)
  531 FORMAT(1XI4,1X120I1)
  540 FORMAT(I5,1X,30I4)
 1001 FORMAT(3I5,F10.2,4X,I1)
 1002 FORMAT(3I5)
 1003 FORMAT(10F8.0)
 1004 FORMAT(10I2)
 1100 FORMAT('1 INPUT COLUMNS TO PROCESS = ',2I7,/,
     *       ' INPUT STARTING ROW = ',I5,/,
     *       ' CELL SIZE = ',F8.2,/,
     *       ' PROCESSING OPTION = ',I1,//,
     *       ' NUMBER OF ROWS OUTPUT = ',I5,'   FROM ',I5,' TO ',I5,/,
     *       I5,' COLUMNS OUTPUT NUMBERED FROM ',I5,' TO ',I5,/)
 1199 FORMAT('OELEVATION LEVELS COMPUTED IN INCREMENTS OF ',F6.1,
     *       ' FROM ',F8.1,' TO ',F8.1,/,
     *                  LEVEL',16X,'ST. ELV.',15X,'END ELV.',/)
 1200 FORMAT(' NUMBER OF QUANTUM LEVELS FOR SLOPE',I5,/,
     * 8X,'LEVEL',17X,'ST.SL.',15X,'END SL.',/)
 1201 FORMAT(5X,I3,5X,A1,2X,2(12X,F10.1))
 1202 FORMAT(I6,2X,2(12X,F10.1))
 1400 FORMAT(1X,'ASPECT OUTPUT (CLOCKWISE FROM NORTH) ',9I4)
 1500 FORMAT('  PRINT OPT. =',I2,'    SLOPE LENGTH PRINT OPT. =',I2,/,
     X       ' 0 - NO,  1 = YES')
 2001 FORMAT(' ** ERROR  ** SLOPE =',F12.1,'  IX =',I6,'  IY =',I6)
 2002 FORMAT(' ** ERROR  ** ELEV. =',F12.1,'  IX =',I6,'  IY =',I6)
 2005 FORMAT('1  *** ELEVATION DISTRIBUTION ***',//,
     *       '            LEVEL   TOTAL CELLS')
 2006 FORMAT(10X,I3,F15.0)
C
C
C          CARD INPUT -
C
C          CARD 1
C            COLS 1-5     (I5)    ROW NUMBER ON INPUT FILE TO START
C                                 PROCESSING.  DEFAULT = 1.
C            COLS 6-10     -      STARTING COLUMN NUMBER TO PROCESS ON
C                                 INPUT FILE.
C            COLS 11-15           STOP COLUMN ON INPUT FILE.
C            COLS 16-25   (F10.2) CELL SIZE.
C            COL 30       (I1)    PROCESSING OPTION -
C                                 0 = PROCESS ALL
C                                 1 = ELEVATION DATA ONLY
```

```
C                                  2 = SLOPE, ASPECT, SL.LENGTH ONLY
C
C          CARD 2
C            COLS 1-5     (I5)     STARTING ROW NUMBER FOR OUTPUT.
C            COLS 6-10    (I5)     ENDING ROW NUMBER FOR OUTPUT.
C            COLS 11-15   (I5)     COLUMN BIAS FOR SHIFTING OUTPUT.
C
C          CARD 3 - (COMPUTES A MAX OF 254 LEVELS)
C
C            COLS 1-8     (F8.0)   STARTING ELEVATION LEVEL
C            COLS 9-16    (F8.0)   ENDING ELEVATION LEVEL
C            COLS 17-24   (F8.0)   ELEV. LEVEL INCREMENT
C
C          CARD 4
C            COLS 1-5     (I5)     NUMBER OF SLOPE LEVELS, INPUT TO FOLLOW.
C                                  MAX 20
C
C          CARDS 5 - (6)
C            COLS 1-8     (F8.0)   START SLOPE LEVEL (1)
C            COLS 9-16    (F8.0)   START SLOPE LEVEL (2)
C            COLS 17-24   (F8.0)   START SLOPE LEVEL (3)
C            COLS 25-32   (F8.0)   START SLOPE LEVEL (4)
C            COLS 33-40   (F8.0)   START SLOPE LEVEL (5)
C            COLS 41-48   (F8.0)   START SLOPE LEVEL (6)
C            COLS 49-56   (F8.0)   START SLOPE LEVEL (7)
C            COLS 57-64   (F8.0)   START SLOPE LEVEL (8)
C            COLS 65-72   (F8.0)   START SLOPE LEVEL (9)
C            COLS 73-80   (F8.0)   START SLOPE LEVEL (10)
C                             INPUT 1 OR 2 CARDS DEPENDING ON CARD 4.
C                             (10 PER CARD)
C
C          CARD 7   ASPECT OUTPUT PARAMETERS
C            COLS 1-2     (I2)     NUMBER CODE FOR UNDETERMINED
C            COLS 3-4     (I2)     NUMBER CODE FOR NORTH
C            COLS 5-6     (I2)     NUMBER CODE FOR NE
C            COLS 7-8     (I2)     NUMBER CODE FOR E
C            COLS 9-10    (I2)     NUMBER CODE FOR SE
C            COLS 11-12   (I2)     NUMBER CODE FOR S
C            COLS 13-14   (I2)     NUMBER CODE FOR SW
C            COLS 15-16   (I2)     NUMBER CODE FOR W
C            COLS 17-18   (I2)     NUMBER CODE FOR NW
C
C          CARD 8 - PRINT OPTIONS
C                   0 = NO     1 = YES
C            COL 2   PRINT ELEVATION, SLOPE AND ASPECT MAPS
C            COL 4   PRINT SLOPE LENGTH CALCULATIONS.
C
C
      CALL CSINIT
      CALL PAGES
      READ (4,1001) ISR,ICOL,LCOL,CELL,IOPT
      READ(4,1002) IROW,LROW,ICBIAS
      IF (IOPT.EQ.2) GO TO 5
      READ(4,1003) STELV,ENDELV,ENCR
      IF (IOPT.EQ.1) GO TO 10
    5 READ(4,1002) NSL
      READ(4,1003)(XSSL(I),I=1,NSL)
      READ(4,1004)IASP
```

```
   10 READ(4,1004) IPO,ISLOP
      IF (IOPT.EQ.2) GO TO 38
      ENDELV = ENDELV+ENCR-1.
   20 NEL = ((ENDELV-STELV)/ENCR)+2.
      IF (NEL.LE.254) GO TO 30
      ENCR = ENCR+10.
      GO TO 20
   30 XSEL(1) = 0.
      XEEL(1) = STELV
      XSEL(2) = STELV
      XEEL(2) = XEEL(1) + ENCR
      DO 35  I = 3,NEL
      XSEL(I) = XSEL(I-1)+ENCR
      XEEL(I) = XEEL(I-1)+ENCR
   35 CONTINUE
      XEEL(NEL) = 99999.
      IF (IOPT.EQ.1) GO TO 42
   38 NL = NSL-1
      DO 40  I = 1,NL
      XESL(I) = XSSL(I+1)
   40 CONTINUE
      XESL(NL+1) = 99999.
C
   42 CONTINUE
      NROW = LROW-IROW+1
      NCOL = LCOL-ICOL+1
      IF (ISR.EQ.0) ISR=1
      NR = NROW+ISR-1
      IC = ICOL + ICBIAS
      LC = LCOL + ICBIAS
      WRITE(5,1100) ICOL,LCOL,ISR,CELL,IOPT,NROW,IROW,LROW,NCOL,IC,LC
      IF (IOPT.EQ.2) GO TO 150
      WRITE(5,1199) ENCR,STELV,XSEL(NEL)
      IF (NEL.LE.26) GO TO 146
      DO 140 I = 1,NEL
      WRITE(5,1202) I,XSEL(I),XEEL(I)
  140 CONTINUE
      GO TO 150
  146 DO 147 I = 1,NEL
      IL = LSL(I+192,8)
      WRITE(5,1201) I,IL,XSEL(I),XEEL(I)
  147 CONTINUE
C
  150 CONTINUE
      IF (IOPT.EQ.1) GO TO 1705
      WRITE(5,1200) NSL
      NL = NSL
      DO 170 I = 1,NL
      IL = LSL(I+192,8)
      WRITE(5,1201) I,IL,XSSL(I),XESL(I)
  170 CONTINUE
      WRITE(5,1400) IASP
 1705 WRITE(5,1500) IPO,ISLOP
      MROW = IROW-1
      LO = 1
      ISTP = 0
      KTR = 0
      M = 0
```

```
      N3 = 0
      NCL = NCOL + 1
      DO 171 I = 1,1080
      IXELV(I) = 0
      IXSLP(I) = 0
      IXASP(I) = 0
      IXLEN(I) = 0
  171 CONTINUE
C
C   ***   COMPUTE DIST BASED ON CELL SIZE
      DO 50 I = 1,8
      DIST(I) = CELL
      IF(MOD(I,2) .EQ. 0) DIST(I) = 1.414214*CELL
   50 CONTINUE
      IXELV(2) = IC
      IXSLP(2) = IC
      IXASP(2) = IC
      IXLEN(2) = IC
      IXELV(3) = LC
      IXSLP(3) = LC
      IXASP(3) = LC
      IXLEN(3) = LC
C
C   ***   READ INPUT FILE INTO ROTATING BUFFER
C   ***   REPEAT FIRST AND LAST RECORDS
C
  100 CONTINUE
      IF(M .EQ. 1) GO TO 110
      KTR = KTR+1
      IF (KTR.GT.NR) GO TO 105
      CALL V$RD(IFN,2160,AR,IST)
      IF (KTR.LT.ISR) GO TO 100
      IF(IST .GT. 0) GO TO 110
      IST = -IST
      GO TO(110,110,105,105,110,400),IST
  105 CONTINUE
      ISTP = 1
      LO = 3
  110 CONTINUE
      IY = AR(1) + 1
      M = M + 1
      N3 = N3 + 1
      IF(N3 .GT. 3) N3 = 1
      N2 = N3 - 1
      IF(N2 .EQ. 0) N2 = 3
      N1 = N2 - 1
      IF(N1 .EQ. 0) N1 = 3
      IF(ISTP .EQ. 1) GO TO 125
      DO 120 I = 1,LCOL
      ELEC(I,N3) = AR(I+1)
  120 CONTINUE
      GO TO 145
  125 CONTINUE
      DO 130 I = 1,LCOL
      ELEC(I,N3) = ELEC(I,N2)
  130 CONTINUE
  145 CONTINUE
      IF(M .LT. 3) GO TO 100
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
C
      N = 4
C     ***  EXTRACT DATA FOR SLOPE COMPUTATION
      DO 300 I = ICOL,LCOL
      K = I - 1
      IF (K.LT.ICOL) K=ICOL
      L = I + 1
      IF(L .GT. LCOL) L = LCOL
      XXEL = ELEC(I,N2)
      IF (IOPT.EQ.1) GO TO 230
      AP(8) = ELEC(K,N1)
      AP(1) = ELEC(I,N1)
      AP(2) = ELEC(L,N1)
      AP(7) = ELEC(K,N2)
      AP(3) = ELEC(L,N2)
      AP(6) = ELEC(K,N3)
      AP(5) = ELEC(I,N3)
      AP(4) = ELEC(L,N3)
      XMAX = 0.
      JJ = 0
      DO 160 J = 1,8
      DIFF(J) = ABS(XXEL-AP(J))
      XDIFF = DIFF(J)/DIST(J)
      IF(XDIFF .LT. XMAX) GO TO 160
      XMAX = XDIFF
      JJ = J
  160 CONTINUE
      IF (JJ.NE.0) GO TO 180
      SLLEN = 0.0
      GO TO 190
 180  SLLEN = SQRT((DIST(JJ)*DIST(JJ)) + (DIFF(JJ)*DIFF(JJ)))
 190  SLOPE = 30.48*XMAX
      IF(XMAX .EQ. 0.) JJ = 0
      DO 210 K = 1,NSL
      KK = K
      IF(SLOPE.GE.XSSL(K) .AND. SLOPE.LT.XESL(K)) GO TO 220
  210 CONTINUE
      WRITE(5,2001) SLOPE,I,IY
  220 CONTINUE
      IXSLP(N) = KK
      IXASP(N) = IASP(JJ+1)
      IXLEN(N) = (SLLEN/10.)+0.5
      IF (IXLEN(N).GT.255) IXLEN(N)=255
      IF (IOPT.EQ.2) GO TO 290
C
C           DO ELEVATIONS
 230  CONTINUE
      DO 260 K = 1,NEL
      MM = K
      IF(XXEL.GE.XSEL(K) .AND. XXEL.LT.XEEL(K)) GO TO 270
  260 CONTINUE
      WRITE(5,2002) XXEL,I,IY
  270 CONTINUE
      IXELV(N) = MM
      ELF(MM) = ELF(MM)+1.
 290  N = N+1
  300 CONTINUE
      MROW = MROW+1
```

```
      IF (MROW.GT.LROW) GO TO 400
      IXELV(1) = MROW
      IXSLP(1) = MROW
      IXASP(1) = MROW
      IXLEN(1) = MROW
      IF (IOPT.EQ.2) GO TO 320
      CALL VSWR(EFN,1080,IXELV,IST)
      IF(IST .EQ. -4) GO TO 350
      IF (IOPT.EQ.1) GO TO 330
  320 CALL VSWR(SFN,1080,IXSLP,IST)
      CALL VSWR(AFN,1080,IXASP,IST)
      CALL VSWR(LFN,1080,IXLEN,IST)
  330 M = 2
      LO = 2
      IF(ISTP .EQ. 0) GO TO 100
      GO TO 400
  350 CONTINUE
      IF (IOPT.EQ.2) GO TO 360
      CALL VSSR(EFN,1,1)
      IF (IOPT.EQ.1) GO TO 400
  360 CALL VSSR(SFN,1,1)
      CALL VSSR(AFN,1,1)
      CALL VSSR(LFN,1,1)
  400 CONTINUE
      IF (IOPT.EQ.2) GO TO 405
      CALL VSEF(EFN)
      IF (IOPT.EQ.1) GO TO 410
  405 CALL VSEF(SFN)
      CALL VSEF(AFN)
      CALL VSEF(LFN)
C
C   ***  PRINT   DATA    ***********************************************
C
  410 CONTINUE
      IF (IPO.EQ.0) GO TO 800
      IF (IOPT.EQ.2) GO TO 590
C
C   ***  PRINT ELEVATION DATA    ***
      IF (NEL.LE.26) GO TO 490
      NRX = (NCOL+29)/30
      DO 480 I = 1,NRX
      CALL VSFC(EFN,0,1)
      CALL PAGES
      IS = (I-1)*30 + ICOL
      IE = IS+29
      IF (IE.GT.LCOL) IE=LCOL
      PARM(1) = ELE(1)
      PARM(2) = ELE(2)
      ISA = IS+ICBIAS
      IEA = IE+ICBIAS
      WRITE(5,510) PARM(1),PARM(2),ISA,IEA
      IS = IS-ICOL+4
      IE = IE-ICOL+4
  420 CALL VSRD(EFN,1080,IXELV,IST)
      IF(IST.EQ.-3 .OR. IST.EQ.-4) GO TO 480
      IY = IXELV(1)
      WRITE(5,540) IY,(IXELV(K),K=IS,IE)
      GO TO 420
```

```
 480  CONTINUE
      NRX = (NCOL+119)/120
      GO TO 590
C
 490  NRX = (NCOL+119)/120
      DO 500 I = 1,NRX
      CALL V$FC(FFN,0,1)
      CALL PAGE$
      IS = (I-1)*120+ICOL
      IE = IS + 119
      IF(IE .GT. LCOL) IE = LCOL
      PARM(1) = ELE(1)
      PARM(2) = ELE(2)
      ISA = IS+ICBIAS
      IEA = IE+ICBIAS
      WRITE(5,510) PARM(1),PARM(2),ISA,IEA
      IS = IS-ICOL + 4
      IE = IE-ICOL + 4
 520  CALL V$RD(FFN,1080,IXELV,IST)
      IF(IST.EQ.-3 .OR. IST.EQ.-4) GO TO 500
      IY = IXELV(1)
      DO 525 K = IS,IE
 525  IXELV(K) = LSL(IXELV(K)+192,8)
      WRITE(5,530) IY,(IXELV(K),K=IS,IE)
      GO TO 520
 500  CONTINUE
C
C    ***  PRINT SLOPE DATA   ********************************************
C
 590  CONTINUE
      IF (IOPT.EQ.1) GO TO 999
      NRX = (NCOL+119)/120
      DO 600 I = 1,NRX
      CALL V$FC(SFN,0,1)
      CALL PAGE$
      IS = (I-1)*120 + ICOL
      IE = IS + 119
      IF(IE .GT. LCOL) IE = LCOL
      PARM(1) = SLO(1)
      PARM(2) = SLO(2)
      ISA = IS+ICBIAS
      IEA = IE+ICBIAS
      WRITE(5,510) PARM(1),PARM(2),ISA,IEA
      IS = IS - ICOL + 4
      IE = IE - ICOL + 4
 620  CALL V$RD(SFN,1080,IXSLP,IST)
      IF(IST.EQ.-3 .OR. IST.EQ.-4) GO TO 600
      IY = IXSLP(1)
      DO 625 K = IS,IE
 625  IXSLP(K) = LSL(IXSLP(K)+192,8)
      WRITE(5,530) IY,(IXSLP(K),K=IS,IE)
      GO TO 620
 600  CONTINUE
C
C    ***  PRINT ASPECT ANGLE DATA   ***************************************
C
      DO 700 I = 1,NRX
      CALL V$FC(AFN,0,1)
```

```
      CALL PAGES
      IS = (I-1)*120 + ICOL
      IE = IS + 119
      IF(IE .GT. LCOL) IE = LCOL
      PARM(1) = ASP(1)
      PARM(2) = ASP(2)
      ISA = IS+ICBIAS
      IEA = IE+ICBIAS
      WRITE(5,510) PARM(1),PARM(2),ISA,IEA
      IS = IS - ICOL + 4
      IE = IE - ICOL + 4
  720 CALL VSRD(AFN,1080,IXASP,IST)
      IF(IST.EQ.-3 .OR. IST.EQ.-4) GO TO 700
      IY = IXASP(1)
      WRITE(5,531) IY,(IXASP(K),K=IS,IE)
      GO TO 720
  700 CONTINUE
  800 CONTINUE
      IF (ISLOP.EQ.0) GO TO 999
C
C  ***  PRINT SLOPE LENGTH *********************
C        30 COLS PER PAGE
C
      NRX = (NCOL+29)/30
      DO 900 I = 1,NRX
      CALL VSFC(LFN,0,1)
      CALL PAGES
      IS = (I-1)*30 + ICOL
      IE = IS+29
      IF (IE.GT.LCOL) IE = LCOL
      PARM(1) = SLEN(1)
      PARM(2) = SLEN(2)
      ISA = IS+ICBIAS
      IEA = IE+ICBIAS
      WRITE(5,510) PARM(1),PARM(2),ISA,IEA
      WRITE(5,511)
      IS = IS-ICOL+4
      IE = IE-ICOL+4
  920 CALL VSRD(LFN,1080,IXLEN,IST)
      IF (IST.EQ.-3 .OR. IST.EQ.-4) GO TO 900
      IY = IXLEN(1)
      WRITE(5,540) IY,(IXLEN(K),K=IS,IE)
      GO TO 920
  900 CONTINUE
  999 CONTINUE
C
C           PRINT ELEVATION FREQUENCY DISTRIB.
C
      IF (IOPT.EQ.2) GO TO 1000
      WRITE(5,2005)
      DO 910 I = 1,NEL
      WRITE(5,2006) I,ELF(I)
  910 CONTINUE
 1000 STOP
      END
ENTRY/COMMON BLOCK NAMES
                      R  000000 TOPODB
EXTERNAL NAMES
```

APPENDIX D

GENERAL INFORMATION CONCERNING DATA SOURCE

GENERAL INFORMATION CONCERNING DATA SOURCE

The NCIC, Office of Research and Standards, Reston, Virginia and the DMATC, Washington, D.C. were contacted in regard to the digital terrain tapes. It was learned that the DMATC prepares two $1^o \times 1^o$ matrices for each 1:250,000-scale quadrangle map. The $\tilde{x}$, $\tilde{y}$ sheet corners and all subsequent readings of each half of a quad map are referenced to an arbitrary coordinate system (ACS). The origin of this ACS is an arbitrary reference point that is different for each $1^o \times 1^o$ area. The approach used at the ERL is to reference the $(\tilde{x},\tilde{y})$ plate readings directly to the UTM grid and then compute coordinates of points in the UTM system directly from the readings. Thus, an angle correction is required for each $1^o \times 1^o$ area.

Further discussions revealed that a photographic process is used to produce a map from the 1:250,000-scale series whereby a "contour" line has a "ditch" type depression. The operator of the digital graphic recorder follows this ditch in the actual extraction of contour data. Further processing involves interpolation of a planar nature. Error sources in the DMATC process are resolution (<10 mils) and operator accuracy (less than resolution error).

It was also verified from the DMATC that there is an "edge" matching problem on the right and left of all quad maps and that the data exhibits a "saw-tooth" effect at the top or bottom edges of quad maps. Since the actual extraction of planar data (x-y plate coordinate readings in inches) is from a non-square map (latitude-longitude map), then the subsequent transformation of these planar data to the regular shaped UTM coordinate system results in these edge and border problems. These problems have been encountered in the research efforts at the ERL. It should be pointed out that these problems are not encountered if the subsequent analysis programs (such as data base programs) are compatible with the latitude-longitude coordinate system.