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FOREST SERVICE, U. S. DEPT. OF AGRICULTURE, 6816 MARKET STREET, UPPER DARBY, PA.

SURBAL: COMPUTERIZED METES AND BOUNDS SURVEYING

Abstract.—A computer program has been developed at West Virginia University for use in metes and bounds surveying. Stations, slope distances, slope angles, and bearings are primary information needed for this program. Other information needed may include magnetic deviation, acceptable closure error, desired map scale, and title designation. SURBAL prints out latitudes and departures, adjusted bearings and line lengths, closure error, acreage, and a plotting of the survey to any selected scale, all at a fraction of the costs for manual methods.

Some of the most tedious, time-consuming, and expensive work in land surveying occurs not in the field with transit and chain, but in the office with notes, mathematical tables, and endless pages of computations. Correcting distances from slope to horizontal, calculating latitudes and departures, determining closure error and acreage—these and other steps in converting field measurements to useful surveys are mathematical operations well suited to automatic processing.

The success enjoyed by other users of electronic equipment for digesting large amounts of data suggested to us the desirability of a computer program specially designed for metes and bounds surveys. Recent development of an electronic plotter capable of reproducing the adjusted survey made this a doubly desirous objective. Land surveyors, enigneers, foresters—anyone concerned with metes and bounds surveying—will find this a useful program—accurate, economical, and amazingly rapid.

What SURBAL[1] Does

SURBAL is a computer program designed to adjust a closed metes and bounds survey, calculate the area within the adjusted survey, and plot the adjusted survey. Any number of surveys, with up to 1,300 lines (calls) in each survey, may be submitted to the computer. The original program calculated latitudes and departures and provided adjusted bearings, adjusted line lengths, closure error, and acreage. It was developed for use on the IBM 7040/7044 computer.

In its present form, SURBAL provides all the preceding information in addition to a plotting of the adjusted survey complete with title, scale, border, and even a north arrow. Besides the computer, SURBAL requires an off-line Calcomp plotter and the Calcomp library subroutines. All this equipment is available at the West Virginia University computer center, where SURBAL was developed.

How to Submit Data

Figure 1 shows how survey data should be submitted to the computer center. Only four kinds of survey information are needed, and these may be submitted in various forms: (1) Station, identification by number, letter, or other convenient designation. (2) Slope distance between stations, in English or metric units (in figure 1 distance is expressed as chains, links, and tenths of links). (3) Slope between stations, expressed in degrees and minutes. (4) Bearing or azimuth between stations, expressed in degrees and minutes.

If the user desires, SURBAL can be modified to accept angle measurements (3) and (4) to seconds. Since these data are punched on cards for use by the computer, it is simplest to transcribe them from survey field notes to tabulation sheets having the same column arrangement as a computer card. These sheets are available from any computer center. In addition to the above survey data, information such as magnetic deviation from true north, the date, and a survey title are needed.

SURBAL users must also specify: (1) plotting scale desired and (2) acceptable error of closure. Plottings may be drawn to any specified scale (1 inch = 100 feet, 1 inch = 5 chains, 1 inch = 10 meters) but the chosen scale may describe a plotting larger than the Calcomp plotting paper (29 inches). In this case, the user may specify that the scale will

[1] Computer program No. 1 is on file at the Northeastern Forest Experiment Station, Biometrics Branch, 6816 Market Street, Upper Darby, Pa. 19082. Complete documentation and source decks also may be obtained from this address.

0	1			0	4	7	2			0	0	0	0			N	8	1	3	0	W
0	2			1	7	7	7			2	8	3	0			N	7	9	3	0	W
0	3			1	4	7	1			2	2	0	0			N	7	5	0	0	W
0	4			2	5	7	7			1	6	3	0			N	5	4	4	5	W
0	5			2	2	3	2			1	1	0	0			N	4	4	3	0	W
0	6			1	9	0	0			1	0	0	0			N	4	8	4	5	W
0	7			2	0	8	9			0	8	3	0			N	5	4	1	5	W
0	8			2	0	9	6			0	8	0	0			N	0	1	3	0	E
0	9			2	5	4	0			0	3	3	0			N	5	2	0	0	E
1	0			2	0	8	7			0	6	0	0			N	1	2	0	0	E
1	1			2	6	0	2			0	8	3	0			N	0	5	3	0	W
1	2			2	4	9	5			0	6	4	5			N	0	3	0	0	W
1	3			4	4	3	9			0	4	0	0			N	1	0	0	0	E
1	4			3	6	2	1			0	1	3	0			N	3	0	0	0	E
1	5			2	6	6	8			0	4	0	0			N	1	0	0	0	E
1	6			1	5	1	9			0	4	3	0			N	2	5	3	0	E
1	7			1	5	4	5			0	3	0	0			N	7	0	0	0	E
1	8			1	7	8	2			0	2	3	0			N	2	5	4	5	E
1	9			0	6	3	3			0	0	0	0			N	2	8	0	0	E
2	0			1	6	9	1			0	2	0	0			S	7	9	3	0	E
2	1			1	9	5	8			0	8	1	5			S	7	5	3	0	E
2	2			1	1	7	1			0	5	1	5			S	8	4	3	0	E
2	3			1	6	1	1			0	4	3	0			S	7	6	0	0	E
2	4			1	4	0	0			0	1	4	5			S	7	1	0	0	E
2	5			2	1	4	6			0	1	4	5			S	6	2	4	5	E
2	6			0	6	0	5			0	2	3	0			S	0	9	3	0	E
2	7			2	7	4	8			0	3	3	0			S	0	1	3	0	W
2	8			2	4	3	5			0	2	4	5			S	0	9	0	0	W
2	9			1	4	0	5			0	1	1	5			S	2	2	0	0	W
3	0			2	5	4	7			0	2	3	0			S	1	7	3	0	W
3	1			3	2	1	1			0	4	3	0			S	0	8	0	0	W
3	2			2	9	1	8			0	7	0	0			S	0	3	3	0	W
3	3			2	2	9	8			1	0	1	5			S	0	9	0	0	W
3	4			3	0	7	9			1	5	4	5			S	1	6	0	0	W
3	5			2	3	3	2			0	7	0	0			S	0	3	4	5	E
3	6			1	4	3	0			0	8	0	0			S	0	0	3	0	W
3	7			1	0	0	0			0	3	0	0			S	0	0	3	0	W
3	8			2	0	4	4			0	8	3	0			S	4	5	3	0	W
3	9			1	1	6	9			1	6	0	0			S	5	4	1	5	W
4	0			2	3	2	3			0	0	0	0			S	7	4	5	0	W

Figure 1.—Card-punching form for submitting field survey notes to computer. The columns are for station, slope distance, vertical angle, and bearing. The unit of slope-distance measurements must be specified because the SURBAL program accepts both English and metric units of length. In this example, chains and links were used for measurements of slope distance, and degrees and minutes for vertical angles and bearings.

be halved repetitively until the plot will fit the paper. Computer processing on a given survey is programmed to terminate if closure error exceeds 1:300. The user may state his preference that the program terminate on any other closure error, or he may prefer that the computer program proceed to conclusion regardless of closure error. The user's choice of alternatives among plotting scales and closure errors must be specified to the computer operator before processing begins.

Technical Information

Most users of SURBAL will want only to know, having submitted the previously specified data in proper form, that all subsequent mathematics and plotting are completed electronically at the computer center. Other users, however, may wish to delve into some of SURBAL'S inner workings. The program is based on commonly used rules of surveying found in any modern surveying text *(see Davis and Foote 1956)*.[2]

SURBAL uses the compass rule to balance all surveys; it corrects latitudes and departures in proportion to the length of the line. The adjusted length and adjusted azimuth are determined from the corrected latitude and corrected departure. The equation for determining corrected latitude is:

$$CL_i = L_i + \frac{M_i\, SF}{T} \qquad (1)$$

where:

CL_i = Corrected latitude of line i.
L_i = Uncorrected latitude of line i.
M_i = Length of line i.
S = Sum of uncorrected latitudes.
F = An algebraic correction factor (equal to $\pm$ 1) that will cause addition or subtraction of the correction as the data require.
T = Total traverse length.

The corrected departures are obtained in a similar manner.
The adjusted azimuth of each line is determined by the equation:

$$A_1 = \text{Arc Tan } \frac{CL_i}{CD_i} \qquad (2)$$

[2] Davis, R. E., and F. S. Foote. SURVEYING—THEORY AND PRACTICE. 1021 pp. McGraw-Hill Book Co., New York. 1956.

where:

A_i = Adjusted azimuth of line i.

CD_i = Corrected departure of line i.

The coordinates of each survey corner are determined by algebraically summing the corrected latitudes and corrected departures. The first station in the survey is considered to be the origin, and this is given the coordinates (0,0). SURBAL calculates the area of each survey by the method of coordinates, and area is determined by the equation:

$$[(X_2 Y_1 + X_3 Y_2 + \text{-----} X_n Y_{n-1} + X_1 Y_n) - (X_1 Y_2 + X_2 Y_3 + \text{-----} X_{n-1} Y_n + X_n Y_1)] \frac{S^2}{2} \quad (3)$$

where:

X_i = X coordinate in inches.

Y_i = Y coordinate in inches.

S = Distance, in feet or other measure, represented by 1 inch on the map. (If S is in feet, area determined will be in square feet, etc.)

What Does SURBAL Print Out?

A sample of computer output for SURBAL is shown as figure 2. Experienced surveyors will recognize all the information needed to provide an area statement and to evaluate its accuracy. Surveys with more lines (calls) simply are printed on more pages. SURBAL also provides a plot of the adjusted survey data as shown in figure 3. All this printout, of course, becomes the property of the surveyor.

What Does SURBAL Cost?

The question finally must be answered: What does computer processing of survey data cost? The answer often comes as a pleasant surprise. It is impossible to predict exact costs because surveys vary in length and complexity. It should be noted, however, that costs vary with number of lines (calls), not with area of the surveyed tract.

For the purposes of cost estimation, survey data processing at the West Virginia University computer center will cost about $0.25 per line, providing computer outputs similar to figures 2 and 3. At this low cost, computer center personnel prefer to deal with problems of more than 100 lines. This $25.00 minimum may be met by submitting a single lengthy survey or by submitting several smaller surveys having a total of 100 or more lines.

Figure 2.—An example of SURBAL data compilation.

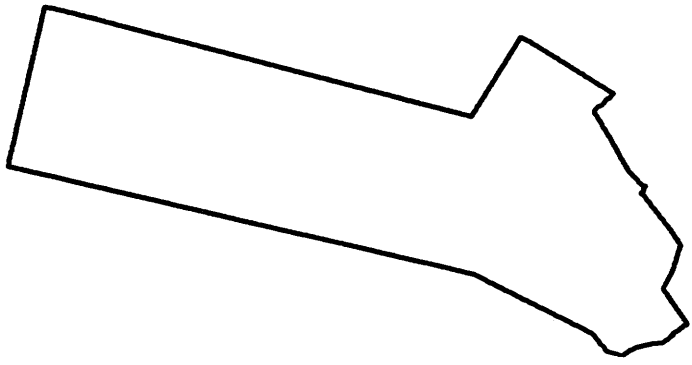
SAMPLE PROBLEM*

Trav. Sta.	Azimuth, degrees	Cnvrted length	Latitude		Departure		Adj. latitude		Adj. depart.		Tot. latitude		Tot. depart.		Adjusted azimuth	Adjusted length
			North	South	East	West	North	South	East	West	North	South	East	West		
AB												0.00	—	0.00		
	0.0	500.0	500.0	—	0.0	—	501.4	—	3.2	—					0.37	501.4
BC											5.01	—	0.03	—		
	45.0	848.6	600.1	—	600.1	—	602.4	—	605.5	—					45.15	854.1
CD											11.04	—	6.09	—		
	110.6	854.4	—	299.4	800.0	—	—	297.6	805.5	—					110.27	858.7
DE											8.06	—	14.14	—		
	168.7	1019.0	—	999.2	200.0	—	—	996.4	206.5	—					168.29	1017.5
EF											—	1.90	16.21	—		
	259.7	1118.0	—	199.9	—	1100.0	—	196.81	—	1092.8					259.79	1110.4
FA											—	3.87	5.28	—		
	305.9	656.8	385.1	—	—	532.0	386.9	—	—	527.8					306.24	654.5

North latitude sum = 1485.18
South latitude sum = −1499.00
East departure sum = 1600.04
West departure sum = 1632.02
Lengths listed above are in feet.
Total latitudes and total departures are scaled to 1 inch = 100.0 feet for plotting.
Total latitudes and total departures are in reference to traverse station AB.
Reference rectangle required for plotting his vertices (0.00, 11.04), (16.21, 11.04), (16.21, −3.87), (0.00, −3.87).
Linear error of closure is 34.84 feet.
Total traverse length is 4996.8 feet: angular error of closure is 23.38 degrees.
Relative linear error of closure is 1/143..
Traverse encloses 1737062.05 square feet = 39.877 acres.

* Based on data from Davis and Foote (1956).

Figure 3.—A plat drawn by SURBAL computer.



TYGART VALLEY FOREST
DAILEY, WEST VIRGINIA
DIVISION OF FORESTRY
WEST VIRGINIA UNIVERSITY
MORGANTOWN, WEST VIRGINIA
DECLINATION 5.00° W
1 INCH = 40 CHAINS OCTOBER 1968
AREA = 497.06 ACRES

Processing at West Virginia University

Inquiries or requests for SURBAL processing should be addressed to Dr. D. L. Kulow, Division of Forestry, West Virginia University, Morgantown, W. Va. 26506. Perhaps the most satisfactory answers to questions about completeness of information, accuracy of results, and economy of computer processing are obtained by submitting one or more surveys of minimum cost to the SURBAL program.

—ROGER N. BAUGHMAN and JAMES H. PATRIC[3]

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