FO-2213 Forest Measurements

Topic 33: Length/Distance, Area, Direction, and Land Description

Chapter 4

Length/Distance

Units of length/distance:

centimeter = 1/100 meter ; 1inch =2.54 centimeters
inch = 2.54 cm = 1/12 ft
foot = 12 inches
yard = 3 feet = 36 inches
chain = 66 feet = 100 links
mile = 5,280 feet = 80 chains
meter = 100 cm = 39.37 inches
kilometer = 1,000 meters = 3,280 ft/5,280 ft = 0.62 miles
pace = average length of 2 steps

Measurement of length/distance:

steel tape = 0.1 ft graduations
Gunter's chain = actually a babit steel tape that has 200 links; 2 chains
DME = electronic distance measuring equipment that uses ultra-sound
laser = laser reflection device that records distance and direction to a target

Depiction/representation of length/distance = Scale

scale = the ratio of map/image distance to the corresponding ground distance.

$$Scale = R.F. = \frac{1}{S} = \frac{d}{D}$$

R.F. = representative fraction which is synonymous with representative proportion
Characteristics of R.F. = 1 in numerator and it is unit-less

equivalent scale = an R.F. with units of measure attached.
Example: if scale is 1:24,000 then 1" = 24,000" or 1" = 2,000 ft. or 1" = 30.3 chains

Area Measurement

Units of area measurement

square feet
square chains; 10 square chains = 1 acre
square meters; 10,000 square metes = 1 hectare
acre = 43,560 square feet which is approximately 208.7 by 208.7 feet
acre = 10 square chains
hectare = 10,000 square meters = 100 by 100 meters = 2.471 acres

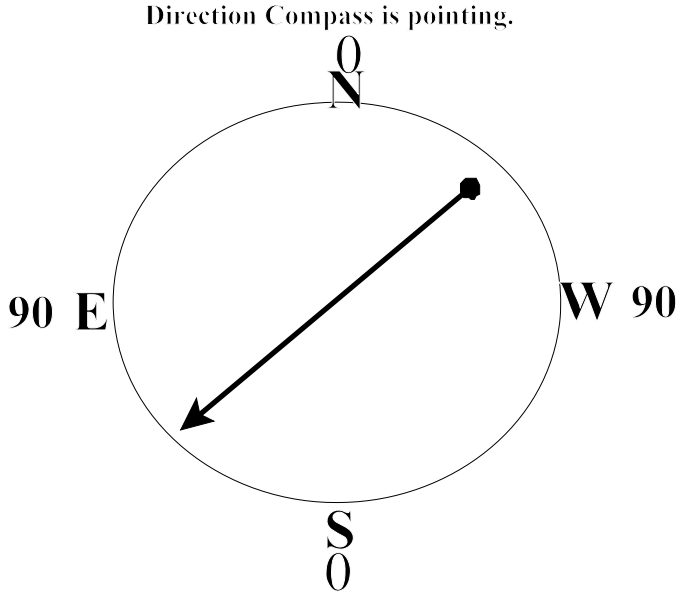
Methods of area measurement

hand compass and pacing
staff compass and steel tape survey
transit and steel tape survey
Global Positioning System (GPS)

Direction Measurement

Magnetic declination = the angle between magnetic and true north poles.

Magnetic compass= a magnetized needle on a pivot point enclosed in a circular housing which points to magnetic north.



On hand compasses and staff compasses, E and W are reversed because the North end of the compass needle is used to indicate the direction the compass is facing.

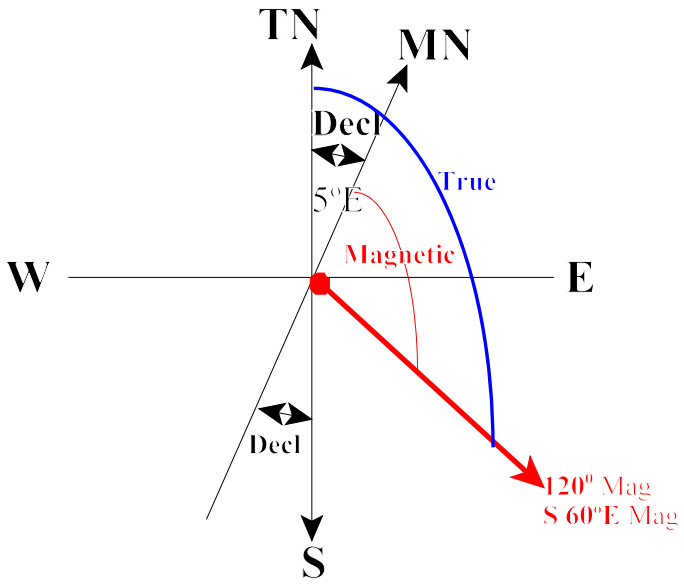
Bearings vs. Azimuth

Azimuth =0^o to 360^o with N=0/360, E=90, S=180, W=270

Bearing = 4 quadrants with angle measured from the North/South TO the East/West
= N/S + (0^o- 90^o) + E/W
= example; N 45^o E or S 60^o E

Magnetic vs. True Azimuth or Bearing = angle measured from magnetic or true north.

Conversion of Magnetic to True Angle or vice vers = drawn a picture, forget the rules!



In Azimuth format with East Declination:

True to Magnetic: True angle - decl = magnetic angle
125° true - 5° decl = 120° mag

In Bearing format with East Declination:

Mag to True: Mag angle + decl = true angle
S 60°E mag + 5° = S 65° E true

Examples of True to Magnetic Angle and vice vers conversion:

True Azimuth	True Bearing	Declination	Mag. Azimuth	Mag. Bearing
75°	N 75° E	5° E	70°	N 70° E
125°	S 55° E	5° E	120°	S 60° E
200°	S 20° W	5° E	195°	S 15° W
280°	N 80° W	5° E	275°	N 85° W

True Azimuth to Magnetic Azimuth: East is least (i.e. -decl) , west is best (i.e. +decl).

Global Positioning Systems (GPS) or Point Geographic Location on the Earth's Sphere

Coordinate Sytems

Latitude - Longitude = the true geographic point location system for a point on the earth's sphere.

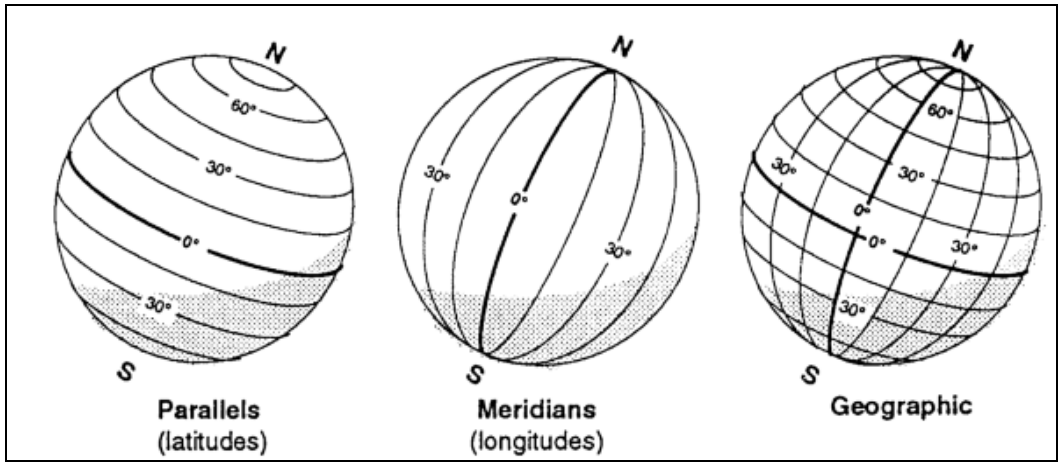
Universal Transverse Mercator (UTM) = an artificial, rectangular coordinate system

Latitude-Longitudes = system of parallels of latitude and meridians of longitude that allow the location of a point on the earth's sphere.

Latitude - measured North or South of the Equator; 0^o - 90^o

Longitude - measured East or West of the Prime Meridian; 0^o - 180^o

Example: MSU campus is approximately $33^o45'$ North latitude and $88^o45'$ West longitude



UTM = artificial rectangular coordinate system.

Starting at the 180^0 meridian of longitude and progressing East: the globe is divided into 6^0 zones of longitude in width; numbered 1 to 60, N and S.

Each zone is defined by an east and west meridian of longitude and a central meridian.

Zone origin is the intersection of the equator and its own central meridian.

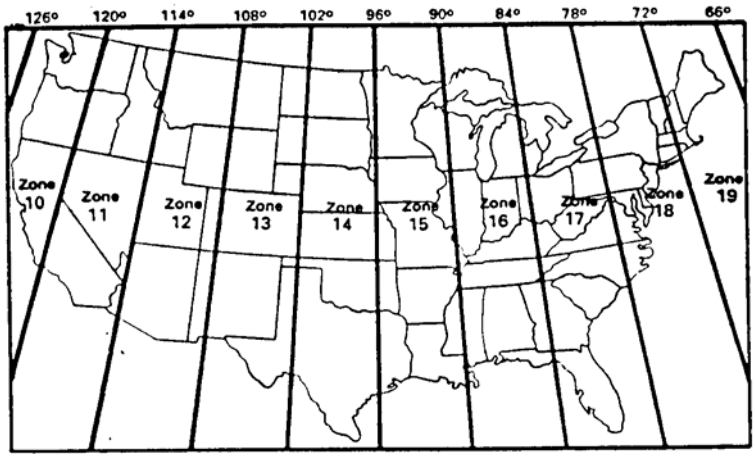
A false origin for the north half of the zone lies 500,000 meters west of the origin.

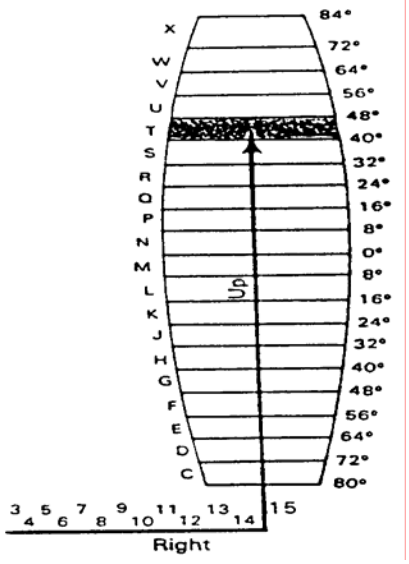
Example: Middle of sidewalk from Thompson to street intersection is approximately:

333,110.76 m E

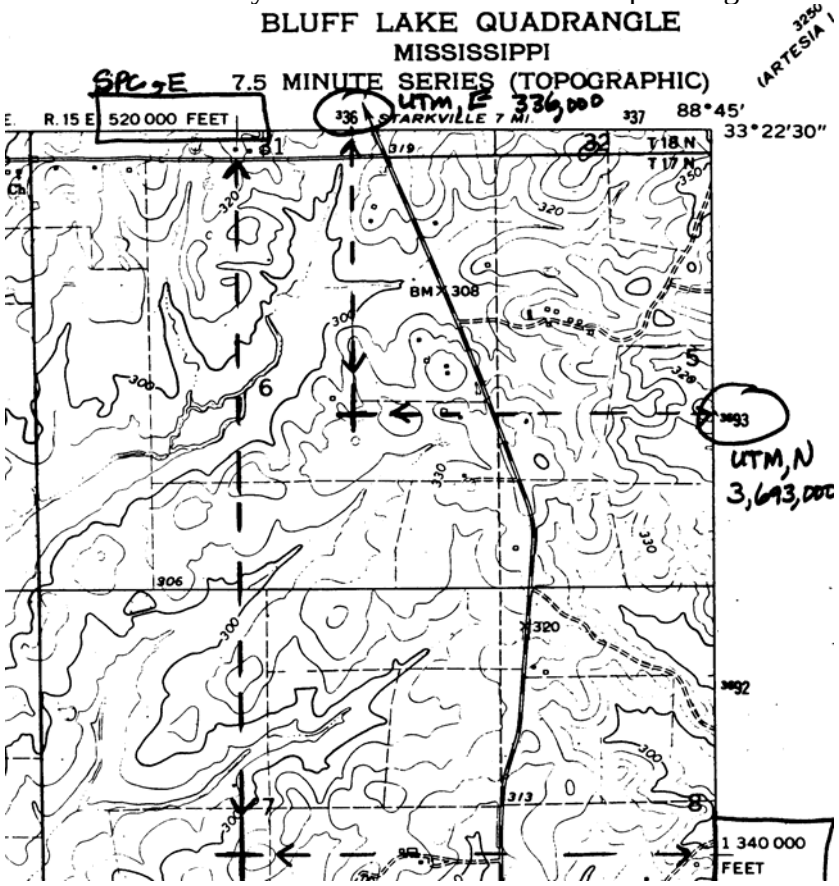
3,702,782.15 m N

Zone 16N





UTM coordinates are easily calculated on a 7.5 minute quadrangle sheet:

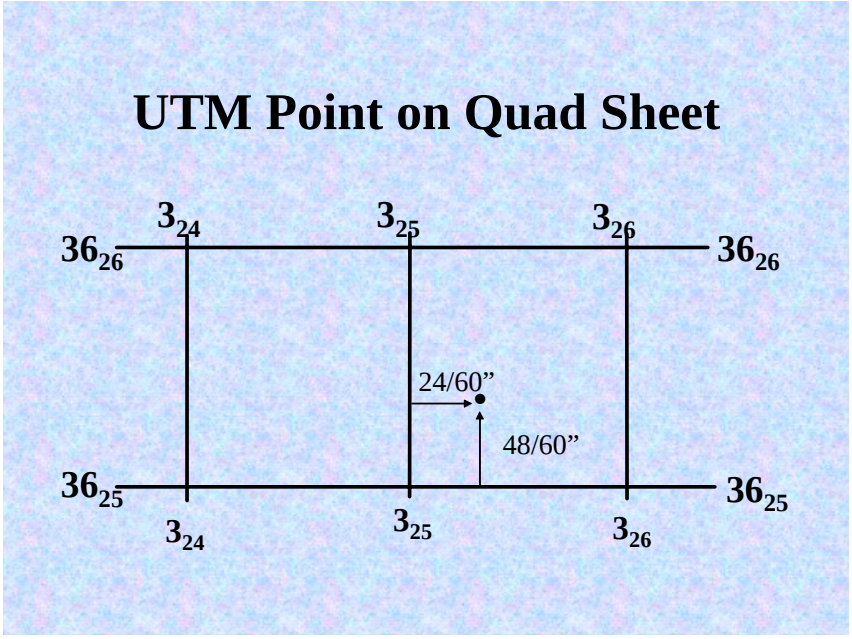


Calculation of UTM coordinates on a Quad sheet involves:

1. Designation of the 1,000 m grid square using the tic marks on margins.
2. Measuring the distance east/west of an Easting grid.
3. Measuring the distance north/south of a Northing grid.
4. Converting the quad sheet distances from inches to meters:

   R.F. = 1:24,000

   1" = 2,000 ft = 609.6 m



1. Measure the x distance (easting) from easting coordinate line to the point using the 60th's scale; example: distance = 24/60 in.
2. Convert the distance to meters and add to easting coordinate distance.

   (24/60 in.)*609.6m/in. = 243.84 m

   243.84 meters + 325,000E = 325,243.8 mE
3. Measure the y distance (northing) from northing coordinate line to the point using the 60th's scale, convert the distance to meters and add to northing coordinate distance; example: distance = 48/60 in.

   (48/60")*609.6m = 487.69m

   487.69 m + 3,625,000N= 3,625,487.69mN

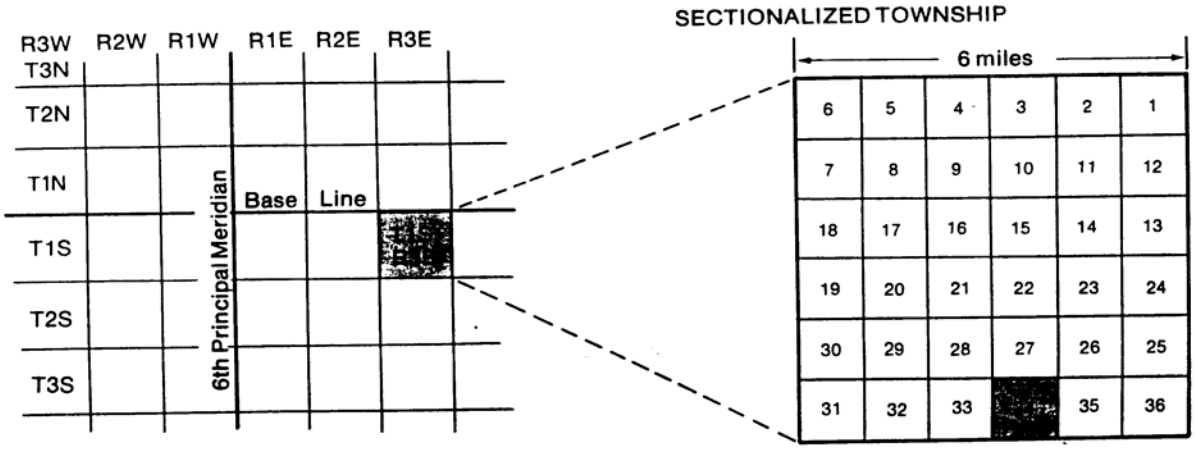
Land Description = Public Land Survey

GLO (General Land Office) is a systematic, land partitioning system by the Land Ordinance of 1785.

Range lines were surveyed at 6 mile intervals north and south of a base line.

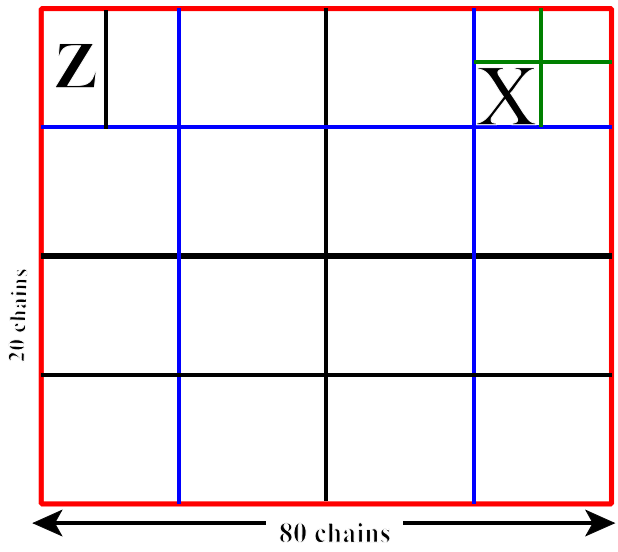
Township lines were surveyed along parallels at 6 mile intervals east and west of the principal meridian.

The 6 x 6 mile squares are called townships.



Divisions of a Section

A section is 1 mile square or 80 chains square, and contains 640 acres.
Legal descriptions are written as partitions of a section in 1/4, ½, etc. parcels:



X = SW1/4, NE 1/4, NE1/4, Sxx, TyyN, RzzE
= 10 acres

Z = W1/2, NW 1/4, NW 1/4, Sxx, TyyN, RzzE
= 20 acres

To locate a parcel, read the description in reverse format.

Land Description = Metes and Bounds Description

Applies to the original 13 American Colonies, only.

Mete = a term that implies the act of metering or measuring.
Bounds = refers to property boundaries or the limiting extent of an ownereship.

Verbal description without reference to geo-spatial coordinates; i.e. Begin at the old oak tree on the north side of the Smith Crossroads; proceed in an easterly direction approximately 80 rods to the big rock; thence southerly approximately 76 rods to the corner of the rail fence; then westerly 81 rods to the middle of the South Creek; thence northerly back to point of beginning. Said parcel contains 40 acres more or less.

Area Determination

Office/Calculation methods:

Dot grid = density of dots/square inch is applied to the scale of the area.
Graphical = drawing an area with known scale; i.e. 1"=10 chains; 10 chn^2=10 ac
Polar planimeter = mathematical integration of a perimeter measurement.
Geometric Area = An area can be subdivided into geometric figures and/or polygons and the area computed with the appropriate area equation:

Square or rectangle: area = L x W
Acres = square feet ÷ 43,560

Triangle: area = 1/2 B H
1 hectare = 10,000 m^2

Irregular polygon:

$$area = \frac{1}{2}(x_1y_2 + x_2y_3 + ..+x_{n-1}y_n + x_ny_1 - y_1x_2 - y_2x_3 - ...-y_{n-1}x_n - y_nx_1)$$

where n = number of coordinate

x_iy_j = *product of coordinates* x_i,y_j

Field methods:

GPS = Areas are calculated with a GPS using the "area" feature with either static or dynamic points. The closed polygon has an area.

Closed traverse = the distance (chains) and direction (bearings) to designated points on the perimeter of an area are used to mathematically compute the enclosed area and the precision associated with the computations.

Computation of A Closed Traverse

1. Place the course number, bearing, and length of each boundary line in columns (1), (2), and (3), respectively.

2. Compute the departure of each course and put them in column (4):

   Departure = (Course length)Sin(Bearing angle)(±)

   Departures of EAST bearings are given a positive sign and departures of WEST bearings are given a negative sign. Alternatively, if we convert the bearing to an azimuth no sign correction is necessary and the

   Departure = (Course length)Sin(Azimuth).

3. Compute the latitude of each course and put them in column (5):

   Latitude = (Course length)Cos(Bearing angle)(±)

   Latitudes of NORTH bearings are given a positive sign and latitudes of SOUTH bearings are given a negative sign. Alternatively, if we convert the bearing to an azimuth no sign correction is necessary and the

   Latitude = (Course length)Cos(Azimuth).

   Hint. When using a spread sheet program, remember to covert degrees to radians using the RADIANS(degrees) function before computing a sin, or,cosine, and to convert radians to degrees after computing an arctangent . If cell A1 is in degrees, compute the sin of the angle in A1 using the expression SIN(RADIANS(A1)). If B1 is the tangent of an angle, use the expression DEGREES(ATAN(B1)) to calculate the angle in degrees. The function DEGREES(radians) converts radians to degrees. In the case, the RADIANS, or DEGREES functions are not available, derive the functions making use of the fact 360 degrees is 2π radians (1 degree = $2\pi/360$ radians or 1 radian = $360/(2\pi)$ degrees).

4. Sum, taking sign into account, all the course departures and put the result in the totals row of column (4).

5. Sum, taking sign into account, all the course latitudes and put the result in the totals row of column (5).

6. Find the closure error(EC):

$$EC = \sqrt{(Sum\ \ of\ \ departures)^2 + (Sum\ \ of\ \ latitudes)^2}$$

7. Find the total course length by summing the individual course lengths. Place the result in the totals row of the course length column(3).

8. Compute the ratio of precision and express as a proportion:

$$Precision = 1 : (Total\ course\ length)/(Closure\ error)$$

If the precision is more than 1/1000 the traverse must be balanced. The method of balancing we will use is called the compass rule.

9. Adjust the departure of each course and place the adjusted values in column (6). The adjustment formula is:

$$Dep_{adj} = Depature - \left(\frac{Course\,length}{Total\,course\,lengths} \right) (Sum\,of\,departures)$$

10. Adjust the latitude of each course and place the adjusted values in column (7). The adjustment formula is:

$$Lat_{adj} = Latitude - \left(\frac{Course\,length}{Total\,course\,lengths} \right) (Sum\,of\,latitudes)$$

11. Calculate the adjusted length of each course and put the results in column (8):

$$Length_{adj} = \sqrt{Dep^2_{adj} + Lat^2_{adj}}$$

12. Determine the adjusted bearing angle:

$$Bearing\,angle = Arctan\left(\frac{Dep_{adj}}{Lat_{adj}} \right)$$

Error of Closure Computation example:

1	2	2	3	4	5	6	7	8	9	10
Course	**Bearing**	**Azimuth**	**Length**	**Depar (Sin)**	**Latitude(Cos)**	**Adj Dep**	**Adj Lat**	**AdjLen**	**AdjAngle**	**Adj Brng**
			(chains)	(+E) (-W)	(+N) (-S)					
1	S24W	204	2.88	-1.1709	-2.6299	-1.1663	-2.6260	2.87	23.95	S23.95W
2	S34E	146	3.11	1.7369	-2.5750	1.7419	-2.5708	3.11	-34.12	S34.12E
3	S44W	224	3.33	-2.3155	-2.3978	-2.3102	-2.3933	3.33	43.99	S43.99W
4	N47W	313	3.55	-2.5930	2.4180	-2.5873	2.4228	3.54	-46.88	N46.88W
5	N90W	270	6.71	-6.7121	0.0000	-6.7013	0.0091	6.70	-89.92	N89.92W
6	S13W	193	12.82	-2.8835	-12.4897	-2.8628	-12.4723	12.80	12.93	S12.93W
7	N65W	295	7.05	-6.3854	2.9775	-6.3740	2.9871	7.04	-64.89	N64.89W
8	N00E	0	13.09	0.0000	13.0909	0.0211	13.1087	13.11	0.09	N00.09E
9	N34E	34	12.88	7.2017	10.6770	7.2225	10.6945	12.90	34.03	N34.03E
10	N90E	90	15.21	15.2121	0.0000	15.2367	0.0206	15.24	89.92	N89.92E
11	S00W	180	6.62	0.0000	-6.6212	0.0107	-6.6122	6.61	-0.09	S00.09W
12	S41W	221	3.41	-2.2366	-2.5729	-2.2311	-2.5682	3.40	40.98	S40.98W
Totals			90.65	-0.1462	-0.1230	0	0	90.65		
		Error	0.19							
		Closure 1:	474.44							

$\sum$(Adj Dep) = 0. and $\sum$(Adj Lat)= 0. $\sum$(Adj Len) = $\sum$(original Lengths)
Error = $\{(\sum depars)^2 + (\sum lats)^2\}^{0.5}$ Closure = 1: (length/error)

Area Computation of Traverse:

13. Accumulate, starting with the first course, the adjusted departures from the balance table and put it in column (3).
Accumulate, starting with the first course, the adjusted latitudes from the balance table and put them in column (4).

14. Find the minimum accumulated departure in column (3) and subtract this value from each accumulated departure placing the results in the "Shifted X-coord column (7).

X-coord =(Accum. departure)-(Min. accum. departures)

15. Find the minimum accumulated latitude in column (4) and subtract this value from each accumulated latitude placing the results in the "Shifted Y-coord column (8).

Y-coord = (Accum. latitude)-(Min. accum. latitude)

16. Compute the Double Meridian Distance(D.M.D.) of each course by adding the "Shifted X-coord" of the course to the "Shifted X-coord" of the previous course. Remember the previous course to the first course is the last course. Place these D.M.D.'s in column (5).

17. The "Shifted X-coord" is the X-coordinate of the end point of the current course and the start point of the next course. It is also a meridian distance shifted to always be positive. Likewise the "Shifted Y-coord" is the Y-coordinate of the end point of the current course and the start point of the next course. It is also a parallel distance shifted to always be positive.

18. **C**alculate the double area of each course by multiplying it's D.M.D in column (5) by the course's adjusted latitude for the course from the Balance Table. Be sure to give the double area the sign of the latitude. Put these results in column (6).

19. Total the double areas taking into account sign and place the result in the totals row. The absolute value of this sum is 2 times the square foot land area of the closed traverse. The acreage of the traverse is thus the absolute(positive) value of,

(Sum of double areas in feet)/[(2)(43560)]; if course length is in feet.
(Sum of double areas in chains)/[(2)(10)]; if course length is in chains.

$$\frac{Sum\ of\ double\ areas\ converted\ to\ acres}{2}$$

For example, if the course lengths are in chains, the calculated double is in square chains. Since 10 square chains make an acre. Thus, the area of the traverse in acres is

$$acres = \frac{Sum\ of\ double\ areas\ in\ square\ chains}{2(10)}.$$

20. Use the X and Y coordinates in columns (7) and (8) to draw a boundary map.

Area Computation example::

1	2			3	4	5	6	7	8
Station	**Course**	**Adj Dep**	**Adj Lat**	**Accum Dep**	**Accum Lat**	**DMD**	**2X Area**	**Shiftd X**	**Shiftd Y**
12-1	1	-1.1663	-2.6260	-1.1663	-2.6260	39.35	-103.34	19.09	17.63
1-2	2	1.7419	-2.5708	0.5756	-5.1968	39.93	-102.65	20.84	15.06
2-3	3	-2.3102	-2.3933	-1.7345	-7.5901	39.36	-94.20	18.53	12.67
3-4	4	-2.5873	2.4228	-4.3218	-5.1673	34.46	83.50	15.94	15.09
4-5	5	-6.7013	0.0091	-11.0231	-5.1582	25.17	0.23	9.24	15.10
5-6	6	-2.8628	-12.4723	-13.8859	-17.6304	15.61	-194.70	6.37	2.63
6-7	7	-6.3740	2.9871	-20.2599	-14.6433	6.37	19.04	0.00	5.62
7-8	8	0.0211	13.1087	-20.2388	-1.5347	0.02	0.28	0.02	18.73
8-9	9	7.2225	10.6945	-13.0163	9.1598	7.26	77.69	7.24	29.42
9-10	10	15.2367	0.0206	2.2204	9.1805	29.72	0.61	22.48	29.44
10-11	11	0.0107	-6.6122	2.2311	2.5682	44.97	-297.36	22.49	22.83
11-12	12	-2.2311	-2.5682	0.0000	0.0000	42.75	-109.79	20.26	20.26
Total		**0**	**0**				**-720.7**		
			Minimum	-20.2599	-17.6304	**Area**	**36.035**	acres	

Sample computations: (be aware of the sign of the value)

1st row up to Column (3) = copied from previous table of adjusted departures and latitudes.

2nd row , Accum Dep = Accum Dep of row + Adj Dep of next row = -1.1663 + 1.7419 = 0.5756;
2nd row, Accum Lat = Accum Lat of row + Adj Lat of next row = -2.6260 + (-2.5708)= -5.1968

When Dep and Lat's have been accumulated, use function MIN(C1:Cn) to find minimum values

1st row, Column (7): Shiftd X = Accum Dep - min(Accum Dep)= -1.1663 - (-20.2599);
1st row, Column (8): Shiftd Y = Accum Lat - min(Accum Lat) = -2.6360 - (-17.6304)

1st row, Column (5): DMD = Shifted X of course + Shifted X of prev course
= 10.09 + 20.26
2nd row, Column (5): DMD = 20.84 + 19.09

Total Double Area = the Sum of the DMD column
Area = Summed double area ÷ 2 * (per acre conversion for unit of measure)
= Summed double area ÷ 2*10 for square chains
= Summed double area ÷ 2*43,560 for square feet

ITMAP Computer Software

Quit and easy solution to a closed traverse. User enters bearings/azimuths and distances (ft/chains, etc.) and the traverse closure is computed. Since this is an on DOS program, it will not sent the output to the printer. User must print output to a "print file" then capture it with a word processor.

```
  Page #  1
  10:12:10 a.m.
  03-14-2007
TRAVERSE:
TRAVERSE IS CLOSED                                  DECLINATION: NONE
AREA: 360.3789 SQUARE CHAINS                        36.03789 ACRES
CHAINS OF CLOSURE = .1927609                        DIRECTION OF CLOSURE = N:51:03:41:E
PRECISION = 1 IN 470.3237                           PERCENT = .2126195
```

SIDES	CORRECTED MAGNETIC BEARINGS	CORRECTED DISTANCE CHAINS	SLOPE NONE	BALANCED LATITUDE	BALANCED DEPARTURE	BALANCED NORTH	BALANCED EAST
1-2	S:23:56:40:W	2.874548		-2.627	-1.167	0.000	0.000
2-3	S:34:07:17:E	3.109438		-2.574	1.744	-2.627	-1.167
3-4	S:43:59:06:W	3.322974		-2.391	-2.308	-5.201	0.578
4-5	N:46:52:45:W	3.548949		2.426	-2.590	-7.592	-1.730
5-6	N:89:55:24:W	6.698909		0.009	-6.699	-5.166	-4.321
6-7	S:12:55:29:W	12.79855		-12.474	-2.863	-5.157	-11.019
7-8	N:64:53:26:W	7.043428		2.989	-6.378	-17.632	-13.882
8-9	N:09:00:17:E	13.10751		13.107	0.022	-14.643	-20.260
9-10	N:34:02:08:E	12.90618		10.695	7.224	-1.535	-20.238
10-11	N:89:55:25:E	15.23517		0.020	15.235	9.160	-13.015
11-12	S:00:05:42:E	6.611163		-6.611	0.011	9.180	2.221
12-1	S:40:58:43:W	3.402863		-2.569	-2.232	2.569	2.232
	Totals:	90.65968		-0.000	0.000		

Comparison of Area Computation with DMD and Irregular Polygon

5 DMD	6 2X Area	7 Shiftd X	8 Shiftd Y	Sum X_1Y_2	Sum Y_1X_2
39.35	-103.34	19.09	17.63	287.61	367.41
39.93	-102.65	20.84	15.06	263.98	279.05
39.36	-94.201	18.53	12.67	279.60	201.93
34.46	83.4982	15.94	15.09	240.69	139.41
25.17	0.22935	9.24	15.10	24.29	96.26
15.61	-194.7	6.37	2.63	35.80	0.00
6.37	19.0397	0.00	5.62	0.00	0.12
0.02	0.27673	0.02	18.73	0.62	135.64
7.26	77.6923	7.24	29.42	213.25	661.36
29.72	0.61372	22.48	29.44	513.18	662.14
44.97	-297.36	22.49	22.83	455.66	462.49
42.75	-109.79	20.26	20.26	357.26	386.83
				2671.94	3392.64
	-720.7			-360.35	
Area	**36.035**	acres		**Area**	**36.035**