3.0 Land Measurements Review

(Chpt 4 in Husch, et al.)

Knowledge critical to the forest scientist is the way land subdivision is carried out in any particular region in which they work

Knowledge of the basic elements of surveying is also crucial to practitioners of forestry science

To these ends, the forest scientist should be adept at pacing, chaining, running compass traverses, and various methods of estimating land area

3.1 Land Subdivision (in the U.S.)

Methods

Metes and Bounds

The original 13 colonies of the United States of America were subdivided and passed into private ownership using the so called "metes and bounds" method, sometimes jokingly referred to as "leaps and bounds."

The term *mete* implies and act of metering, measuring, and assigning by measure, and *bounds* refers to property boundaries or other limits or constraints to the extent of an ownership.

In some instances, however, especially older metes and bounds surveys consist entirely of descriptions without measurements, such as in the following example:

> "starting at the pine tree blazed on its east side, thence along a hedgerow to a granite boulder on the bank of the Wampum River, thence along the river to the intersection of Cherokee Creek …"

U.S. Public Land Survey

Most of the U.S. west of the Mississippi River and north of the Ohio River, including Alabama, Mississippi, and portions of Florida has been subdivided in accordance with the US Public Land Survey (Exhibit 5). The first law governing public land surveys was passed by Congress in 1785.

The "Northwest Territory" (later becoming the state of Ohio) was chosen as the experimental area for the development of this rectangular system

The original intent was to establish *townships* exactly 6 miles square, followed by subdivision into 36 sections of exactly 1 square mile each. At first, no allowance was made for curvature of the earth's surface, resulting in numerous problems. Subsequently, Congress passed Survey Rules so that the system evolved into its present day form.

The origin of a rectangular system (there are more than 30 such origins in the U.S.) begins with an *initial point*, usually established by astronomical observation

Extending outward from the initial point is a true north-south line known as a *principal meridian* and a true east-west base line that corresponds to a parallel of latitude. These two lines constitute the main axes of a system (Exhibit 5). Each principal meridian is referenced by a name or a number.

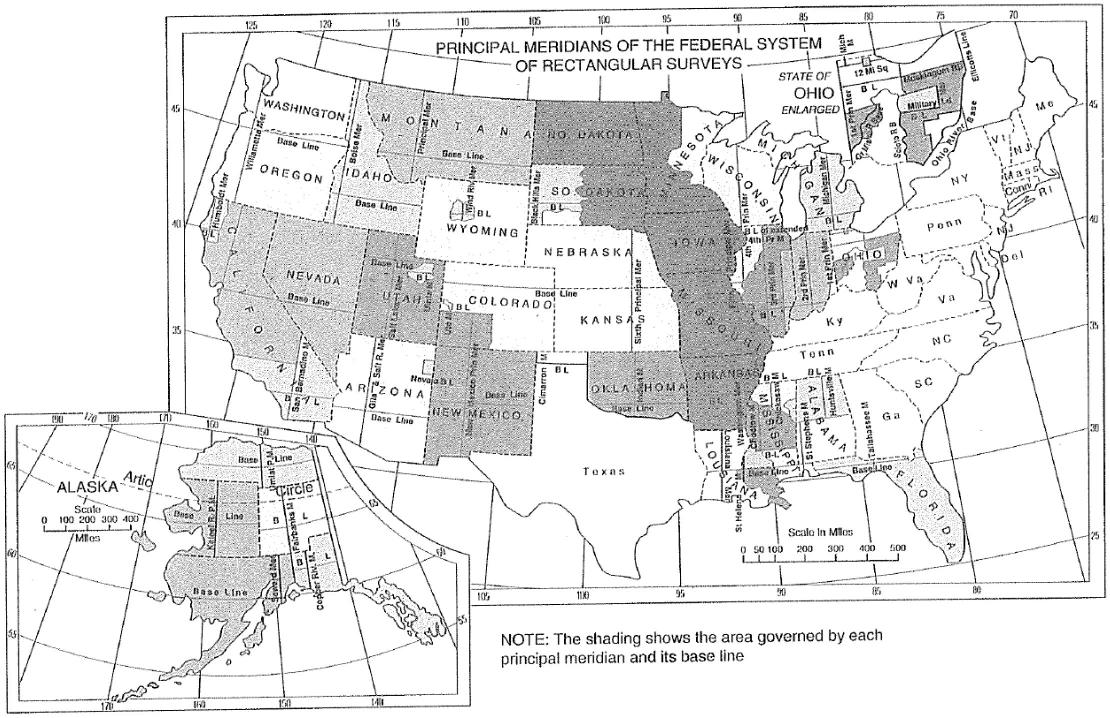


Exhibit 5.
States subdivided under the U.S. Public Land Survey.

Starting at the initial point, the area is divided into *tracts* approximately 24 miles square, followed by subdivision into 16 *townships* approximately 6 miles square, and then into 36 *sections* each approximately 1 mile square. Exhibit 6 shows an idealized system. The townships and sections are set up in the following manner.

At 24-mile intervals north and south of the base line, *standard parallels* are extended east and west of the principal meridian. These parallels are numbered north and south of the base line as “first standard parallel north,” and so on.

Also, at 24-mile intervals along the base line and along all standard parallels, *guide meridians* are run on true north bearings, thus corresponding to true lines of longitude. Each guide meridian starts from a *standard corner* on a base line or on a standard parallel and ends at a *closing corner* on the next standard parallel to the north. Standard parallels are never crossed by guide meridians. Guide meridians are numbered east and west from the principal meridian as “first guide meridian east” and so forth.

The 24-mile tracts are divided into 16 townships by north-south *range* lines and east-west *township* lines. Range lines are established as true meridians at 6-mile intervals along each standard parallel and are run due north to the next standard parallel. Since range lines converge northward just as guide meridians do, the width of a township decreases from south to north, the shape is trapezoidal

The survey of townships within a tract begins with the southwest township and continues northward until the entire west range is completed; then it moves to the next range eastward and again proceeds from south to north. Townships are numbered consecutively northward and southward from the base line and eastward and westward from the principal meridian

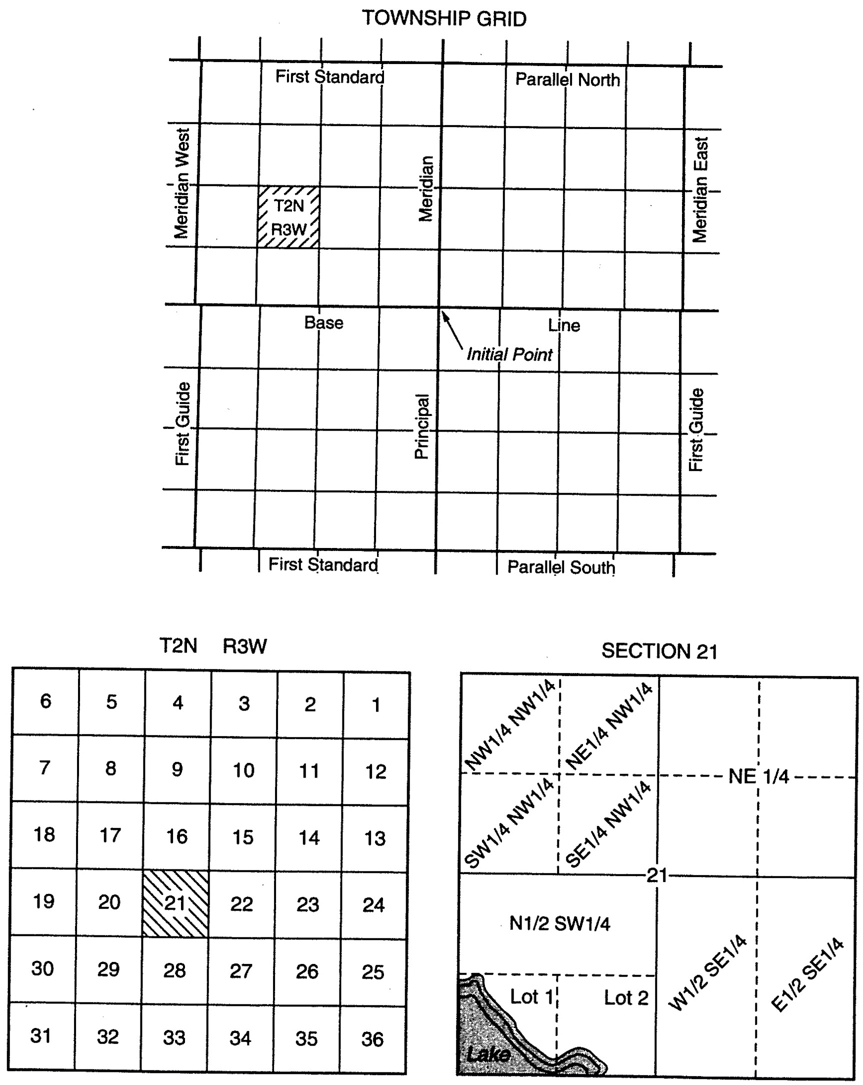


Exhibit 6.
Idealized subdivision of townships and sections. As an example, the principal meridian depicted in the top figure might be designated as "5th Principal Meridian."

Section establishment begins in the southeast corner of a township by running lines 1 mile apart parallel to eastern range lines and 1 mile apart parallel to southern township lines. By starting in the southeast corner of the township, irregularities are 'thrown' into the northern and western tiers of sections in each township. Survey lines are first run around section 36, then 25, 24, 13, etc. (see Exhibit 6).

Survey corners that are actually established on the ground with monuments include section corners and quarter corners. Quarter sections may later be subdivided into 40-acre parcels known as "forties."

A complete land description begins with the smallest land parcel and covers each division in order of size basis, and ends with the principal meridian involved. Thus, the forty composing the most northwesterly portion of section 21 in Exhibit 6 would be described as NW ¼ NW ¼ S21, T2N, R3W, 5th P.M.

Parcels of land that have an area considerably smaller than the 40 or 160 acres intended, due either to accumulated irregularities in the northwesterly portions of sections or by local subdivision agreement are typically referred to as "*lots*" and may simply be numbered.

3.2 Distances

The fundamental unit of horizontal distance used by foresters is the *surveyor's,* or, *Gunter's chain* of 66 ft. Each chain is divided up into 100 *links*, each link is thus 0.66 ft, or 7.92 inches in length. Distances on all U.S. Government Land Surveys are measured in chains and links.

Measurement Methods

Pacing

For rough accuracy (1 in 50) of horizontal distance measurement in the field

Definition: Average length of two (2) natural steps, that is a count is made each time the same foot touches the ground.

A person's pace is calibrated by walking a minimum of a three chain, linear course at least three times and then an average number of paces-per-chain is calculated – the person of average height / stride will average about 12 to 13 paces / ch.

Inevitable shortening of the pace on sloping ground can be handled by repeating the count at certain intervals (calibrated to amount of slope), such as, 1, 2, 3, 3, 4, 5, 6, 6, etc.

Always record horizontal distances traveled in the field in units of chains or feet, never in # of paces!

Chaining

For best accuracy (1 in 1,000) of horizontal distance measurement in the field

Steel, cloth, or plastic graduated tapes may be used

Measuring distance by "chaining" is a two (2) persons operation. Traditionally, the lead person is called the head chainman and the other is called the rear chainman. Typically, the head chainman begins with 11 chaining pins. One pin is placed at the point of origin, then the head chainman moves ahead carrying the remaining 10 pins and the "zero" end of the chain (or tape). The head chainman may also carry the compass, keeping the crew and the chain on course; alternatively, the rear chainman may assume compass duty to direct the head chainman on the proper course.

A good head chainman counts paces to equal the length of the tape to anticipate when the chaining interval will be reached. When the tape has nearly run out past the point of origin, the rear chainman calls out, "Chain!" The head chainman then carefully pulls the tape taught, the rear chainman aligns their end of the tape directly over their pin, and calls "Stick!" The head chainman then sticks a pin into the ground directly beneath their zero end of the tape and calls back, "Stuck!" The rear chainman then picks up the first pin, and the process is repeated until the desired length has been measured. When the head chainman "sticks" the last pin, a distance of 10 chains have been traversed, and the rear chainman walks up to the head chainman to pass the 10 pins collected to the head chainman for continuing measurement, if necessary.

Electronic

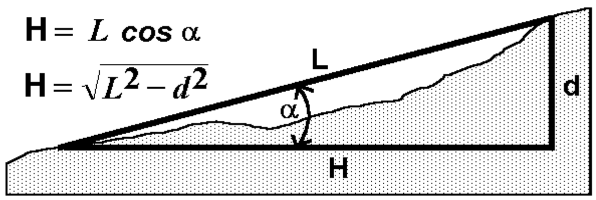
For intermediate (1 in 500) accuracy of horizontal distance measurement in the field

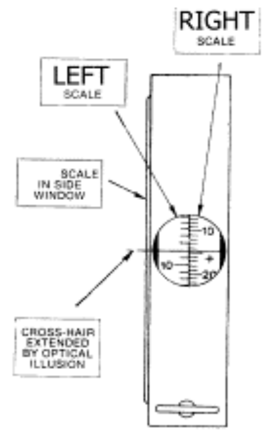
Electronic Distance Measurement (EDM) devices have been used in surveying since the late 1960's

The most common and useful are the so-called Laser Rangefinders that bounce a laser pulse off of an object measuring the speed of its return multiple times to obtain an average, then converting to distance through the known speed of light (186,282 miles per second)

Correcting for Slope

Most often in the field, it will only be possible to measure distances on sloping ground in variegated terrain. All slope distances must be converted (adjusted) to horizontal by use of geometry or more commonly trigonometry.





Clinometer

The most common instrument used in the field to convert distances along sloping ground to horizontal distance is the clinometer. The clinometer is an instrument with a rotating dial that indicates angle of elevation as a difference from where the observer is located.

After aligning the cross hair with the target, the angle of inclination is read through the viewfinder. Percent scale is on the right; degree on the left. Depending on your application, record in either degrees or percent

3.3 Directions

Angular measurement is the other component necessary to complete land measurements

The compass is the device used for measuring a particular direction in units of angular deflection from magnetic north

A compass consists of a magnetic needle on a pivot point, enclosed in a circular housing that has been graduated in degrees. Since the earth acts as a huge magnet in some sense, compass needles in the northern hemisphere align themselves with the horizontal component of the earth's magnetic field, commonly termed *magnetic north*. Since a sighting base is attached to the compass housing, it is possible to measure the angle between a line-of-sight and the position of the needle, or magnetic north. Such angles are termed *magnetic bearings* or *azimuths*, depending on what compass scale is being used. The figure below depicts the azimuth scale graduations on the inner side of the bold circle, and is incremented always in the clockwise direction between zero (0) and 360 degrees. The bearing scale graduations are depicted on the outer side of the bold circle. Bearings are horizontal angles comparable to azimuths, but are referenced to one of the quadrants of the compass, namely, NE, SE, SW, or NW. For example, a bearing of N60°E, coincides with an azimuth of 60°, whereas a bearing of S60°W corresponds to an azimuth of 240°.

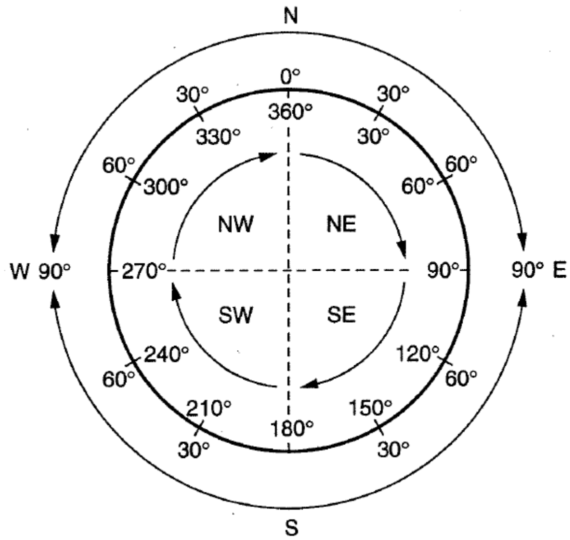


Exhibit 1.
Relationship between compass azimuths (inner circle) and bearings (outer circle).

Magnetic north does not correspond to "true" or "geographic" north for most places on earth. The angle formed between geographic north and magnetic north is termed *magnetic declination*. So, allowance must be made for this factor in converting magnetic azimuths and bearings to true angular measures.

East declination indicates that magnetic north is east of geographic north, whereas *west* declination indicates the reverse. Isogonic charts, such as in Exhibit 2 are issued periodically by government agencies. The *agonic line* is the name for places on the earth in which magnetic north and geographic north exactly coincide, that is, where there is zero declination.

Declinations are changing constantly everywhere. In the U.S., the agonic line is shifting at an average rate of 1 min. westward per year, but in some areas can be as high as 5 min. per year.

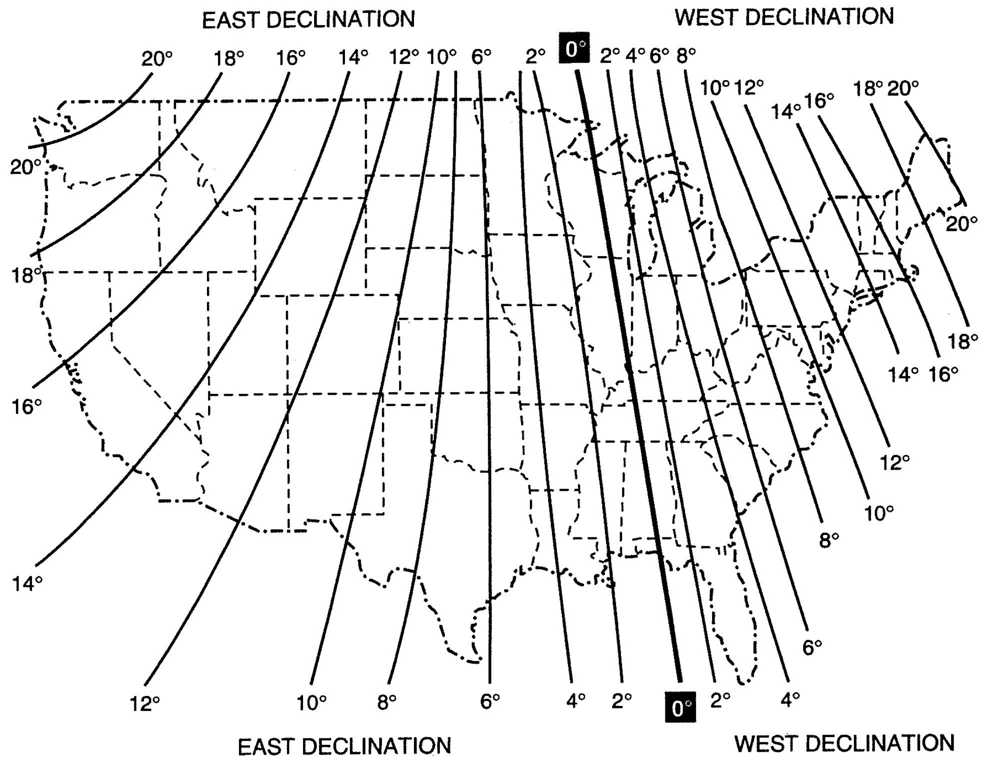


Exhibit 2.
Approximate magnetic declination chart of the conterminous U.S., circa 1990. The agonic line is bold.

It is extremely important to use the current, correct declination for your particular area when making corrections from magnetic azimuths and bearings to true angular readings, employing the simple procedure appearing in Exhibit 3.

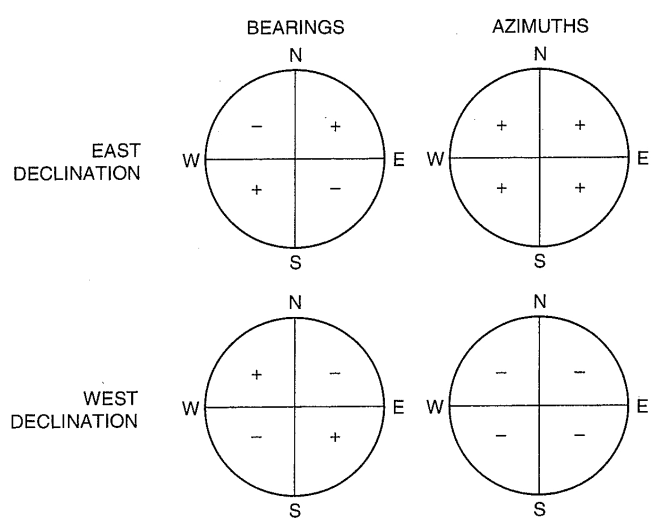


Exhibit 3.
Algebraic signs for adjusting magnetic azimuths and bearings to true angles. For, example, with 5° west declination, a magnetic bearing of S40°E would have a true bearing of S45°E.

3.4 Areas

Forest and environmental scientists are concerned with determining land area for several purposes including the area of a stand as delineated on a map or as viewed on an aerial photograph, area contained within retraced property lines, within a timber sale boundary, or other closed traverse, etc.

Measurement Methods

<u>Graphing</u>

If a closed traverse is plotted on cross-section paper, the total area can be quickly computed simply by counting the number of enclosed squares.

Where less than half a square is inside the polygon, it is ignored; squares that are bisected by an exterior boundary line it counts as half.

This method provides reasonable accuracy when traverses are plotted correctly and when finely subdivided cross-section paper is used.

<u>Dot Grids</u>

If a piece of clear tracing paper were placed over a sheet of cross-section paper and pin holes punched at all grid intersections, the result would be a dot grid.

This area determination method is based on the same principles as the graphing method. The dots *representing* squares are merely counted in lieu of the squares themselves.

The principal benefit over the graphing method is that fractional squares along boundaries are less troublesome, because the dot determines whether the square is tallied.

This method is ideal for determining areas on a map or aerial photo.

The optimum number of dots to be counted per sq. inch depends on the map scale and the size of the area involved and the precision required. Denser grids are used for small regions or small-scale maps or when high precision is needed. Sparser grids are used for large regions or large-scale maps or when rough precision suffices.

In all cases, it is recommended that an *average* dot count be obtained by several random orientations of the dot grid

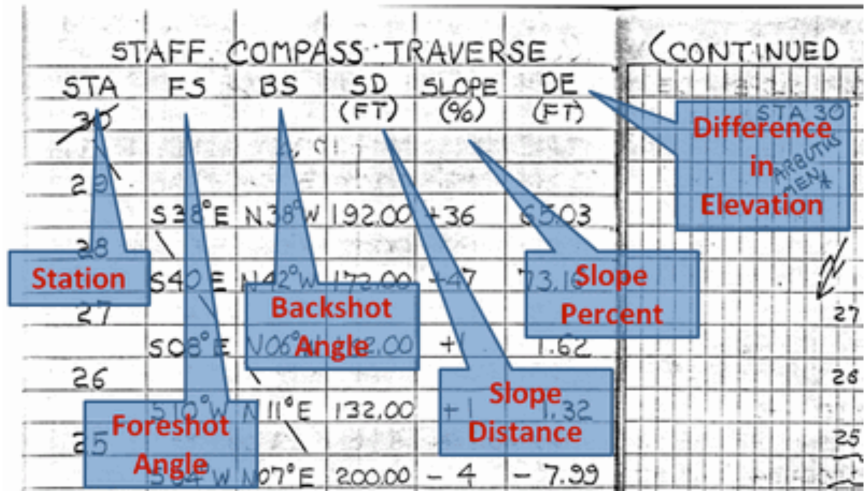
<u>Double Meridian Distance (DMD)</u>

Where there are no ownership disputes a simple closed traverse with a hand compass (or staff compass) and chain will provide sufficient accuracy for determining area in the field, i.e., on the ground.

The most reliable property corner or other fixed known point best serves as the primary control point or starting point, and the traverse may be run either clockwise or in a counterclockwise direction.

Backsights as well as foresights with a compass should be taken on each line, and if needed, numbered or otherwise enumerated stakes driven into the ground at each compass station.

The field data tally sheet should look as follows (with same headers, though DE is calculated in the office, not in the field):



Immediately after the traverse is completed, *interior angles* should be computed. If bearings (or azimuths) have all been properly read and recorded, the sum of all the interior angles should be equal to $(n-2)\ 180°$, where n is the number of sides in the traverse (closed polygon).

Once interior angles have been checked, the traverse is plotted at a convenient scale. If horizontal distances, as well as angles, have been properly measured and recorded, the plotted traverse should appear to "close." At this point, the enclosed area can be calculated using the DMD method. The DMD can be used once a pair of (X, Y) coordinates is generated for each point. The formula is:

$$area = \frac{1}{2}\left[\left(X_1Y_2 + X_2Y_3 + \cdots + X_nY_1\right) - \left(X_2Y_1 + X_3Y_2 + \cdots + X_1Y_n\right)\right]$$

See Exhibit 4 as an example.

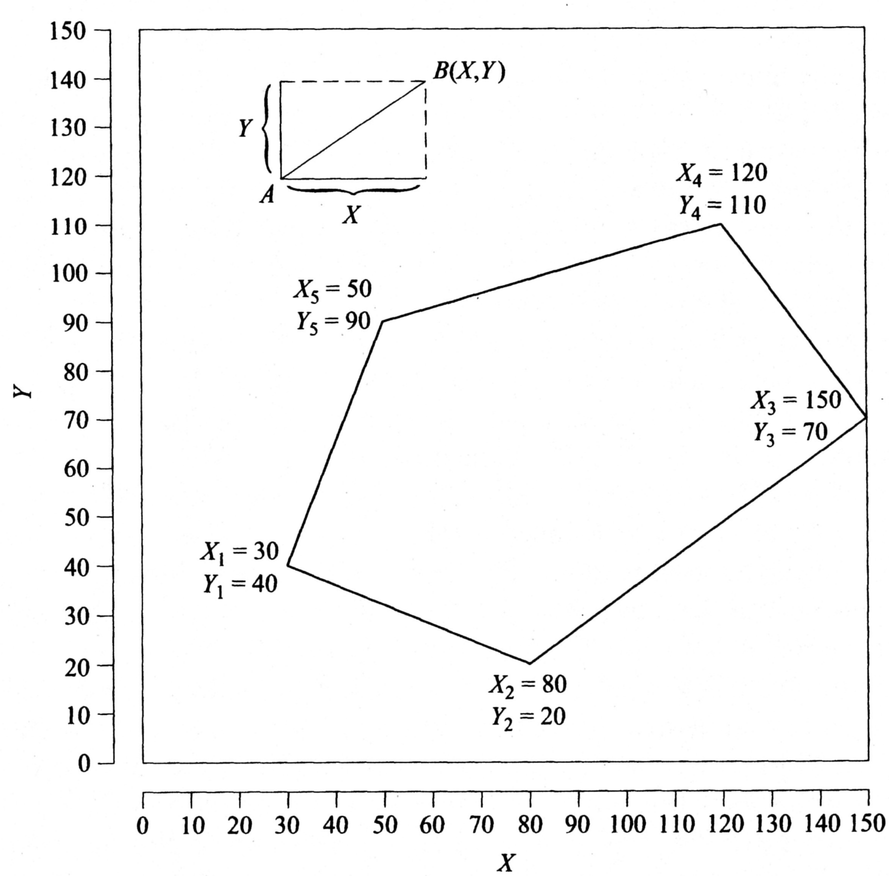


Exhibit 4.

Coordinates for the vertices of a polygon derived from a closed traverse. For area determination, the starting station can be assigned the coordinates (0, 0), then coordinates of all other locations (corners) can be computed using trigonometry. The area of the illustrated polygon is 6350 square units. If the graduations on the axes represented units of feet, then the area would be 6350 sq. ft.