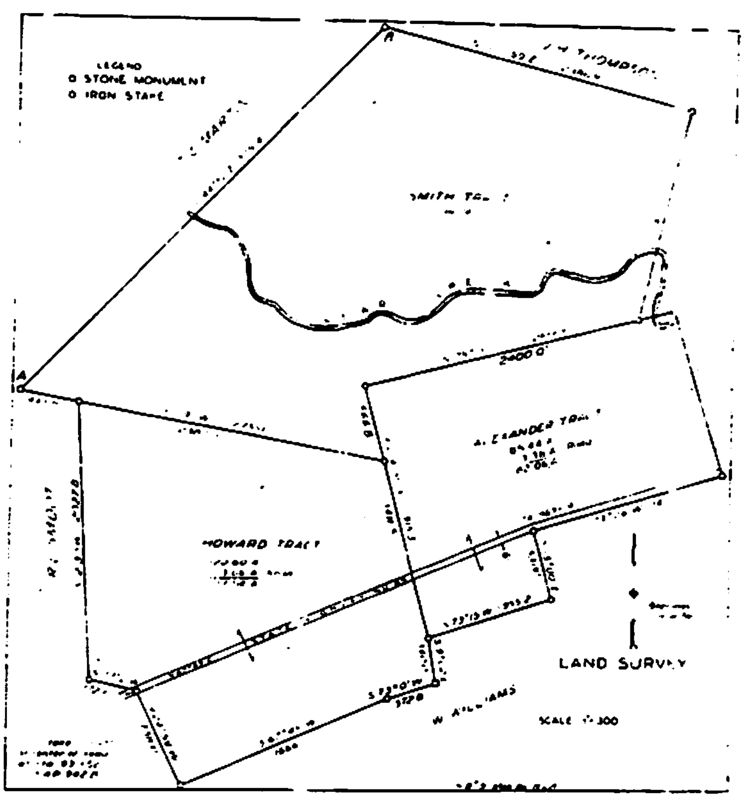
STATE VOCATIONAL-TECHNICAL SCHOOL OF LOUISIANA

MAP DRAFTING AND RELATED COMPUTATIONS FOR PLANE SURVEYING



MAP DRAFTING AND RELATED COMPUTATIONS FOR PLANE SURVEYING

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OF LOUISIANA

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INTRODUCTION

The object and purpose of this manual is to acquaint the student with, and give the student a working practical knowledge of the drawings and related calculations that are connected with plane surveying. Plane surveying deals with areas of limited extent where is is unnecessary to consider the curvature of the earth. It deals with the relative location of points on or near the earth's surface. Geodetic surveying takes into consideration the shape of the earth and this manual will not go into that part of surveying drafting.

It is assumed that the student is familiar with the use and care of drafting instruments and equipment such as are used in a good basic drafting course. Greater care in the execution of the drawings of surveying is usually required than in ordinary mechanical or architectural drafting. In order to keep the desired consistent relation between the field measurements and the completed map, considerable care and skill in plotting and drafting is required.

In mechanical drafting dimensions are usually noted and scaled dimensions from the drawings are not frequently used. In the drawings connected with surveying, many dimensions are omitted and it is necessary for the users of the maps to rely on scaled distances and angular values that are obtained by measurement from the map.

Drawings of Surveying:

The ordinary drawings connected with plane surveying consist of maps, profiles and cross-sections.

Maps:

A map is a graphical representation, by means of lines and symbols, of a certain position of the earth's surface. Since the earth's surface is curved, the shape of the earth being that of an oblate spheroid of revolution, and the surface must be presented on the plane of a sheet of paper, there will always be some distortion in the finished map. In the relatively small areas considered in plane surveying, this distortion cannot be measured by ordinary means. The drawings are therefore made as though the earth's surface, over the area being surveyed and mapped, is flat. All measurements made in surveying are horizontal measurements or the measurements are reduced to the equivalent horizontal measurements before being used in map plotting.

Profiles:

A profile in survey drafting is a drawing showing a vertical section along a certain surveyed line. These are usually made by plotting the elevations of points located at relatively short measured distances along a certain located line, such as the center line of a highway, railroad or canal. An elevation, as the term is used in

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Profiles: Continued

surveying, is the vertical distance of a point above or below a fixed reference plane. The reference plane most commonly used in surveying is mean sea level. Profiles are along and in the direction of the line surveyed and are plotted as a vertical section. Horizontal and vertical scales are necessary. The roughness of the earth's surface along the line surveyed determines the scales to be used. The horizontal and the vertical scales used are not usually the same. Profiles are usually plotted on squared, cross-section paper, or plan-profile paper.

Cross Sections:

A cross section is a drawing showing a vertical section usually at right angles to the survey line. Information for plotting cross sections is obtained by running elevations along lines usually located at right angles to the survey line and out to sufficient distance on each side of the survey line to obtain the desired information. Readings for elevations are taken on the cross line at places where there is a change in the slope of the terrain. Another method is to take different readings and record the elevations only where the readings show a selected contour value. The cross lines to the survey line are spaced or located at whole station numbers on the survey line and at changes in direction of the survey line. These cross lines are also placed at any other locations along the line where additional information is desired or the topography indicates that they are needed. The purpose of the cross lines is to furnish information for locations. They give primary information to determine the shape and configuration of the ground surface on each side of the survey line. Figure 1 shows a typical location of the cross lines on which elevations are taken on a survey line for plotting cross sections. In Figure 1 the full line represents the traverse line and the dashed lines represent the cross section lines.

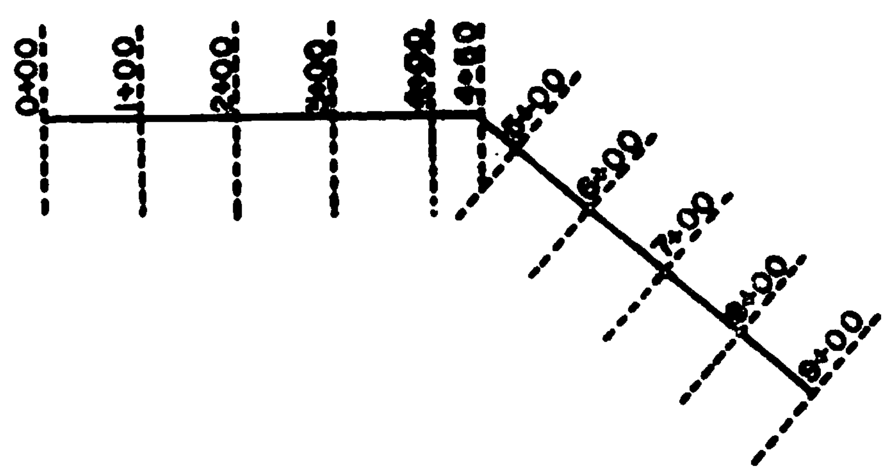

Fig. 1 — Route cross-sections

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Traverses:

The expression "traverse" has been mentioned in the preceding discussion. A traverse is, as used in surveying, a succession of points, at more or less regular measured intervals, connected by straight lines the directions of the lines and the distances between points having been measured. There are two types of traverses. A traverse that begins at a certain point and returns to the point of beginning is called a closed traverse. This is the type traverse encountered in the survey of a tract or parcel of land. A traverse that does not return to the point of beginning is known as an open or continuous traverse. Station numbers are usually used to indicate distances along an open traverse. A station is a unit of 100 feet. This is known as a full station. The fractional part of a full station is known as a plus station. The beginning or starting point in an open traverse is called station 0+100. Open traverses are usually numbered in stations continuously from the beginning point to the end of the traverse. A point at a distance of 782.52 from the beginning of an open traverse would be numbered 7+82.52. The seven indicates the number of full stations and the 82.52 indicates the fractional part of a full station.

During the operation of running a traverse, stakes or markers are set at regular intervals on the line, usually 100 feet apart. Sometimes the distance between stakes is reduced to 50 feet or 25 feet or less. Figure 1 illustrates the method of numbering stations on an open traverse. Each line on a traverse is known as a course. Thus in Figure 8, AB would be called a course.

Examples of open traverses are the surveys for highways, railways, canals and pipelines.

Distances:

Distances are measured in the field with a steel tape, usually 100 feet long. The process of measuring distances is called taping or chaining. Distances are almost always measured in feet. Another unit of measurement used widely at one time was the Gunter's chain. This was a linked wire chain which was 66 feet long broken down into 100 links. Each link was 7.92 inches long. This unit of measurement was used, by law, in the original surveys authorized by the U. S. Government.

Two types of measurement of angles and distances are encountered. These are observed quantities which are actually observed or measured in the field. The others are calculated quantities which are calculated from measured quantities.

The actual distance between any two stations is found by substracting the smaller station number from the larger station number.

In closed traverses, the actual distances between changes in directions of the lines are recorded in feet instead of station numbers.

Distances: Continued

Figure 8 is an example of a closed traverse.

All measurements made during the survey are recorded as they are made in a durable notebook. The notebook is known as a Field Book. Notes and figures from this field book are used by the drafter in making the drawings and maps required. Erasures are not permitted in a field book. A line is drawn through the figure to be corrected and a new figure written.

Kinds of Maps:

It has been stated before that a map is a graphical representation, by means of lines and symbols, of a portion of the earth's surface. A map shows the location of objects, both natural and artificial, on or near the surface of the earth.

There are several types of maps such as topographic, geographic, planimetric, real estate, road maps, land survey maps and many others. If the shape or configuration of the ground surface is shown or indicated on the map, it is known as a topographic map. If the relief of the ground surface is not shown on the map it is known as a planimetric map. Geographic maps show the location of communities, roads, railroads, political subdivisions and much other information.

Scales:

Practically all drawings related to surveying are drawn to scale, that is, a certain distance on the map represents a proportional distance on the ground. The ratio of a distance on the map to the corresponding distance on the ground is known as the scale of the map. We may state the scale as 1" on the map represents 100 ft. on the ground or 1 inch represents any other desirable distance on the ground. The scale may also be stated in another manner such as 1/5000. This means that one unit of measurement on the map represents 5000 units of measurement on the ground, the same units of measurement being used, whether they be inches, yards or miles. Another type scale used is a graphical scale. The scale is drawn on the map and represents actual distances. The advantage of this scale is that any distortion due to shrinkage or expansion of the paper also distorts the scale equally and the scale or ratio remains true. A noted scale is one that states that 1 inch represents so many feet such as 1 inch equals 1000 feet. This means that one measured inch on the map represents 1000 feet on the ground. Figure 2 shows some typical graphical scales.

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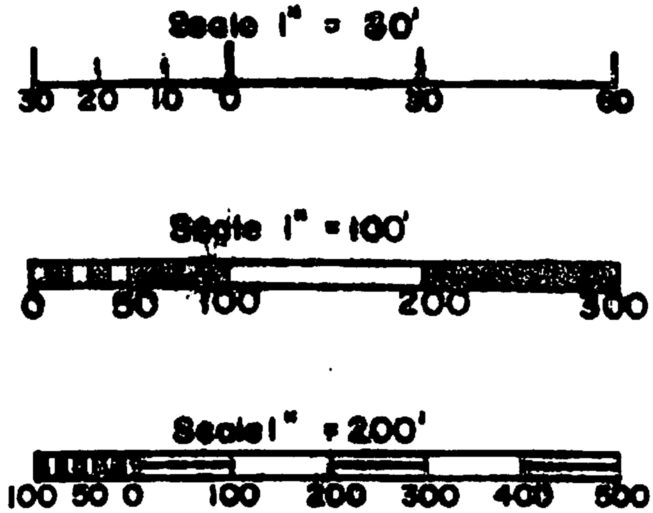

Fig. 2– Scales

North:

All maps should show in which direction the north is in order that the user may orient the map with direction on the ground. The north is indicated by an arrow with the head pointing north. The subject of meridians, or north-south lines, will be discussed later under the subject of direction of lines.

Titles:

Each map should include a title. This gives enough information for the map to be used intelligently. The title should show the name or subject of the map, the authority or who made the map, the direction of the meridian, the scale and any other information needed to use the map.

If conventional signs out of the usual are used, a legend is given showing exactly what the signs or symbols mean or represent. Anything shown out of the ordinary should be explained by a notation at a convenient place on the map.

Symbols:

Objects are represented on a map by certain signs and symbols. Many of these are conventional, that is they are so widely used that they are easily recognized. When a certain sign or symbol becomes accepted widely to mean a certain feature or structure it becomes conventional. The student will soon make a plate showing many generally accepted signs and symbols to represent works, structures and vegetation.

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Map Projections:

This manual and the drawings to be made will deal only with plane surveying. To more accurately represent large and extensive portions of the curved earth's surface various map projections have been devised to reduce distortion. Geodetic survey mapping is not considered or discussed in this manual.

Lettering:

Lettering on a map is of great importance. Poor lettering will ruin the appearance of an otherwise perfect drawing. Good lettering ability can be acquired only by study and frequent practice. It is assumed here that the student has learned the principles of lettering in the basic course in drawing and can continue with the required practice to become skilled in lettering.

Notes and Legends:

Notes and legends are used on a map for explanatory purposes to avoid any doubt in the map users mind. They should be brief but clearly understandable. A key to any but widely accepted symbols should be shown on the map. An acceptable place for notes and legends is near the title block where they are easily seen.

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DIRECTIONS OF LINES

Meridians:

The direction of a line in surveying is usually referred to some fixed line. This fixed line to which other lines are referred is usually a meridian. For any point on the earth's surface there is a fixed meridian, that is a north-south line. A meridian is a north-south line. If this line runs through the observer's point on the earth and the geographic poles, that is the axis on which the earth rotates, it is known as a true meridian. If the line passes through the observer's point on the earth and in the direction that a compass needle points, it is known as a magnetic meridian. The ture meridian and the magnetic meridian coincide only at certain positions on the earth. A compass needle points to the magnetic north pole. The magnetic pole and the geographic pole are not located at the same place on the earth. The geographic north pole is unvarying and remains constant. The magnetic pole is not constant but changes approximately systematically in cycles over periods of time.

The direction of the magnetic meridian may be obtained by noting the direction of the north seeking end of an ordinary compass. The direction of the true meridian can be obtained by astronomical observation.

Another type meridian sometimes used is called an assumed meridian. On small surveys when the exact meridian is unknown, a meridian approximately north is assumed and the lines of the survey are referred to this meridian which is then called an assumed meridian.

Declination:

The angular difference between the true north and the magnetic north is known as the magnetic declination. If the compass needle points to the east of true north, the declination is called east declination. If the needle points to the west of true north, the declination is said to be west. In the United States the declination varies from approximately 24 degrees east of true north to approximately 24 degrees west of true north. The U. S. Government publishes and has for sale, charts showing the declination, annual changes in declination and a line through the U. S. where the declination is zero. These charts are available from the Government Printing Office in Washington, D. C.

Figure 3 shows how true north, magnetic north and the magnetic declination are indicated. True north is indicated by an arrow with a full head and tail. Magnetic north is indicated by an arrow with a half head and a half tail. The angular value of the declination is written in the space between the north ends of the arrows. The directions of lines may be shown by several means. These are usually bearings, azimuths, interior angles, azimuth from back line or angles to the right and deflection angles.

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Declination: Continued

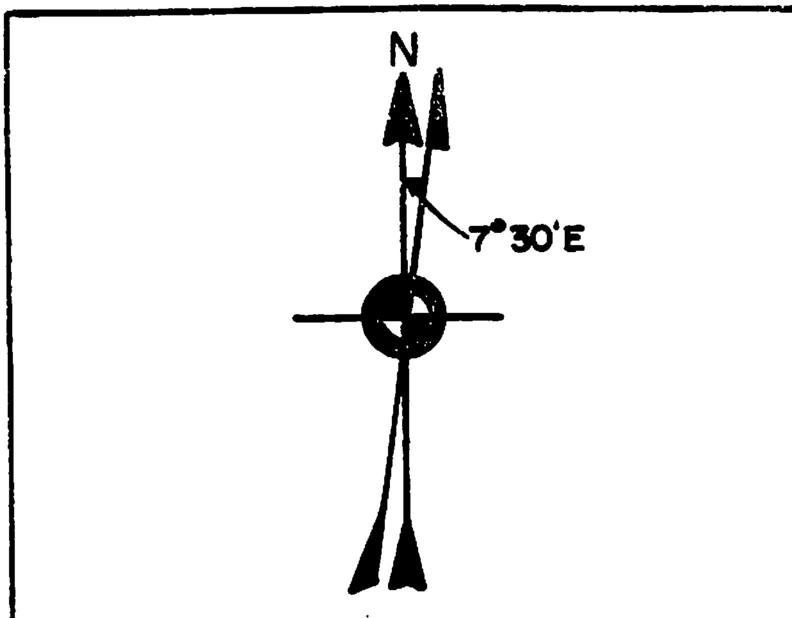

Fig.3— Meridian arrows

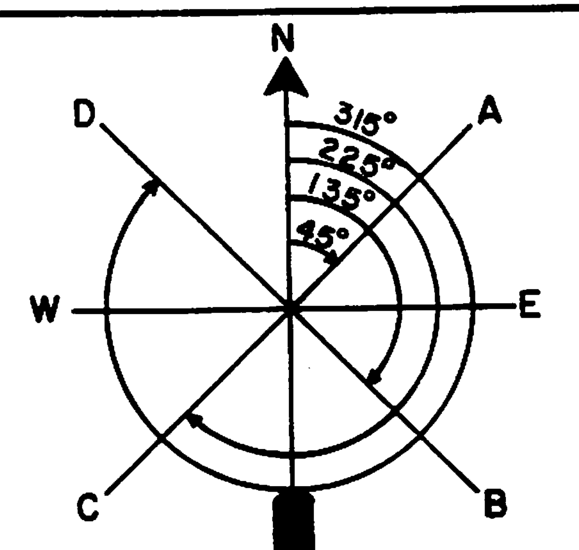

Fig. 4 — Azimuths from north

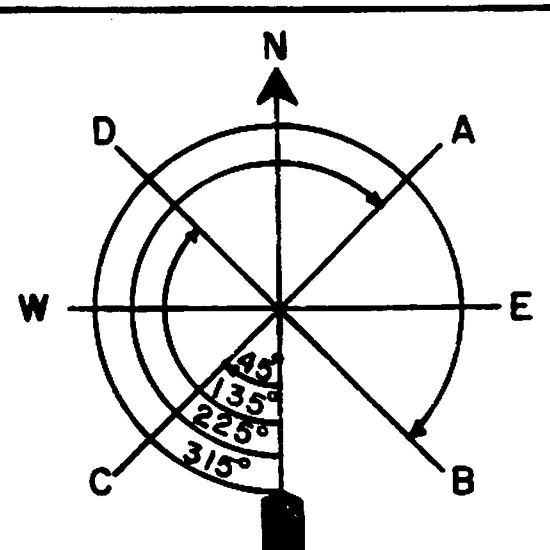

Fig. 5 — Azimuths from south

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Azimuths:

The azimuth of a line is the direction of the line given by the angle between the meridian and the line, measured in a clockwise direction from the meridian. This value can vary from 0° to 360°. Azimuths can be measured from either the north or from the south. Figure 4 illustrates azimuths of lines in each quadrant measured from the north. Figure 5 shows the azimuths of the same lines reckoned from the south. Azimuths are called true azimuths, magnetic azimuths, or assumed azimuths depending on whether they are reckoned from the true meridian, the magnetic meridian or an assumed meridian.

Bearings:

The direction of a line may be defined by its bearing. The bearing of a line is indicated by the acute angles between the line and the meridian in each quadrant in which it falls. If the line falls in the N. E. quadrant the bearing is north and east, in the S. E. quadrant the bearing is south and east, in the S. W. quadrant the bearing is south and west, and in the N. W. Quadrant the bearing is north and west. The angular value is the size of smaller angles between the meridian and the line. Figure 6 illustrates the bearing of a line in each quadrant. Thus, the bearing of line OA is written N45°E, OB is S45°E, OC is S45°W and OD is N45°W. The numerical value of the bearing angle can vary only from zero degrees to 90 degrees. At 90 degrees the direction of the line becomes either due east or west and is so written. The values illustrated are in even degrees. If the angular value measured contains minutes it is written to include the minutes in the measured value. Thus, a measured angle of 38°41' in the S. E. quadrant would be written S38°41'E.

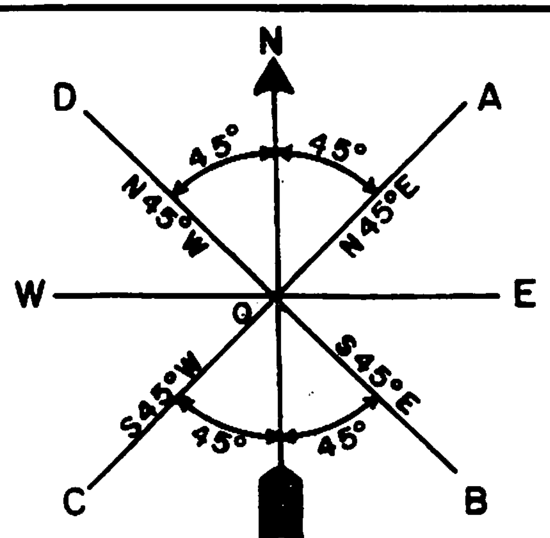

Fig. 6— Bearings

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Bearings: Continued

Bearings are called true bearings, magnetic bearings or assumed bearings depending on whether they are reckoned from the true meridian, the magnetic meridian or an assumed meridian.

A line running due north can be written as N. or north. A line due east can be written N90°E or east. The same goes for a line running due south or due west.

Deflection Angles:

A deflection angle is the angle between the extension of the preceding line and the new line. Deflection angles are always stated as being right or left. If the angle between the extension of the preceding line and the line is turned in a clockwise direction it is recorded as right. When turned counterclockwise it is recorded as left.

Figure 7 illustrates deflection angles to the right and to the left. The deflection angle at B is 30°L, at C is 45°R and at D 20°L. The value of deflection angles may vary between zero and 180 degrees.

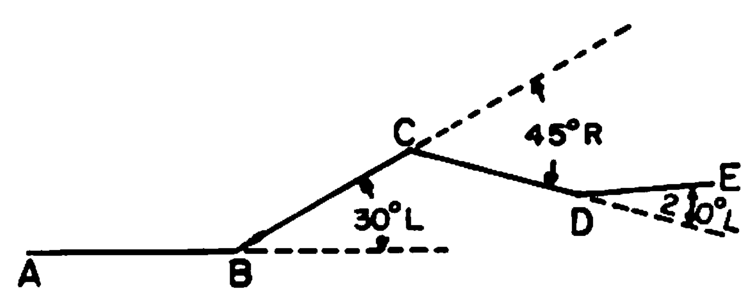

Fig. 7—Deflection angles

If a closed traverse is surveyed using deflection angles a check on the accuracy of the measurement of the angles is easily made. In any closed figure the algebraic sum of the deflection angles is 360 degrees. The angles to the right are considered positive and the angles to the left are considered negative. The algebraic sum of the angles is 360 degrees, the sign is of no importance; it only indicates the direction taken around the figure.

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Interior Angles:

In a closed figure the included angle between two sides inside of the figure is known as an interior angle. This method of measuring angles is used on many property surveys. Figure 8 illustrates interior angles. Interior angles may be of almost any size.

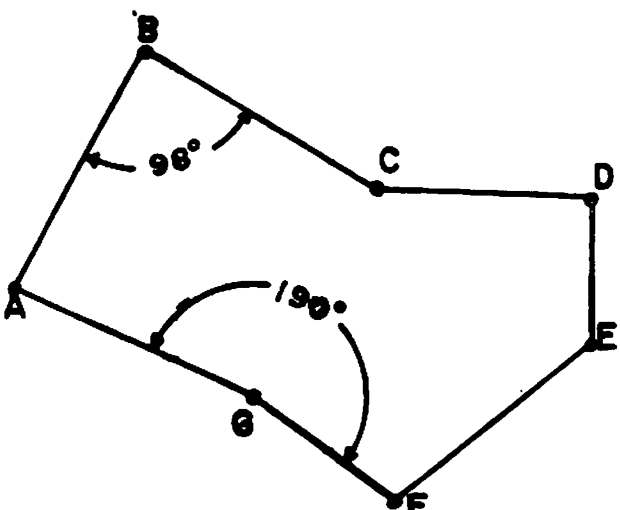

Fig. 8— Interior angles

In any closed figure the sum of the interior angles is equal to the number of sides minus two times 180°. This is usually written (n-2) x 180°, n being the number of sides in the figure. This is a definite check on the accuracy of the measurement of the interior angles in the survey of a closed traverse. This check is usually made at the time of the measurement of the last angle. It is always applied before any other calculations are made. The sum of the measured angles usually does not equal (n-2) x 180° since there is usually some small error in reading angles. If the misclosure in angular value is small and all of the angles were measured under equal conditions, the error is usually distributed equally among the angles to give a mathematically closed angular value. This is known as the angular adjustment of the traverse. Sometimes the error of angular closure is arbitrarily placed in one angular measurement that was made under difficult conditions.

Angles to Right:

Angles which are measured in a clockwise direction from the preceding to the following line are known as angles to the right or azimuths from the back line. These angles may be of almost any value. Figure 9 illustrates angles of this type.

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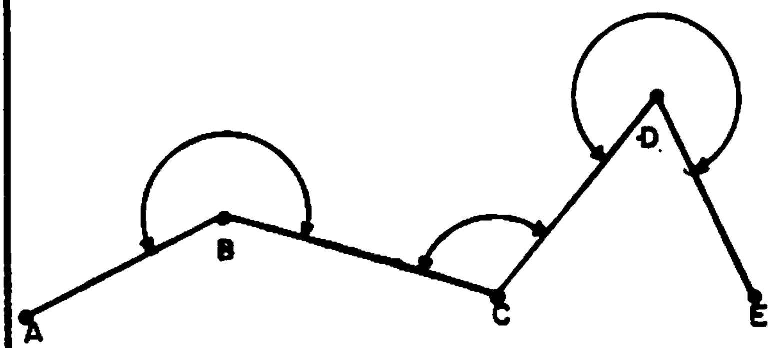

Fig.9– Azimuth from back line or angles to the right.

Angles in General:

Angles in general are measured in the field by use of several special types of surveying equipment. They are measured most commonly by means of a surveyor's transit. This instrument is known as the universal surveying instrument and can be used to measure horizontal and vertical angles, stadia distances, differences in elevation and magnetic bearings. Other means of measuring angles are by tape, plane table alidade, sextant, and magnetic compass.

Values that are measured directly in the field are known as observed values. Values that are obtained indirectly by some form of calculation are known as calculated values.

Any of the above discussed systems of measuring angles or directions can be converted to another system most easily by drawing a simple sketch [illegible] aking a simple calculation. Thus in Figure 7 if the bearing of line AB i[illegible], then the bearing of line BC is $90^{o}-30^{o} = 60^{o}$. The line is in the N. E. quadrant and the bearing is N60^{o}E. The beginner should always use a sketch to show the existing relations between the systems under consideration.

PLOTTING ANGLES

After measurements are made in the field and recorded in the notebook it is the job of the drafter to transform this field information into a map or other drawing. Two of the primary operations are the scaling of distances and the plotting of angles. Sometimes the use of conventional signs and symbols is involved. Usually the map is plotted on a heavy, good grade of drawing paper. The drawing is then checked and a tracing made. From the tracing reproductions are made by one of the methods to be discussed in Section 11 of this manual. In some cases a skilled drafter will work directly on tracing paper or cloth.

The drawings assigned in this manual will be drawn first on drawing paper and then traced in ink on a good grade tracing paper.

The plotting of angles will be taken up first. There are several methods of plotting angles. Some are widely used and some are not often used in plotting. The methods of plotting angles to be discussed are the protractor method, tangent method, chord method and the use of the drafting machine.

Protractor Method:

The protractor method of plotting angles in survey drawings is not widely used except where the map is fairly small or unimportant. With an ordinary six inch protractor the error in plotting may be as much as 15'. The larger the diameter of the protractor used, the smaller the accidental error introduced will be. Figure 10 is used in discussing the use of the protractor in plotting deflection angles. The first line is fixed by instructions or by estimation. The distance from A to B is then scaled using a needle point to mark the location of B. It is good practice to extend the line AB very lightly in either direction from B to properly orient the protractor at point B. The deflection angle at B is then laid off and marked with a needle point. A light line of indefinite length is then drawn through B and the marked needle point. The recorded distance from B to C is then scaled off along this line. When point C has been located and checked the protractor is then oriented at C and the process of laying off the deflection at C is then repeated as was done at point B. The other points on the line are then located in like manner until the complete traverse is plotted. The main objection to this method of plotting a traverse is that if an error is made in plotting an angle at any point it affects to a similar degree the direction of all of the succeeding lines. The linear error in plotted position of succeeding points increases with distance.

In plotting the directions of lines from a meridian using either bearings or azimuth it is customary to draw lightly a meridian through each point. The bearing or azimuth is then measured with the protractor to the next point. The distance to the next point is then scaled off. A meridian is then drawn through the located point and the process continued until the full traverse is plotted. An error in the plotting of one direction by this method does not introduce an error in the direction of the following lines but it does introduce a constant linear error in the plotted locations of succeeding points.

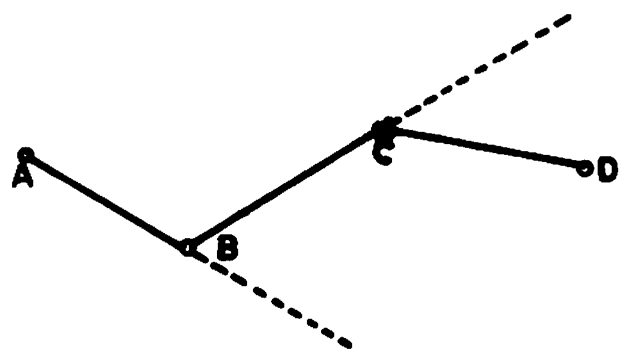

Fig.10-Protractor method of plotting deflection angles.

Tangent Method:

In the plotting of angles by the tangent method linear measurements and a table of the natural tangents are used. These angles plotted are as accurate as the linear measurements can be made. A large enough scale unit is used so as to make the error introduced in the plotting to be negligible. Figure 11 is used in discussing the tangent method of plotting angles. AB represents the plotted position of the initial line of a deflection angle traverse. The line AB is then extended lightly for an indefinite length. Ten units are then scaled off on the prolongation of line AB and point E located with a needle point. Any units on the engineers scale can be used and a scale is usually selected to give sufficient room to work on the sheet of drawing paper. From a table of natural tangents the tangent of 20° is found to be .364. A perpendicular of indefinite length is erected at point E. From point E a distance of 10 x .364 or 3.64 inches is scaled off on the perpendicular line erected at E and marked with a needle point. This locates point F. A line of indefinite length is now drawn lightly through points B and F. The distance between BC is now scaled along the line through B and F. This locates point C in the proper plotted position. The angle between the extension of line AB and the line BF is the required 20° angle. In a right triangle the length of the opposite side from an angle divided by the length of the side adjacent to the angle is equal to the natural tangent of the angle. In this case 3.64 divided by 10 is equal to .364 which is the tangent of 20°.

The tangent method works well on angles up to 45°. For angles above 45° the size of the tangent of angle increases rapidly. Above 45° the length of the perpendicular erected would become too long to be plotted readily. Point C in Figure 11 will will be used in discussing a method of plotting deflection angles greater then 45°.

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Tangent Method: Continued

The deflection angle at C is taken as 75°R. In this case the base line of 10 units instead of being a prolongation of BC is a base line of 10 units in length erected at C perpendicular to line BC. Point G on the perpendicular at C is located at 10 units from C. The perpendicular offset at G in this case is 10 times the cotangent of 75°. In this case the cotangent of 75° is .268 and the length of the perpendicular offset at G is equal to 10 x .268 which is 2.68 inches which is scaled off from G to point H. A line drawn through C and H plots a deflection angle of 75° to the right at C. The distance from C to D is scaled off along the line through C and H and this locates point D. The plotting of deflection angles by the tangent method is much more accurate than plotting angles by the protractor method provided long enough units are used. It is subject to the same objections brought out in the protractor method in that an error in plotting of the directions of one line affects to the same degree the directions of all following lines.

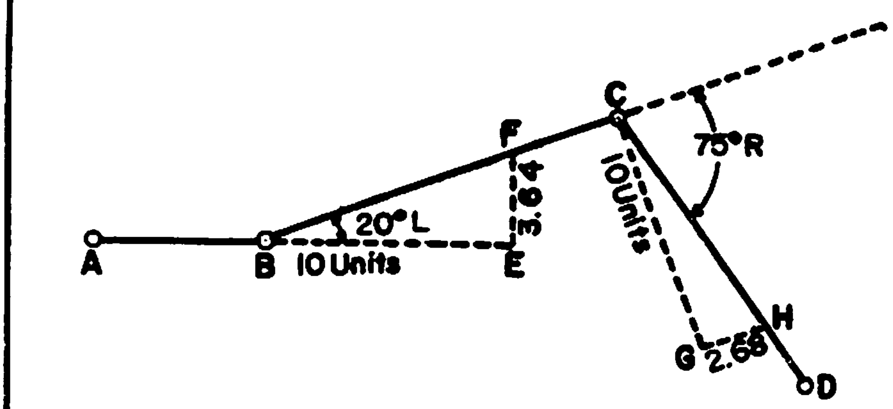

Fig. 11— Tangent Method

Chord Method:

The chord method of plotting angles is sometimes used. It is similar to the tangent method. There is slightly more calculating to do than in the tangent method. Some engineering handbooks give a table of chord lengths for various angles. When a table of chords is available, the method is as quick or quicker than the tangent method. In a circle of a given radius there is a definite relation between the chord and the chord's subtended angle. Figure 12 shows the theory and mathematics used fo. obtaining the chord length when a radius of five units is used. It is to be noted that any length units can be used. The reason five

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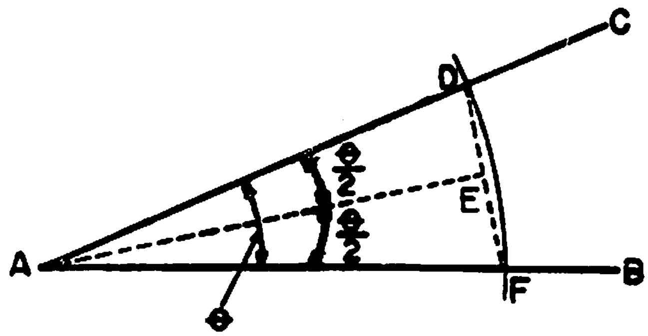
<u>Chord Method:</u> Continued

units are selected for the radius is that in the end, multiplication by ten is involved which simplifies the calculations. The sine of ½ the angle to be plotted is obtained from a table of natural sines. The multiplication by ten is then a simple matter of moving the decimal place one place to the right and the chord length for the particular angle is obtained for use in plotting the angle. It is to be noted that the sine of ½ of the angle is to be used and not ½ the sine of the angle.



$DE = AD \sin\frac{\theta}{2}$, $2DE = \text{Chord } DF = 2AD \sin\frac{\theta}{2}$. If AD is taken as 5 units Chord $= 10 \sin\frac{\theta}{2}$.

Fig.12— Chord Method Proof

Figure 13 is used in discussing the procedure to be used or followed in plotting a deflection angle by the method of chords. The deflection angle at B to be plotted is 32° to the left. The line AB is extended lightly far enough to be at least five units in length. Inches can be used as the unit or any other unit on the engineers scale. The units used must be long enough to allow accurate scaling of the calculated chord length. With the drawing compases set to give a radius of five units the arcs FG and DE are drawn. The length of arc DE is drawn long enough so that an angle of around 32° at B will intersect the arc DE. The next operation is to find in the tables the sine of ½ of 32° which is 16°. The sine of 16° is found to be .276. Now 10 x .276 = 2.76 inches which is the required chord to give a deflection angle at B of 32°. Now with the compasses set to draw an arc with a radius of 2.76 inches use the intersection of arc FG with the extension of line AB as the center and describe an arc HI intersecting arc DE. Next draw a light line of indefinite length through point B and the intersection of arcs DE and HI. This line gives the direction of line BC and a deflection angle of 32° to the left at B. The recorded length of line BC is now scaled from point B along the line through B and the intersection of the two arcs DE and HI. This fives the proper location of point C as plotted by the chord method.

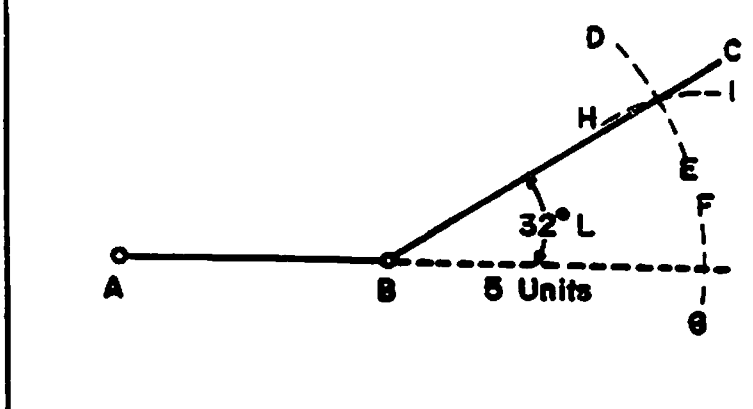


Fig.13 – Chord Method

Latitudes and Departures:

Another method of plotting sometimes used is known as plotting by latitudes and departures of individual courses. This method is very similar to plotting by the method of tangents. In this case the hypotenuse of the right triangle is made equal to the length of the course and the legs of the right triangle are calculated. Figure 14 is used in discussing this method. The side of the right triangle parallel to the meridian is called the latitude. The side perpendicular to the meridian is called the departure.

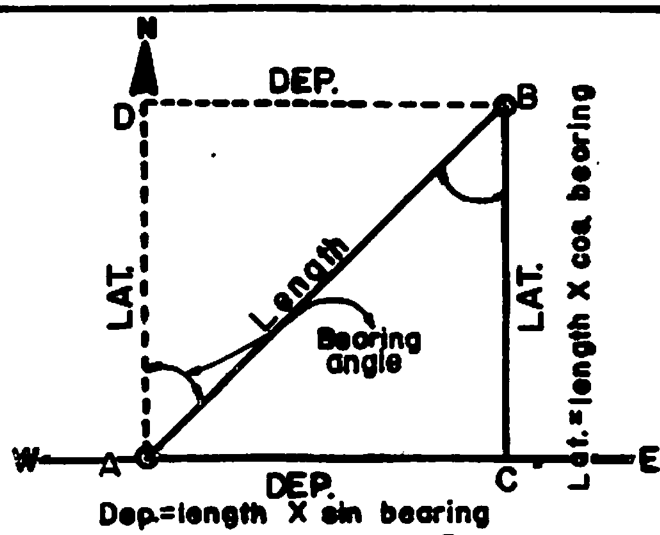


Fig.14 – Latitudes and Departures

Latitudes and Departures: Continued

The numerical value of the latitude is equal to the product of the length of the course and the cosine of the bearing angle. The numerical value of the departure is equal to the product of the length of the course and the sine of the bearing angle.

In plotting point B the calculated length of the departure is first scaled along a line perpendicular to the meridian at point A to establish point C. A meridian line is then drawn through point C and the calculated length of the latitude of the course scaled from point C. This locates point B. The line for the course AB is now drawn from A to B.

Other uses of latitudes and departures in mapping will be discussed later in this manual.

Drafting Machines:

In the above discussed methods of plotting angles only ordinary drafting equipment such as the T-square, triangles, protractors and scales were used. Most engineering and drafting offices today are equipped with drafting machines. This instrument combines in one piece of equipment, which attaches to the drafting board, the functions of the T-square, triangles, scale and protractor. Simply, a drafting machine consists of two arms with a pivoted protractor head attached. The pivoted protractor head is equipped with receptacles for two scales at right angles to each other, one for vertical lines and the other for horizontal lines. The mechanical linkage by bands is such that each scale remains parallel to its original preset direction as the protractor head is moved to any position on the drafting board. The protractor head can be simply and quickly oriented to any base and locked and angles measured from this base.

A drafting machine with a civil engineers protractor head is available which is designed with map drafting in mind. With this machine angular and linear measurements made in the field by the survey crew can quickly be reproduced on the drawing board. The protractor circle is equipped with a vernier so that angles can be plotted or read to one minute. It is estimated that 50 percent or better of mapping drafting time is saved by the use of a drafting machine as compared with regular T-squares, triangles, protractors and scale equipment. Any person with a basic knowledge of mapping drafting can be taught to operate these drafting machines in a very short period of instruction.

Since drafting machines are now almost universally used this is the type equipment drafting students will certainly use when they enter industry. They should be part of the equipment of any school teaching map drafting to the students who are to enter industry well prepared as drafters.

PLOTTING TRAVERSES

In most present-day surveys the lengths of the courses are measured in feet and decimals of a foot. By law, most of the original government surveys used as the unit of measurement the surveyor's or Gunter's chain. The Gunter's chain is 66 feet in length, called 1 chain, and made up of 100 links; each link being 0.66 of a foot, or 7.92 inches.

Open traverses are numbered in stations continuously from the beginning. In dealing with closed traverses it is customary to give the length and direction of each course and to assign to each change in direction, or corner, a lettered or numerical identification.

Open Traverses:

Open traverses may be plotted by any of the methods of plotting angles previously discussed. The direction of the line is established and the distance of the course is scaled. An appropriate scale ratio is used to make the finished drawing of the desired size.

Closed Traverses:

Closed traverses may be plotted by any of the previously discussed methods of plotting angular values and using the selected scale for plotting distances.

Coordinates:

There is another very important method of plotting traverses, both open and closed that has not been previously discussed. This is the method of plotting points by coordinates. This is based on the method of latitudes and departures touched upon previously and using Figure 14 to illustrate what latitudes and departures are.

By definition the latitude of a course is parallel to the meridian and the departure of a course is perpendicular to the meridian. For this reason in plotting by coordinates, or total latitudes and total departures, a system of rectangular coordinates is used. The meridian is used for one axis of the system and a line perpendicular to the meridian, as an east-west line, the other axis. It is customary, in order to avoid negative coordinates, to select the origin of the coordinates in such a location as to place the entire survey in the northeast quandrant. This is not of necessity but only of convenience. Any point on the traverse may be selected as the origin. North is considered positive and south is considered negative. Also east is considered positive and west negative. Figure 20A shows the signs in each quadrant.

Figure 15 is used in discussing the method of plotting points by coordinates. Coordinates are sometimes referred to as total latitudes and total departures from the point of origin. Using Figure 15 to illustrate, the first procedure is to

Coordinates: Continued

compute the latitude and deaprture of each course of the traverse. This is done by the method illustrated in Figure 14 and described in the previous discussion of latitudes and departures and their calculation from the course length and bearing. It is seen from Figure 15 that the location of point 1 is on the meridian and is north of the origin a distance equal to the sum of the latitudes of course 4-5 and course 5-1. The distance east of the meridian is 0 since the meridian axis was selected as passing through point 1. The location of point 2 north of the origin is the sum of the latitudes of courses 4-5, 5-1, and 1-2. The location of point 1 east of the origin is equal to the departure of course 1-2. We now have the coordinates of point 2. This point can be plotted by rectancular coordinates. This is done by scaling the proper distances north from the origin and east from the origin.

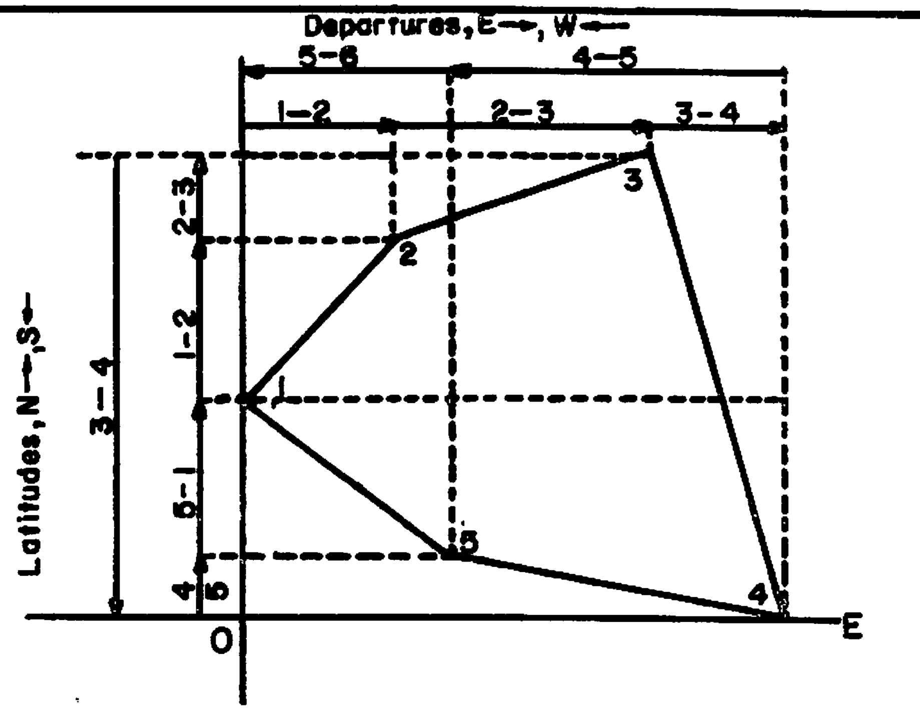


Fig.15.—Closed traverse—Latitudes and Departures

In a like manner the north coordinate of point 3 can be found by adding the latitudes of courses 4-5, 5-1, 1-2, and 2-3 and the east coordinate by adding the departures of courses 1-2 and 2-3.

In normal practice latitudes and departures along with coordinates are calculated by machine using special calculation sheets designed for this purpose. The student will be assigned problems of this type later and the calculations and forms used will be discussed and illustrated.

Coordinates: Continued

From the above discussion and from the geometry of Figure 15 it is seen that, in plotting a closed figure by coordinates, the sum of the north latitudes must be equal to the sum of the south latitudes and also the sum of the east departures must be equal to the sum of the west departures. In actual practice some errors always exist in field measurements. This will cause the sum of the computed north and south latitudes to be of different values. The same holds for the computed east and west departures. This is normal and to be expected. The differences found are known as the error of closure in latitudes and departures. This will be brought out more clearly under the adjustment of surveys.

The use of coordinates in surveying computations and plotting is now considered standard. It is the most widely used of any method and also the most accurate. An error in the plotting of any one point does not affect the plotted position of any other point.

In this method of plotting the position of any point from the origin is given by stating the distance the point is either north or south of the origin and the distance the point is either east or west of the origin. This is very much like graph plotting in elementary algebra.

LATITUDES AND DEPARTURES

The method of calculating the latitude and departure of an individual course of a survey was discussed briefly in Section 3 and was illustrated by Figure 14. In Section 4 the meaning of total latitude and total departure was briefly discussed using Figure 15 to illustrate their meaning. Figure 15 illustrates that in any closed traverse the algebraic sum of the latitudes must be equal to zero. Also the algebraic sum of the departure must be equal to zero. It must be kept in mind that north latitudes are considered positive and south latitudes are considered negative. Likewise east departures are positive and west departures are negative.

In going around any tract of land it is obvious, from Figure 15, that the distances traveled north and traveled south must be equal in order to arrive back to the point of beginning. This also is true for distances traveled east and west.

In general, when the algebraic sum of the north latitudes and south latitudes are calculated for any closed traverse that has been surveyed in the field, they will not be numerically equal. That is, the algebraic sum of the positive and negative latitudes will not usually be equal to zero. This same condition is also encountered when the algebraic sum of the departures are calculated. Theoretically, the algebraic sum of the latitudes must be equal to zero and the algebraic sum of the departures must be equal to zero if there are no errors in the measurement of distances or angles in the field work. However, in actual practice, there are always some errors present in the measurement of both distances and angles. This is due to numerous reasons both instrumental and personal. Due to these normal errors, an unadjusted traverse will not usually close in either plotting on drawing paper or by calculation of latitudes and departures. It is seen from Figure 16 that the amount of misclosure can be calculated mathematically.

<u>Error of Closure:</u>

Figure 16 shows a closed unadjusted traverse for which the latitudes and departures have been calculated. The algebraic sum of the latitudes is not equal to zero and the algebraic sum of the departures is not equal to zero. In this case the distance AF in the right traingle AFA' is the amount the north latitudes and the south latitudes fail to agree. The distance FA' in the same right triangle is the amount the algebraic sum of the east and west departures fail to agree. AF is the misclosure in latitude and FA' is the misclosure in departure. The linear misclosure is shown by the line AA' which is the hypotenuse of the right traingle AFA'. Since the misclosure in both latitude and departure is known, the length and direction the linear misclosure represented by line AA' can now be calculated.

In this case, the misclosure represented by line AA' is equal to $\sqrt{AF^2 + FA'^2}$ in distance. The direction of the line AA' is given by the angle FAA' and the tangent of this angle is equal to FA'/FA. The tangent of the angle being known, the angle can be found from a table of natural tangents. This angle gives the bearing of the line of misclosure. In this case the bearing would be in the southeast quadrant. A rough sketch will show in which quadrant the direction of misclosure lies.

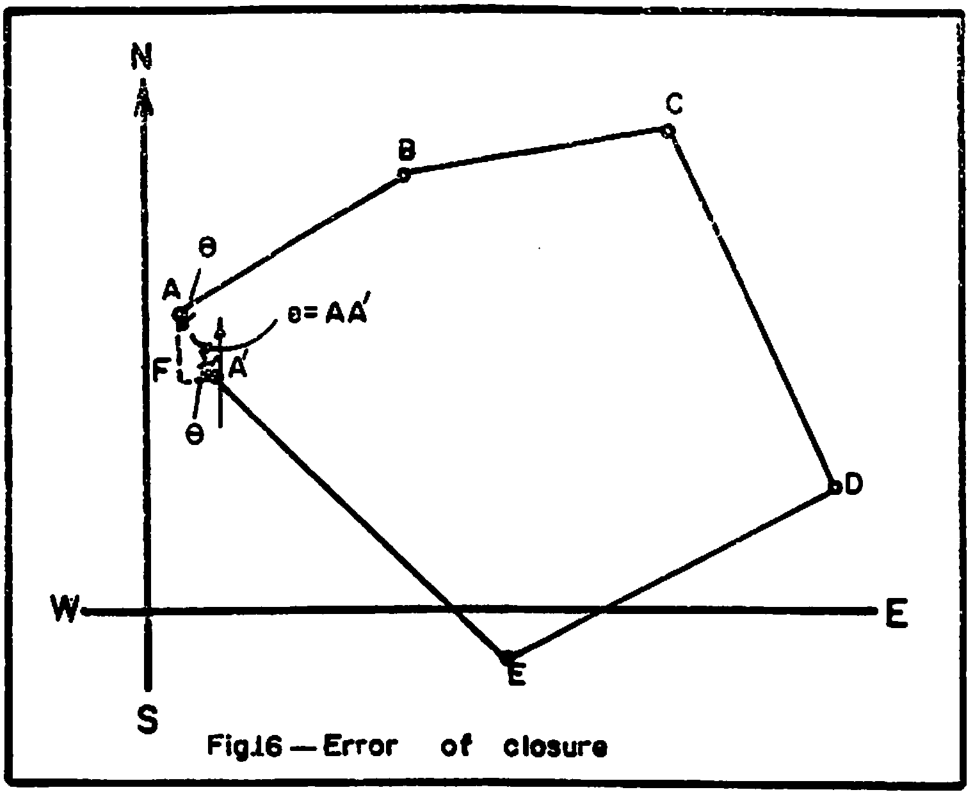


Fig.16 — Error of closure

Balancing the Survey:

The unadjusted traverse must now be adjusted or balanced to make it close mathematically. It is assumed that the angular adjustments have been made before calculating the latitudes and departures. This angular adjustment is made by the method previously explained. That is, in any closed figure, the sum of the interior angles must be equal to $(n-2) \times 180^{\circ}$, where n is the number of sides. If the sum of the measured angles fail to meet this condition, the difference or misclosure is usually divided equally among the angles to make this condition exist. In the case where deflection angles are measured for a closed traverse, the algebraic sum of the deflection angles must equal to 360 degrees. Angles to the right are considered positive and to the left, negative. It is of no consequence whether the sign of the sum is negative or positive.

When the latitudes and departures for a traverse have been computed and the misclosure in latitude and departure have been determined the survey is then balanced in order for the traverse to create a mathematically closed geometric figure. The balanced survey will cause the sum of the north latitudes to equal to the sum of the south latitudes and the sum of the east departures to equal to the sum of the west departures.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Balancing the Survey: Continued

There are several rules for balancing a survey such as the compass rule, transit rule and the Crandall method. The compass rule is probably the most widely used and assumes that the misclosure is due to angular errors as much as to distance measurement errors. The compass rule will be given and illustrated here. This rule distributes the error of closure proportional to the length of each line. The compass rule states that the correction to be applied to the latitude or departure of each course is to the total correction in latitude or departure as the length of each course is to the total length of the traverse. Sample plate 10 illustrates the method of balancing a survey. The individual latitudes and departures of each course are calculated. The sum of the north latitudes is shown to be 1668.76 feet and the sum of the south latitudes is shown to be 1670.37 feet. These are not equal and show an error in latitude of 1.61 feet too much south. Likewise, the sums of the departures show an error in departure of 5.03 feet too much west. These errors are distributed among the courses, proportional to their lengths, so that the latitudes and departures will balance.

The linear error of closure is equal to $\sqrt{1.61^2 + 5.03^2}$ which is equal to 5.28 feet. The total length of the traverse is 4657.0 feet. Since the total error in latitude is 1.61 feet the correction to be applied to the line BC in latitude is equal to 686.4/4657.0 x 1.61 which is .237 feet. Since the total error is too much south, the corrections are subtracted from the south latitudes and added to the north latitudes. The correction in departure to be applied to the line BC is equal to 686.4/4650.0 x 5.03 which is equal to .741 feet. Since the error in departure is too much west, the corrections are subtracted from the west departures and added to the east departures. The corrections in latitude and departures are shown in the column of corrections. The corrections are given the proper plus or minus signs showing if they are to be added or subtracted from the unadjusted latitudes or departures to give the corrected latitudes or departures. When the corrections are applied properly to the unadjusted latitudes and departures the adjusted latitudes and departures are obtained and the sum of the north latitudes should be equal to the sum of the south latitudes. Likewise the sum of the east departures and the sum of the west departures should be equal. When these conditions exist, the survey is balanced and the adjusted latitudes and departures are considered correct and can be used in calculating areas and coordinates.

The numerical sum of the individual corrections in latitude, without regard to sign, must be equal to the total correction in latitude. Also the numerical sum of the corrections in departure must be equal to the total correction in departure.

Since the correction in latitude or departure for each line is proportional to its length a constant can be calculated which simplifies the calculations. On sample plate 10, the constant for latitude correction is the total error in latitude divided by the total length of the traverse. This gives the correction per foot of line to be applied. This constant is multiplied by the length of each line which gives the correction in latitude to be applied to the unadjusted latitude of the line to obtain the adjusted latitude. The constant for departures is employed in the same way.

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Balancing the Survey: Continued

Sample plate 10 shows the adjusted latitudes and departures of an acutal survey and how they were obtained. The right-hand side of sample plate 10 concerns the calculation of the area within the closed traverse. This will be discussed under the subject of calculation of areas.

The computation of coordinates from the adjusted latitudes and departures is usually next in order after the latitudes and departures have been adjusted. The coordinates of points on a survey are sometimes referred to as total latitudes and total departures and have the same meaning.

The use of latitudes, departures and coordinates is now standard practice in most surveying and mapping work. For this reason every mapping draftsman should be acquainted with their use and computation.

In computing coordinates for a survey it is first necessary to select an origin for the coordinates. It is usually selected so as to place the entire survey in one quadrant. It is convenient to select the northeast quandrant to avoid negative coordinates. Sometimes the origin is a fixed monument on the ground such as is the case when surveys are tied to a state coordinate system. After the latitudes and departures have been adjusted the coordinates are calculated by simple addition and subtraction.

Sample plate 10A shows the calculation of the coordinates for the traverse for which the latitudes and departures were calculated on sample plate 10. The coordinates calculated on sample plate 10A are the coordinates used in plotting the control traverse on sample plate 7P. The control traverse on plate 7P (the P being for preliminary) is the horizontal control used for constructing the contour map shown on sample plate 7. The origin here selected is the lower left hand corner of the rectangle enclosing the topographic map to be constructed for sample plate 7. The coordinates of point A were selected to be 370 feet north of the origin and 450 feet east of the origin so that the traverse would fit the space on the map. The coordinates for point A are 370'N and 450'E. The process of determining the coordinates of the other points on the traverse is a matter of adding algebraically the individual adjusted latitudes and departures to the coordinates of point A. Thus the total latitude of point B is the total latitude of point A plus the latitude of the line AB. The total latitude of point B is 370.00 + 588.02 which is 958.02. The total latitude of point C is 958.02 + 677.29 which is 1635.31. The total latitude of point D is 1635.31 plus 404.08 which is 2039.39. The total latitude of point E is 2039.39 + (-354.70) which is 1684.69. The addition is continued on around the traverse until all total latitudes are obtained. This is continued back to the point of beginning. A check on the arithmetic is obtained here because if there is no mistake in arithmetic, the calculated total latitude of point A will be the same as that assigned to it in the beginning.

Balancing the Survey: Continued

The total departures are calculated in exactly the same manner as are the total latitudes . It must be kept in mind that the sums are algebraic, that is, a positive value is assigned to north latitudes and a negative value is assigned to south latitudes. Departures are considered positive if east and negative if west.

When the latitudes and departures are adjusted this will change slightly the distances and bearings of the courses of the traverse. In land surveys this alteration of lengths and bearings is sometimes made. This is a laborous computation and is not necessary when areas, closure and coordinates only are needed. When this correction is required the calculation is simple but tedious. The adjusted latitude is one leg of a right traingle and the adjusted departure is the other. For example, the measured length of the course AB is 595.2 feet. The altered length is $\sqrt{588.02^2 + 92.81^2} = 595.30$. In the same right triangle, the tangent of the altered bearing is the corrected departure divided by the corrected latitude. In this case the altered bearing line AB is obtained thus: tangent of altered bearing angle is equal to 92.81/588.02 which is .15783. From a table of natrual tangents the angle is found to be $8^{o}58'$. A sketch will show in which quadrant the bearing angle is located. In this case, the bearing is $N8^{o}58'W$. These altered distances and bearings are given in the last two columns of sample plate 10A. The altered bearings and distances are calculated exactly as was the linear misclosure and direction of misclosure which was previously discussed and was illustrated by Figure 16.

In making any calculations the use of a suitable form saves time, eliminates unnecessary work, makes the calculations systematic and allows easy checking of the calculations by another person.

The form used on sample plates 10 and 10A are convenient to use. The calculations are made by the use of some type of calculating machine. The rotary type calculator is almost essential for these type calculations. Slide rule work is not satisfactory for these calculations.

Before the time when the use of the calculating machine became almost universal logarithms were used for these types of computations. Today the high cost of labor and the moderate cost of calculating machines prohibits the use of logarithms and hand calculations and these methods will not be discussed.

Plotting by Coordinates:

The method for computation of coordinates has been given. Plotting by coordinates is the most reliable method of plotting. It is recognized as the only practical method of plotting extensive surveys covering large areas. Rectangular coordinates are also used in calculating areas of land and cross sections. The coordinate axes are usually north-south and east-west reference lines. The origin of this system of rectangular coordinates may be at any desired place inside or outside the survey.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Plotting by Coordinates: Continued

In plotting by coordinates a grid system of lines is first drawn. The coordinate lines for this system must be carefully constructed to insure that the coordinate squares are actually square. The sides and diagonals should be measured for each square. To insure accurate plotting the coordinate lines must be constructed as accurately as possible. The sizes of the coordinate squares will depend upon the extent of the survey, the scale used and the type mapping being done.

In plotting by coordinates the coordinate line nearest the plotted point is used to measure from rather than measuring from the origin.

Systems of coordinate squares are shown on sample plates 3, 4 and 7P together with the procedure of plotting from the coordinate lines.

In plotting by coordinates each point is plotted by its total latitude and total departure. The location is checked by scaling the distance between points given in the survey notes. This check should always be applied as the plotting progress.

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CALCULATION OF AREAS

Many times the main object of a survey is to determine the area of a tract of land. Several methods are available for determining area. The method used depends upon the type survey made, the shape of the tract and the precision of the desired results.

The usual units of area are the acre and square foot. An acre is equal to 43,560 square feet. Some original surveys were measured with a Gunter's chain which is 66 feet long. One acre is equal to 10 square chains.

Triangles:

A simple method of determining area is to plot the boundaries to scale and divide area into triangles. Scale the base and altitude of each triangle. Compute the area of each triangle and add the area of all triangles to obtain the total area. The area of a triangle is found by multiplying the base by the altitude and dividing by two. This is not a very accurate method and is not used where accurate results are desired. It is sometimes used in determining the area of irregular cross sections for earthwork calculations and will be discussed in Section 9.

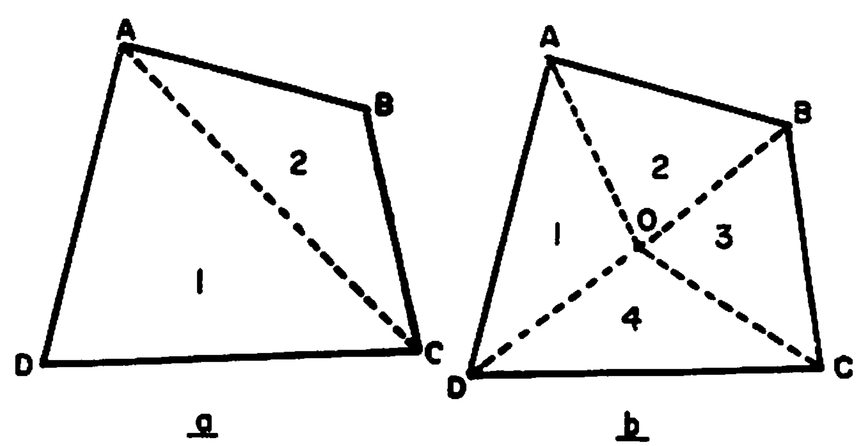

Fig. 17 —Areas by triangles

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Triangles: Continued

Sometimes a small tract of land can be divided into triangles and two sides and the included angle measured for each triangle. Figure 17a shows such a tract. A transit is set up at C and the sides CD and CA and the included angle DCA are measured for triangle 1. The same is measured for traingle 2. The area of each triangle is computed and the areas of the two triangles are added to get the total area.

When the lengths of two sides and the included angle in a triangle are determined the area is found by the formula $A = \frac{1}{2} ab \sin C$ where a and b are the two sides and C is the included angle.

Occasionally in the survey of a small tract of land, where the boundaries are grown over with brush or otherwise obstructed, it may be convenient to set up the transit in the interior of the tract and measure the distance to each corner. The angle between each pair of lines to corners is also measured. Figure 17b shows an example of this condition. Two sides and the included angle for each triangle are then known. The area of each triangle is then determined and the areas added to obtain the total area.

Where the lengths of the three sides of a triangle are known the area is given by the formula $A=\sqrt{s(s - a)(s - b)(s - c)}$ where $s = a + b + c/2$ and a, b, and c are the lengths of the three sides.

Coordinates:

Where the coordinates of the corners of a tract of land have been determined the area of the tract can readily be determined by the coordinate method.

Figure 18 is used in discussing this method. ABCD is a tract of land for which the area is to be determined. The total latitudes and departures, or coordinates, of corners ABCD are calculated by the method previously discussed under the subject of latitudes and departures in Section 5. NS is the reference meridian and WE the reference parallel. These are the reference meridian and reference parallel from which the total latitudes and total departures are calculated. The total latitude is referred to as the parallel distance and the total departure is referred to as the meridian distance. Thus for point A the meridian distance is represented on Figure 18 as M_1, and the parallel distance by P_1. Likewise the location of point B from the reference lines is indicated by M_2P_2, C by M_3P_3 and D by M_4P_4.

Meridian distances are considered positive if they lie east of the reference meridian and negative if they lie west of the reference meridian. Parallel distances are considered positive if they lie north of the reference parallel and negative if south. For convenience the reference meridian and parallel should be selected so that all meridian and parallel distances are positive. This simplifies the computations.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Coordinates: Continued

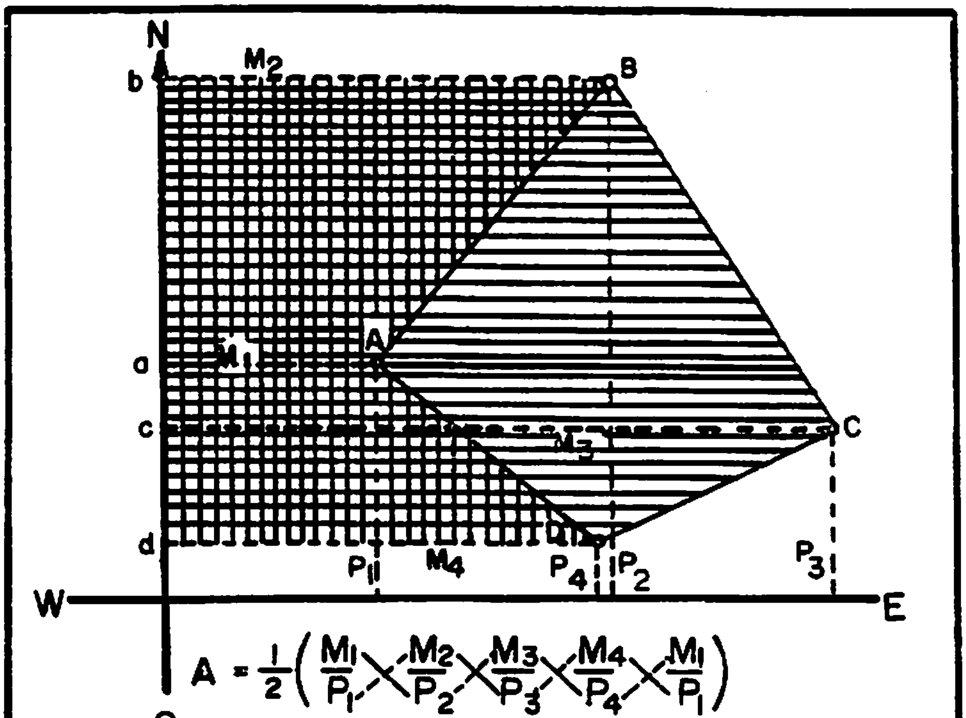

Fig.18 — Area by coordinates

In Figure 18 the reference lines were selected to have all of the meridian and parallel distances positive.

When all of the meridian distances and parallel distances have been determined they can be tabulated in a convenient conventional determinate form that has been developed in analytic geometry that simplifies the area calculation. In using this form each meridian distance is tabulated above the corresponding parallel distance as is shown in Figure 18. After the tabulation is made the coordinates connected by solid lines are multiplied together and all of the coordinates connected by dashed lines are multiplied together. The solid line products are added together and the dashed line products are added together. One-half the difference of these sums gives the area within the figure. The tabulation shown on Figure 18 may be written in the equation form $A = \frac{1}{2}\ (M_1P_2 + M_2P_3 + M_3P_4 + M_4P_1) - (M_2P_1 + M_3P_2 + M_4P_3 + M_1P_4)$

In tabulating the meridian distances and corresponding parallel distances the first must be repeated at the end as shown by Figure 18.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Coordinates: Continued

Another method of computing the area within a closed traverse that is almost universal in the surveying practice is the double-meridian distance method. This is called the DMD method. It is a convenient form of the coordinate method just described but does not involve the direct use of coordinates.

DMD:

The meridian distance of a point is its total departure from the reference meridian. The meridian distance of a straight line is the meridian distance to its mid-point. The double meridian distance of a straight line is the sum of the meridian distances to its two ends. Thus in Figure 19 the meridian distance of line AB is cC, the meridian distance of A is aA and the meridian distance of B is bB. The double meridian distance of the line AB is aA plus bB.

It is obvious from Figure 20 that if the reference meridian is passed through the most westerly corner of the survey all of the double meridian distances to each course of the traverse will be positive. This is a convenience in computing and the practice of passing the reference meridian through the most westerly corner is usually followed. However, this is not necessary if one wants to deal with both positive and negative meridian distances.

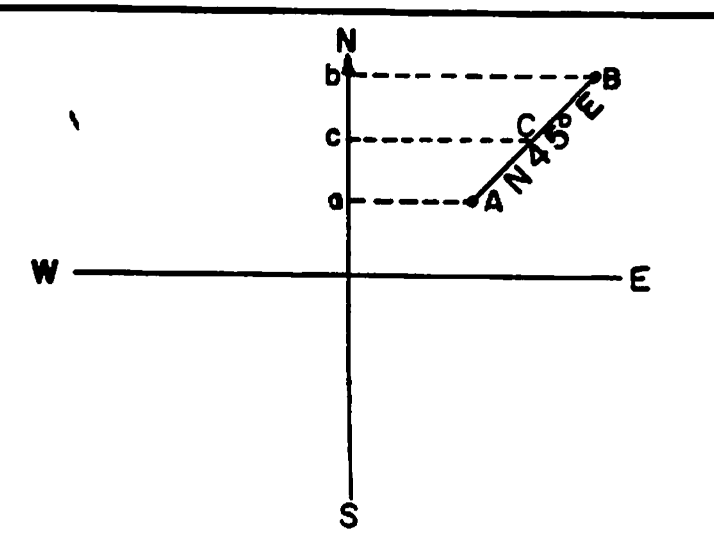

Fig 19 — Meridian Distances

Calculating areas by the DMD method is a matter of computing the areas of trapezoids or triangles and summing the individual areas. In Figure 19 it is seen that the orthographic projection of a line upon the meridian is the latitude of the line. This forms, in Figure 19, the trapezoid abBA whose area is aA + bB/2 x ab. The distances aA + bB is the DMD of the course AB. Thus the double area of any trapezoid or triangle formed by projecting a course on the meridian is equal to the product of the double meridian and the latitude of the course. That is, the double area = DMD x latitude.

In Figure 20, the areas of the trapezoids formed by projecting the northerly bearing lines on the meridian are hatched with horizontal lines. The trapezoids formed by projecting southerly bearing lines are hatched with vertical lines. North can be considered positive and south negative. Where the cross-hatching is shown, that portion of the area has been computed once as positive and once as negative and therefore cancels out, leaving the area only within the traverse.

DMD: Continued

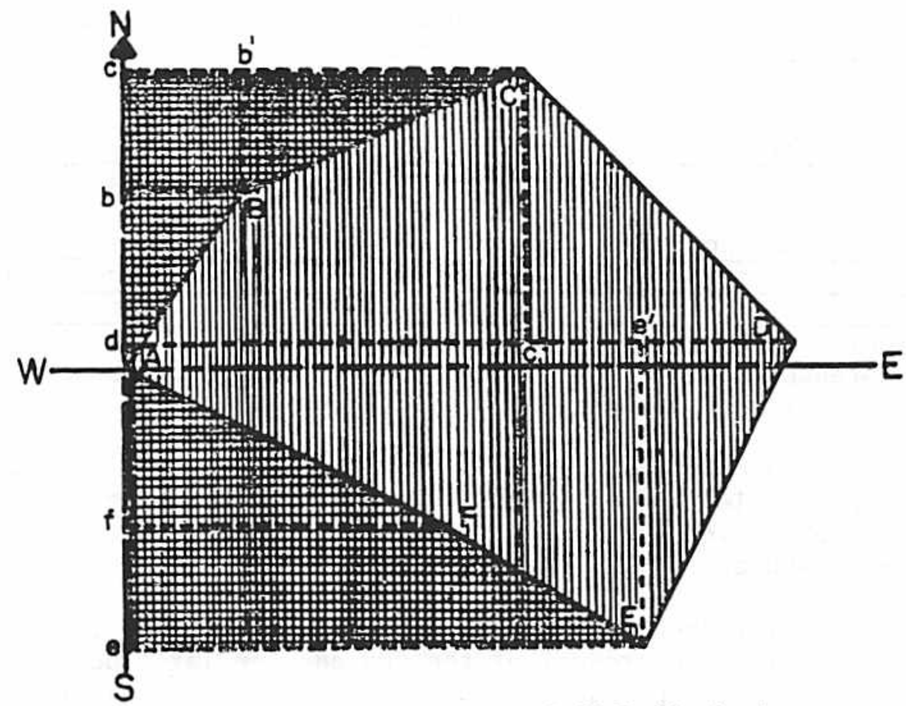

Fig. 20— Area by D.M.D Method

Again looking at Figure 20, the double area of triangle ABb is the product of bB and bA which is equivalent to the product of the DMD of course AB and the latitude of AB. When the course BC is projected on the meridian, it forms the trapezoid bBCc. The double area of this trapezoid is bB plus cC times bc. Again this area is the DMD of course BC times the latitude of BC. The area of these trapezoids formed by projecting courses bearing north are hatched with horizontal lines.

The trapezoid formed by projecting the south bearing line CD is shown by the letters dDCc. The double area of this trapezoid is equal to dD plus cC times dc. Again the double area of the trapezoid is the product of the DMD of the line CD and its latitude. This time where the hatched lines cross, the double area has been computed twice, once negative and once positive so it cancels out the portion of the area outside of the traverse. Likewise, the computation of the double areas of the trapezoids formed by projecting the remaining lines DE, EF, and FA upon the meridian can be continued. In the end all of the area projected upon the meridian and outside the traverse will be canceled out, leaving only the double area within the closed traverse. This double area divided by two gives the required area.

Sample plate 10 shows a convenient form for calculating DMD's from adjusted departures and double areas from the DMD's and the adjusted latitudes.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DMD: Continued

There are three easy convenient rules for determining DMD's that are arrived at from the above discussion and Figure 20. These rules are listed in any ordinary textbook on surveying and are given below.

1. The DMD of the first course is equal to the departure of the first course. For example on Figure 20 the DMD of course AB is equal to bB which is the departure of course AB.
2. The DMD of any other course is equal to the DMD of the preceding course plus the departure of the preceding course plus the departure of the course itself.
3. The DMD of the last course is equal to the departure of that course but of opposite sign. For example, the DMD of the last course FA on Fig. 20 is seen to be the distance fF. The departure of course FA if Ff, or west, which is the same as fF but is considered of opposite sign.

Referring now to the calculation form shown on sample plate 10 it is seen that the double areas of each projection on the meridian is obtained as the product of the DMD and the latitude. Point B was selected as the beginning point as it is the most westerly point and all DMD's will be positive.

Two columns are shown for the double areas, one being north and the other south. If the latitude is north, the product of the DMD and the latitude is entered in the north column. If south, the product or double area is entered in the south column. As an example, for course BC the latitude is 677.29N and the DMD is 113.63. The product of these is 76,960.46 which is the double area of the trapezoid. This number is entered in the north column. This process is continued until all courses have been calculated. The north and south columns are then each added. The difference of the two columns is double the area in the traverse. The difference is divided by two to obtain the area. Since the measurements were made in feet the answer is in square feet. The square feet are converted to acres by dividing by 43,560. This gives the area in acres which it was desired to compute.

In some printed forms, north is listed as positive and south as negative. Likewise, west is considered negative and east as positive.

Figure 20A shows the signs of both the latitude and departure for a line in each of the four quadrants in which bearings are located.

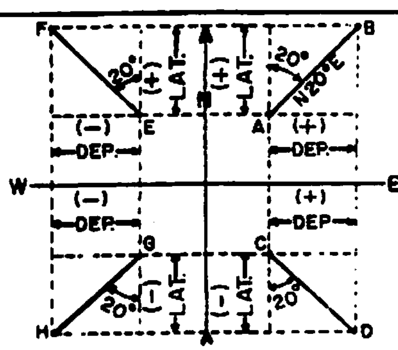

Fig.20A— Latitudes and Departures

ROUTE SURVEYS WITH CIRCULAR CURVES

Fundamentals of Route Surveys:

Route surveys are surveys of relatively narrow and long strips of territory. They are made for the purpose of making studies for the location and construction of such public utilities as highways, railways, canals, pipelines and power lines. They are conducted to obtain information such as topography, location of structures and objects and to establish a survey line of the ground. Probably the most wide use of route surveys at present is for highway location and construction.

Generally an open traverse survey is made along the proposed location. A relatively narrow strip on either side of the proposed general route is mapped showing all features such as streams, buildings, structures and other natural and artificial features. Ground configuration is usually obtained by running cross lines to the traverse for obtaining elevations. Using the information developed in the field survey, the drafter constructs the maps, profiles and cross sections. He/she also constructs the contour maps. The drawings made by the drafter are used by the engineers in selecting the final location, working earthwork calculations and estimating costs. Sample plate 6 shows a typical plan-profile construction. These are usually made on plan-profile or cross section paper.

Open traverses for route surveys are plotted in the same manner as was explained for the plotting of angles and open traverses. These open traverses are sometimes plotted by coordinates as is illustrated on sample plate 4. Open traverses must be plotted carefully and thoroughly checked since there is no check by closing the traverse.

Plate 1 shows the plotting of a group of open traverses by different methods. The method used in plotting an open traverse will depend upon the information given in the field notes of the survey and how they are computed in the final form.

The field method used in route surveying is usually the transit-tape method. Usually a level party follows the transit party and runs profile levels on the center-line of the survey. Thirdly, another crew follows and runs the levels on the crosslines. Notes from each group are used by the drafter in making maps.

Fundamentals of Curves:

In route surveying the traverses are first staked out as a series of straight lines. In highway and railway locations it is necessary to employ curves at the points of change in direction of the straight lines. This is necessary to avoid sharp angular bends and to allow vehicles to change directions of travel gradually and safely. The arcs of circular curves are usually employed for this purpose. Spiral easement curves are often employed to make the transition from the straight line to the circular curve more gradual. Only circular curves will be discussed in this manual.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Fundamentals of Curves: Contineud

A survey drafter will be required to plot route surveys including circular curves and should therefore be acquainted with the basic principles of circular curves.

In offices where curves are plotted frequently, curve templates are used. These are obtainable in sets for various degrees of curves. In the problems given in this manual curves will be plotted from the given radii.

The sharpness of a curve may be stated in two ways. These are the length of the radius and the degree of curve. The degree of curve has two definitions. The longer the radius of a curve, the more gentle is the change in curvature.

The two definitions of degree of curve are by the arc basis and the chord basis. The degree of curve by the chord basis means the angle subtended at the center of the curve by a chord 100 feet long. This is illustrated by Figure 21. Here D represents the degree, or angle subtended at the center, by a chord of 100 feet represented by the line AB. The degree of curve by the arc definition means the angle subtended at the center by an arc length of 100 feet. This is shown by Figure 22 where D is the degree of curve, AB is the arc of 100 feet and R is the radius.

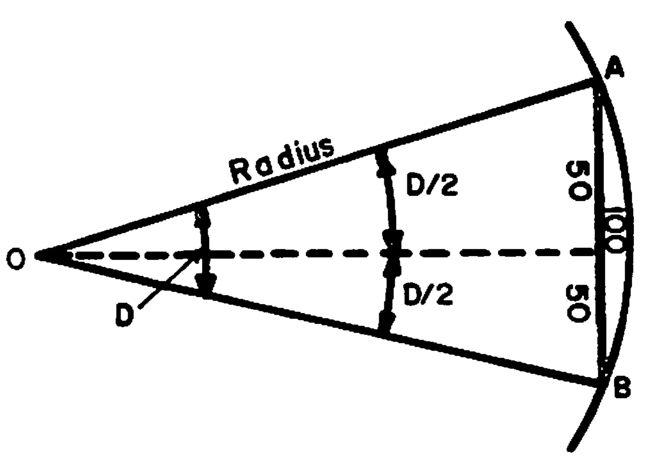

Fig.21 — Degree of Curve-chord basis.

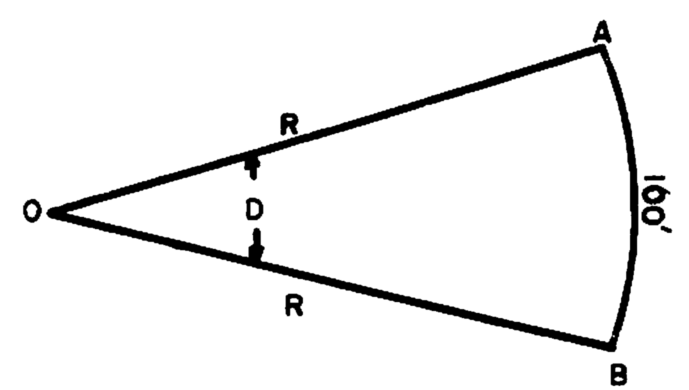

Fig.22—Degree of curve-Arc basis.

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Fundamentals of Curves: Continued

The straight lines connecting circular curves are called tangents because they are tangent to the circular curves.

The point where the two tangents intersect when extended is called the vertex or point of intersection and is abbreviated V or PI. Figure 23 represents two tangents with a circular curve joining the two tangents. The intersection angle I is measured in the field during the route survey. The curves are calculated in the office. The beginning of the circular curve is called the point of curve and is written PC. The ending of the curve where it becomes tangent to the straight line is called point of tangency and abbreviated PT. The distance from the PC or PT to the vertex is called the tangent distance and is shown as T. R represents the radius of the curve. E is the external distance and is the distance from mid-point of the circular arc to the vertex. M is called the middle ordinate and is the distance from the mid-point of the long chord to the mid-point of the arc. The long chord is the line from the PC to the PT. By plane geometry the intersection angle is equal to the central angle subtended by the curve.

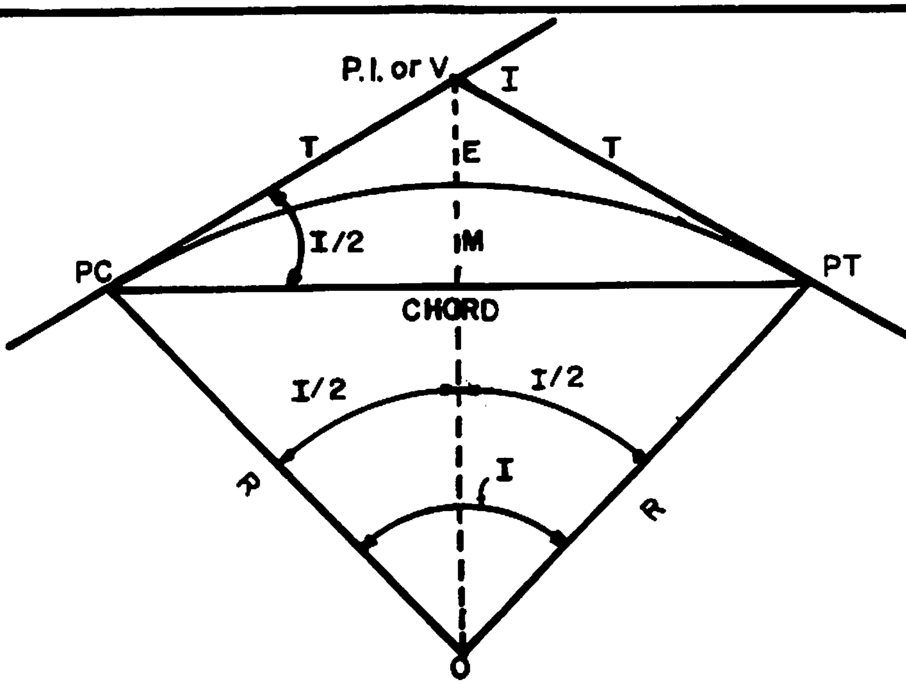

Fig23—Curve terms

Figure 24 shows how the length of a circular curve is found. The length of the curve is I/D x 100 where 100 foot chords are used in the chord definition of degree of curve. This is a close approximation of the length of the curve since it sums up the chords. This formula gives the exact length of the curve by the arc definition.

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Fundamentals of Curves: Continued

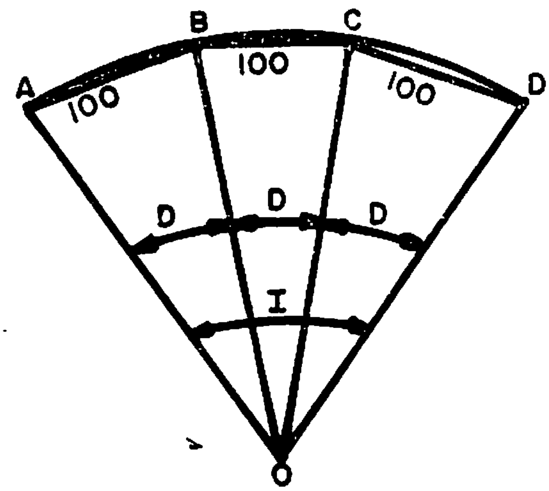

Fig24—Length of curve.

Figure 25 shows a horizontal circular curve with the formulas for computing the values of the various parts of the curve. This is the third curve from the point of beginning shown by Figure 1, sample plate 4.

Plotting Route Surveys with Circular Curves:

After the final curve computations have been made, the station numbering around the curve is the same as for tangents and is continuous around the curve. The final station numbers of the survey show continuously the distance at any point from the beginning of the survey. In Figure 25 the PC is station 27 + 41.4, the length of the curve is 717.8. The station number at the PT is 27 + 41.4 plus 7 + 17.8 which is 34 + 59.2. The final stationing is continued from here to the next curve and then continuously on to the end of the line.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

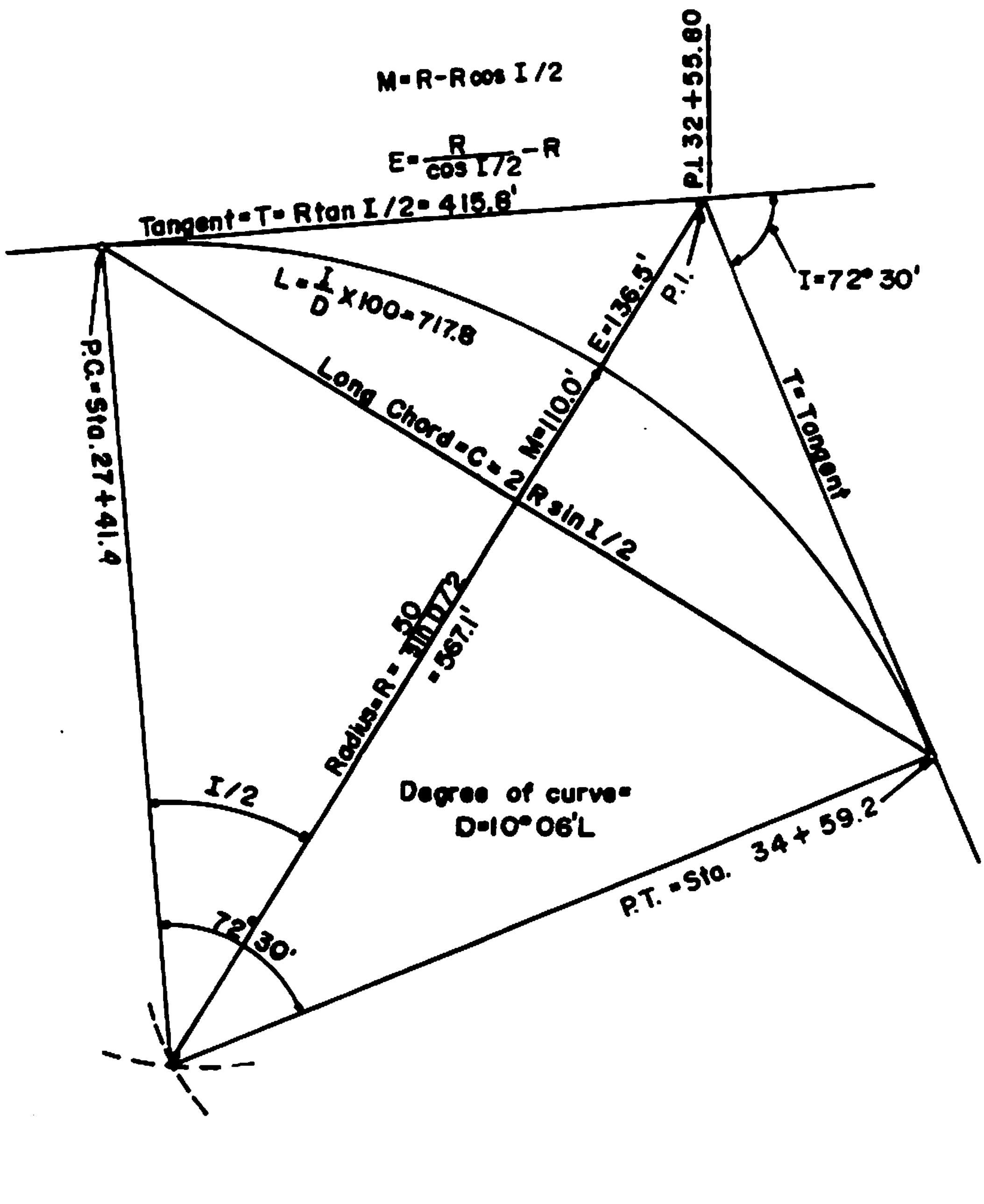

Fig.—2 5 Horizontal Circular Curve

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Plotting Route Surveys with Circular Curves: Continued

In plotting route surveys, the traverse is first plotted. The curve data is obtained from the curve calculations usually shown in the field book. Examples of this are shown in the field notes for drawing plate 4. The curves may be drawn by using a set of curve templates and selecting a template to fit the curve to be drawn. When curve templates are not available, it is easy to draw in the curve with a beam compass. In each method the PC and the PT must be located on the traverse for the curve being drawn. It is to be noted that the tangent distances on each side of the vertex must be the same. The tangent distance is obtained from the curve data in the field book. The tangent distance is then scaled off each way from the vertex to locate the PC and the PT. The radius of the curve is then obtained from the curve data in the field book. With the length of the radius set off on the beam compasses, an arc is described with the center at the PC and then with the center at the PT. The intersection of these arcs locates the center of the curve 0 shown on Figure 25. Now with this same radius of the curve and 0 as the center, the curve is drawn in from the PC to the PT.

It is to be noted that the PI for this curve is at station 32 + 55.80 and the tangent distance of the curve given in the field notes is 415.8 feet. When this tangent distance is subtracted from the station number of the PI it does not give the station number of the PC. Also when the tangent distance is added to the station number of the PI, it does not give the station number of the PT. This is due to the necessary condition that the open traverse must be first run before information is available for selecting the proper curves and computing the curve data. In making the survey for the traverse, the stationing is started at the beginning with 0 + 00 and the stations are numbered continuously from beginning to end. After the open traverse was run, the coordinates of the PI's were computed and used for plotting the traverse. The station numbers of the PI's were numbered as they were in the field notes for the traverse survey. After the traverse was plotted, curves to fit the field conditions were selected and the curve data computed. It is then necessary to go back into the field and stake out or run in the curves. It is to be noted from Figure 25 that the length from the PC to the PT following the tangents is 415.8' + 415.8' is equal to 831.6'. The length of the arc from PC to PT is given as 717.8. The difference in distance along the tangents and along the curve is then 831.6' - 717.8' = 113.8'. The distance around the curve is 113.8' shorter than by way of the tangents. When the curves are plotted, the stationing is now numbered from the beginning of the traverse continuously and around the arcs of the curves. This changes the original stationing after the PC of the first curve.

On Figure 1 of sample plate 4 the first curve has a tangent distance of 171.8. The PI is station 9 + 07.0. Therefore, since no curves occur from the beginning, the PC is found to be at station 7 + 35.2. This is determined by subtracting the tangent distance from the station number of the PI or 9 + 07.0 - 171.8 = 7 + 35.2. The curve data gives the length of the curve as 335.2'. This is the

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Plotting Route Surveys with Circular Curves: Continued

length of the arc. Continuing the stationing around the curve, the PT station number is the PC station number plus the length of the curve or 7 + 35.2 + 335.2 = 10 + 70.4. It is now necessary to find the distance from the PT of the first curve to the PC of the second curve in order to find the station number of the PC of the second curve if the stationing is now to be carried continuously on the tangents and around the curves from the beginning to end. The distance from the PI of the second curve to the PI of the first curve is 24 + 02.20 - 9 + 07.00 = 1395.20 feet. These stations are from the first traverse survey and are correct for the traverse. Now by adding the tangent distance of the first curve and the tangent distance of the second curve and subtracting this sum from the distance between PI for curve 1 and PI for curve 2, we obtain the distance from the PT of the first curve to the PC of the second curve. That is, 1495.20 - 171.8 - 437.8 = 885.6. By adding this distance between the PT and the PC to the station at the PT of the first curve we obtain the station number of PC of the second curve which is 10 + 70.4 + 885.6 = 19 + 56.0. This process is continued for the other curves, tangents and tangent distances to the end of the traverse. The last reworked station number then gives the distance from the beginning to the end with the distances measured around the curves where they occur.

Figure 2 is plotted and worked in exactly the same manner.

Figure 1 is the survey for a railway and the curves are calculated using the chord definition of the degree of curve. Figure 2 is the route survey for a highway and using the arc definition of the degree of curve. Each figure shows the survey of the centerline of the roadways.

TOPOGRAPHIC MAPS

Fundamentals:

Topographic maps differ from the other usual maps in that in addition to the natural and artificial surface features they show the configuration of the ground surface. Topographic maps show, by suitable and appropriate symbols, streams, vegetation, cultivation, structures and relief. The configuration of the earth's surface such as hills, valleys and depressions is called relief. Topographic maps are required for the study and design of engineering projects that involve land forms. They are a necessary aid to military commanders in planning and executing military operations. They are necessary for geological studies and have many other uses.

Relief:

The relief on a map can be represented by shading, hachures and contour lines. Pictorial means of indicating relief do not directly indicate elevations. Contour lines on a map are the only symbols that directly indicate elevations on the ground surface. Contour lines are the most widely used method of indicating relief on a map and is the most practical method.

Hachures:

Hachures are rows of short lines drawn parallel to the steepest slope. The thickness, spacing and direction indicate the direction and degree of slope. Hachures are rarely, if ever, used on modern topographic maps. Hachures are shown on Fig. 26.

Contours:

A contour is an imaginary line on the ground, all points on the line being of the same elevation. It can be thought of as a line formed by the intersection of a level surface with the ground such as the shoreline of a lake without waves on the water. If the water should fall , say 5 feet, then the new shoreline would represent another contour five feet less in elevation.

Contour Intervals:

The contour interval is the vertical distance between contours. The selection of the contour interval depends upon the scale of the map, the purpose of the map and the configuration of the ground which the contours represent. In flat country the interval would necessarily be small. For small-scale maps in rugged areas the contour interval would have to be large. It is customary to make each fifth contour line on a map much heavier than the other lines and to label it with its value.

Symbols:

Objects shown on a map are represented by signs and symbols. Some of the conventional signs and symbols representing structures, works, land forms, vegetation and water are shown on Fig. 26 and sample plate 5.

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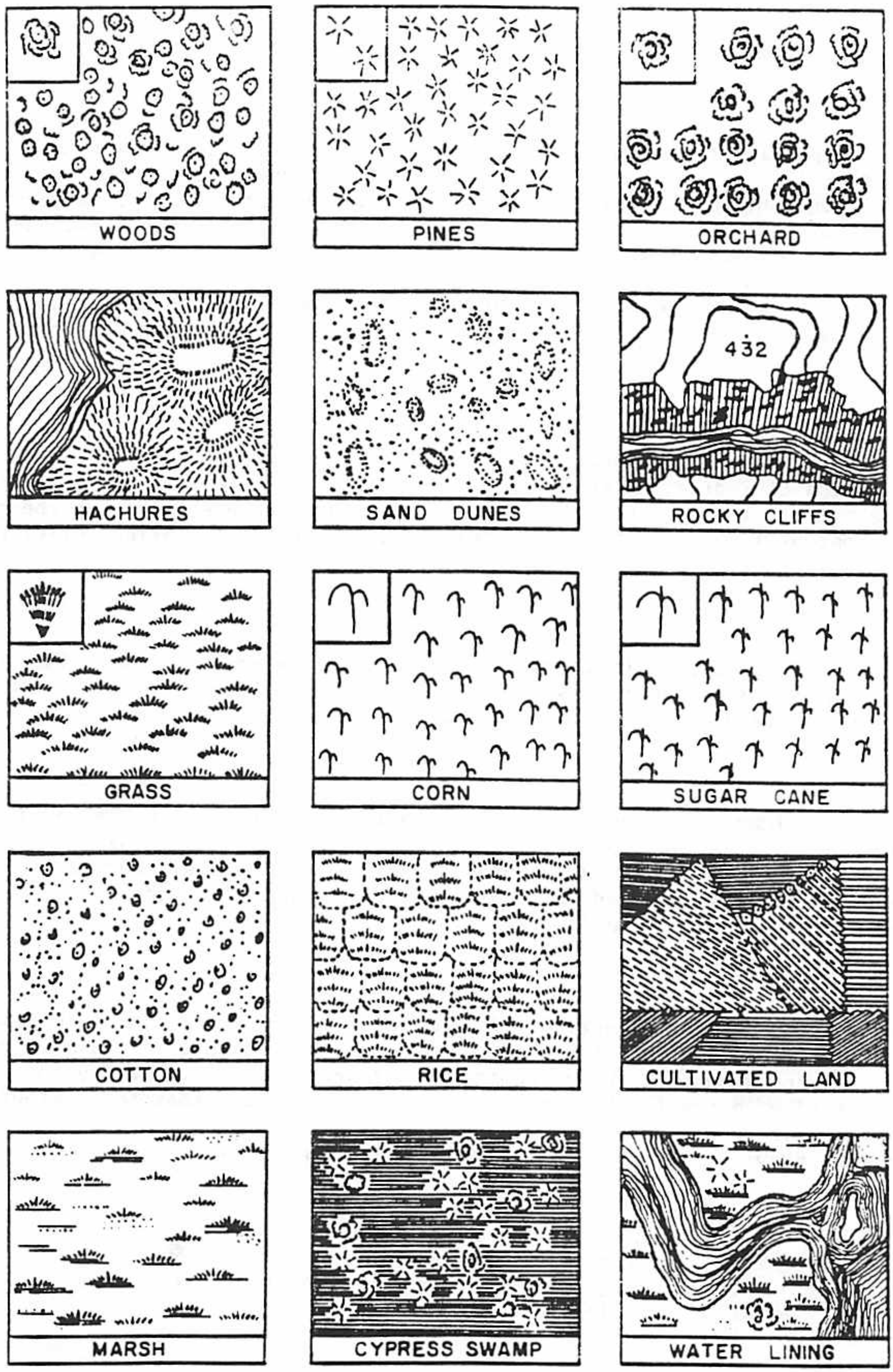

Fig.26—Topographic Symbols

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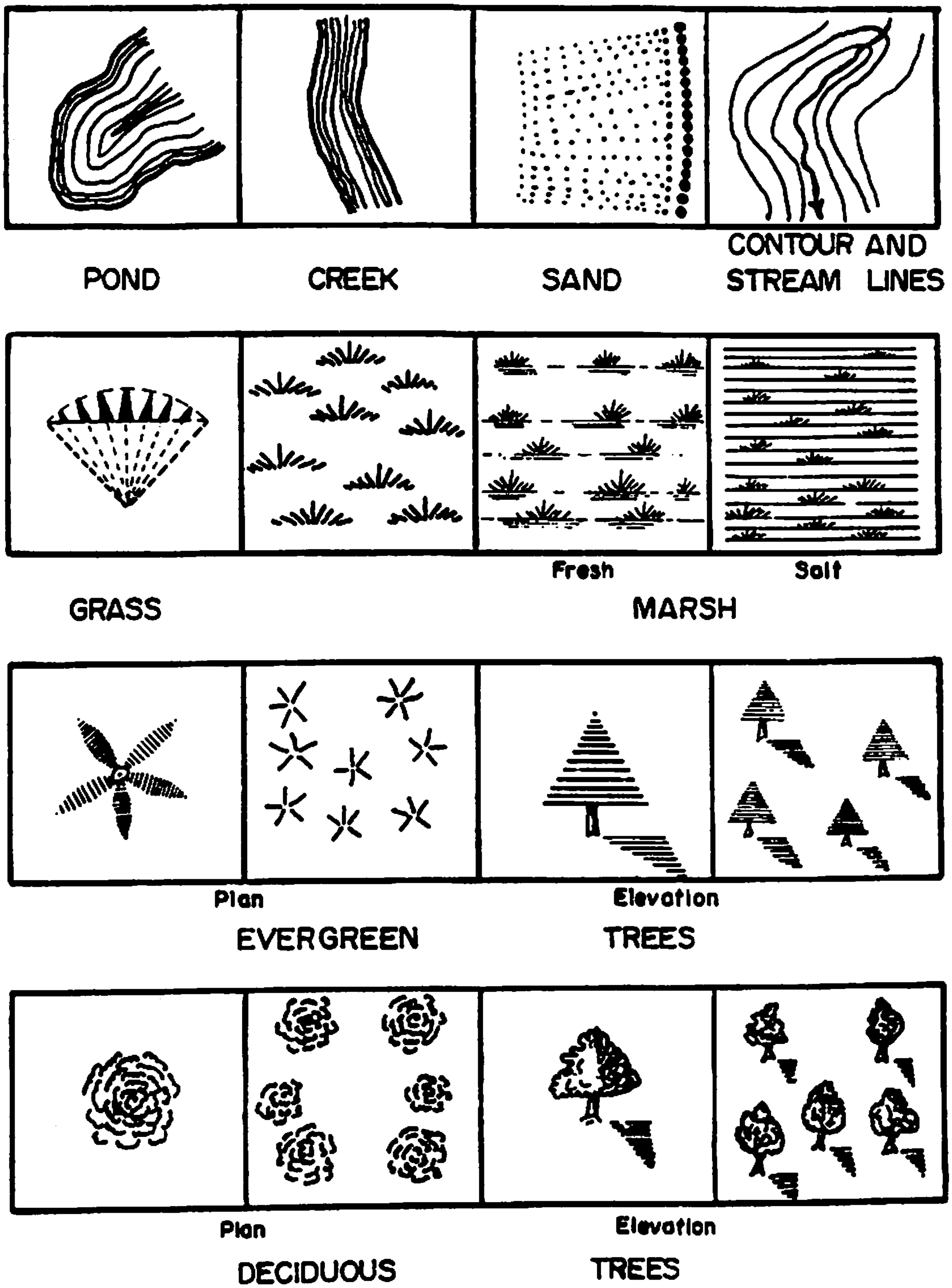

Fig.26-A CONVENTIONAL SIGNS AND SYMBOLS — DETAILS

Topographic Control:

In obtaining information for the construction of a topographic map it is good practice to first run an accurate traverse within the area to be mapped. The traverse is usually closed. Latitudes and departures are calculated, the traverse adjusted and coordinates are calculated. From the coordinates the traverse is plotted accurately. This is known as the horizontal control. An example of this is the control traverse plotted on sample plate 7P used for constructing the contour map for plate 7. From the points located by the horizontal control traverse a survey of somewhat less accuracy, usually stadia, is made locating all of the details of features to be shown on the map. The field notes for plate 7 show the results of such a survey.

In addition to the horizontal control it is necessary to have what is known as vertical control. Vertical control consists of establishing bench marks, or markers of a more or less permanent character, the elevations of which are determined at convenient intervals. These are used as control in determining the elevations of the ground points used in constructing a contour map.

Topographic Details:

The usual means of obtaining topographic details are by transit and stadia or the plane table. In the use of the plane table the contour map is made in the field. Since field drafting is done by the plane table operator, this means will not be discussed.

The usual systems used for locating and obtaining elevations of ground points for constructing a contour map are the trace-contour, grid or checkerboard, cross-profile and random shot systems.

In the trace-contour method points on the ground whose elevation is that of the contour desired are located on the ground then plotted on the map. Lines on the map are drawn, connecting points of the same elevation. This method is illustrated on sample plate 6.

In the grid or checkerboard system the area to be mapped is divided into a system of squares or rectangles. The elevations at the corners and of critical points on the lines between the corners are determined by some convenient means. This grid system is plotted and the elevations determined are indicated in the proper location on the grid. The contours are then drawn by interpolating or estimating the position of the desired contours. Figure 27 shows an area contoured using the grid system.

In the cross-profile method lines are run out at right angles to the traverse line far enough to obtain the desired information. On these lines the contour points or the elevations at changes in slope are determined with their distances out from the traverse line. The points are then plotted and points of equal elevation on the map are joined by contour lines. The method of cross profiles is illustrated by Figure 1 and on sample plate 6.

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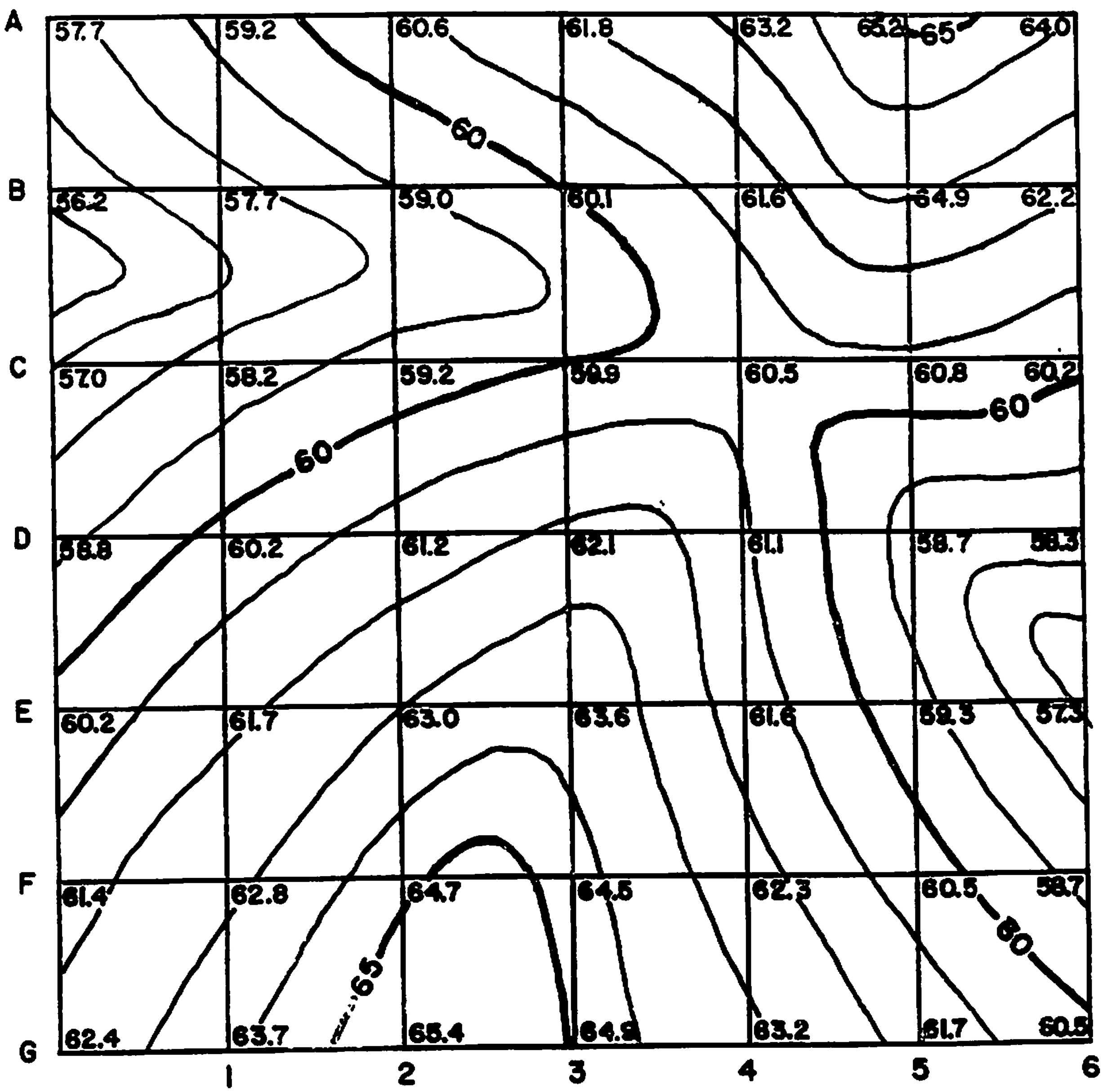

Contours — grid system

Fig. 27

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Topographic Details: Continued

The random shot method is employed by first establishing a horizontal and vertical control system. From this control system the details are located. This is done by locating ground points and their elevations. Usually they are located by means of a direction and distance from a control point. The transit-stadia method is usually employed. The stadia distance to the point is recorded and the vertical angle is read and recorded. From these recordings the horizontal distance to the point and its elevation are calculated. The field notes to be used in plotting plate 7 is an example of the note keeping and elevation and horizontal distance calculations. In this case, directions are shown by azimuths.

In plotting by this method, the control traverse is first plotted carefully by coordinates. The field notes for the control traverse are shown on page 30 of the field book. The calculated latitudes and departures for plotting the traverse are shown on page 31 of the field book. After the control traverse is plotted, the notes for the detail, shown beginning on page 32 of the field book, are used for plotting the detailed information. The plotted control traverse is shown on sample plate 7P and is used in discussing the method of plotting.

The field notes on page 32 show at the top of the page that the instrument was at station A of the control traverse. The first column headed obj. is the object to which readings were taken. Column 2, headed Az is the azimuth of the object sighted. The notes indicate that azimuth angle is from the north. Column 3 shows the vertical angle read and it is indicated whether the sign of the angle is positive or negative, that is, up or down. Column 4 is the rod interval which indicates the slope distance. Column 5 shows the calculated difference in elevation between the center of the instrument and point read on the rod, known as the rod index. By taking the rod index the same as the height on instrument, or HI, above the ground the calculated difference in elevation gives the difference in elevation between the point on the ground at the rod position and the station under the instrument. Column 6 shows the horizontal distance calculated from the rod interval and the vertical angle. This is the same for small angles but is shorter for larger angles. The seventh column shows the calculated elevation of the point under the rod. This is obtained by taking or adding, depending on the sign, the difference in elevation and the elevation of station A. A set of notes is given for each station from which details were obtained. The right-hand side of the sheet gives a description of the point.

The five items used in plotting the detail are the object, azimuth, distance, elevation and description of the point. Now, using the notes showing the instrument at station A as shown on sample plate 7-P, the first point is plotted by measuring on azimuth of 115°14' from the north. On the line in this direction from A, a distance of 305 feet is scaled which locates point 1. The elevation of point 1 is shown in the notes to be 450.0 feet. This is best written by making the located

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Topographic Details: Continued

point the decimal in writing the elevations. The remarks show point 1 to be the edge of the water of the lake. The first seven points show the outline of the lake. From the remarks column, the buildings, roads, and water edge can be drawn in. In many instances, the remarks column lists points as GP. This is a ground point for which the elevation was obtained. All of the other points are plotted in the same manner. From the elevations written at the ground points, the contours can be drawn by interpolation or estimation connecting all points of equal elevation.

Contouring:

The process of connecting points of equal elevations on a map by contour lines is generally known as contouring. There are several rules that must be followed in contouring and these are listed below.

1. The distance on the map between contour lines varies inversely as the slope of the ground. On steep slopes the contour lines will be close together and on gentle slopes farther apart. On regular and uniform slopes the contour lines will be even distances apart and on uneven slopes uneven distances apart.

2. The slope between points on the map, where elevation control is given, is assumed to vary uniformly. This is used in spacing contours and locating the contours which are to be drawn. The contours are best located by eye and the distances out from ground points are only estimated.

3. Contour lines do not cross one another since each contour represents a different elevation on the ground and if allowed to cross it would present the impossible situation of having a point on the ground with two different elevations. There is the special case of an overhanging cliff where the contours would appear to cross but actually do not as one would actually be above the other. The contour underneath is dashed to clear this seemingly crossing of contours. This is illustrated on sample plate 7 as the pictorial condition of contours appearing to cross by the feature labeled "overhang."

4. Contour lines do not merge with one another of the same or different values. In the case of a vertical cliff or cut they would appear to merge but would not as they are spaced vertically at different elevations.

5. Contour lines always close either on or off the map. Since a contour can always be visualized as the shoreline of a body of water, it can be seen that it always must close as there can be no ending of a shoreline and it must close back on itself.

Contouring: Continued

6. A single contour line alone cannot lie between contours of lower or higher elevation. For the feature labeled "saddle" on sample plate 7, it can be seen that is a contour is thought of as a shoreline and the hills were inundated part-way up there would be contours on either side of the valley of equal value representing the two summits. As the water is imagined lowered, there would be contours of equal value to represent each side of the shoreline. As long as there was even a minute amount of water in the valley between the hills, there would be two contours of equal value representing the shoreline. At no time could there be a shoreline of only one side.

The preceding rules must be followed in contouring a map. In contouring it is considered good practice to first outline lightly the ridge lines and the valley lines. The position of each contour value to be used can then be located on these ridge and valley lines. After this is done, contour lines can be drawn connecting points of equal value following the general rules listed above.

Sample plate 7 shows some typical land forms and how they are represented by contour lines. The contours representing the land forms are general and no values are indicated. The arrows show the direction of slope.

PROFILES AND CROSS SECTIONS

The definitions, as used in surveying drafting, of a profile and of a cross section were given in the beginning of the text in the introduction. They will be repeated here for convenience. A profile is a drawing showing a vertical section along a certain surveyed line. A cross section is a drawing showing a vertical section usually at right angles to the survey line.

Profiles and cross sections have been previously discussed in relation to obtaining information for the construction of the plan profile of a route survey. Sample plate 6 illustrates how cross lines to a survey line were used in mapping the topography on either side of a survey line. It also illustrates how a profile was constructed along the line of the survey. This section will deal with profiles and cross sections in their use in computing earthwork, fixing grades and vertical curves.

Plotting Profiles:

Profiles are plotted from level notes. The level notes show the elevations along the survey line obtained by a level crew. They may also be plotted from elevations taken from a contour map. They are usually plotted on regular profile paper. The vertical lines are usually ½ inch apart and the horizontal lines 1/10 or 1/20 inch apart. Printed sheets of this paper are available at any drafting supply store. This is sometimes called plan-profile paper. The bottom portion is ruled with horizontal and vertical lines for plotting the profile and the top portion is unruled and left blank. The unruled portion at the top is used for plotting the plan view of the survey.

The horizontal and vertical scales used are not usually alike. The vertical scale is exaggerated because the horizontal distances are very great as compared to the changes in elevation. Sample plate 6 shows a plan profile where the horizontal scale is 1 inch equals 200 feet while the vertical scale is 1 inch to 10 feet. On this drawing the profile is shown for the surveyed route and the alternate route which is a straight line from the beginning to the end of the traverse. The unruled portion of the sheet shows the plan view of the survey and the contoured area on either side of the survey line. The station numbers increase from left to right. Many sheets are sometimes necessary if the route survey is of any extent lengthwise. Sometimes rolls of paper are used.

In the case of sample plate 6 the plan is drawn to scale and the horizontal profile distances are not exact. Elevations for profile plotting were obtained from the contour map. These were projected vertically downwards from the plan view to obtain the location on the ruled section. This is customary. When the elevations of the ground points have been plotted on the ruled paper, the line connecting the ground points is drawn in freehand. The ground points connected by a line gives a profile of the route plotted.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Fixing Grades:

The ground profile is used as a basis of study to fix the grade location. Several factors control the location of the grade line. Some of the factors controlling grade location are stream crossings, beginning and ending points and routes through towns and villages. Maximum rates of grade for the type traffic for which the road or railway is used is an important controlling factor in grade selection. In as far as possible the grade is selected and fitted to the ground so that as nearly as possible the cuts will equal the fills. The amount of dirt removed from the cuts should just about be the amount required to fill the low places. This avoids costly long hauls for dirt to fill low places · to dispose of dirt from the cuts. A grade line is shown on sample plate 6.

Plotting Cross Sections:

Cross sections are usually plotted on regular cross-section paper. This is usually ruled 10 x 10 to the inch. The cross sections are usually plotted from the cross-section field notes. The horizontal and vertical scales may or may not be the same. The scales used depend on the accuracy required in computing the cross-sectional areas and upon the amount of relief. Sample plate 8 is an example of the plotting of a series of cross sections for the purpose of calculating earthwork.

Cross sections are sometimes taken from the center line out in each direction from the center line. Sometimes in the case of a borrow pit they are taken out from a survey line at the edge of the pit. Sample plate 8 shows cross sections taken from the edge. They were taken to determine the amount of dirt to be excavated for a street that would allow drainage.

The field notes for sample plate 8 are given beginning on page 50 of the field notes. The left-hand sheet shows the notes used in determining the height of the instrument. The right-hand sheet shows the elevation of the point on which a reading was taken, the distance out from the control line and the rod reading. The elevation was obtained by subtracting the rod reading from the height of instrument. Only the distance and elevation are used in plotting the cross sections. The station number of the section is shown on the left-hand page.

The vertical scale is 1 inch equals 1 foot and the horizontal scale is 1 inch equals 5 feet. The first section at station 0 + 00 is placed in the upper left-hand corner of the sheet and the following sections are placed one underneath the other. When one line-up of sections fills the space to the bottom of the sheet a new line is started at the top of the sheet. A horizontal line is drawn at each plotted elevation and distance. The distance out is written at the bottom of the line and the elevation at the top. Actually this distance out from the line, together with the elevation, gives the coordinates of the point. These coordinates are used when a calculating machine is used to find the area of the cross section.

The station number of each cross section is listed under the cross section. The area of each cross section is indicated within the section and states if it is cut or fill. The volume of earth between each two sections is shown between the two sections and whether it is cut or fill.

Areas of Cross Sections:

In order to calculate the volume of earthwork it is first necessary to calculate the areas of the cross sections. The areas are in terms of square feet usually. There are three usual methods of computing the areas of irregular cross sections. The first method is by use of the planimeter. This is a mechanical device for finding irregular areas. The tracing point is used to make a trace around the closed figure. The dial readings are a measure of the area. A description of and a discussion on the use of the polar planimeter can be found in any standard text on plane surveying.

Another method formerly widely used in determing the area of cross sections was to divide the irregular section into triangles, scale the base and altitude, compute the area of each triangle in the section and sum up the individual areas to obtain the area of the section.

Figure 28 is an example of the method of triangles. The base and altitude are scaled in inches. These figures are used to obtain the areas of the individual triangles in the section. When the areas are summed the sum gives the area of the section in square inches. Now the vertical scale is 1 inch to 1 foot and the horizontal scale is 1 inch to 5 feet so the area in square feet represented by 1 square inch on the paper is 1 x 5 or 5 square feet. The area calculated in inches is multiplied by 5 to obtain the area in square feet.

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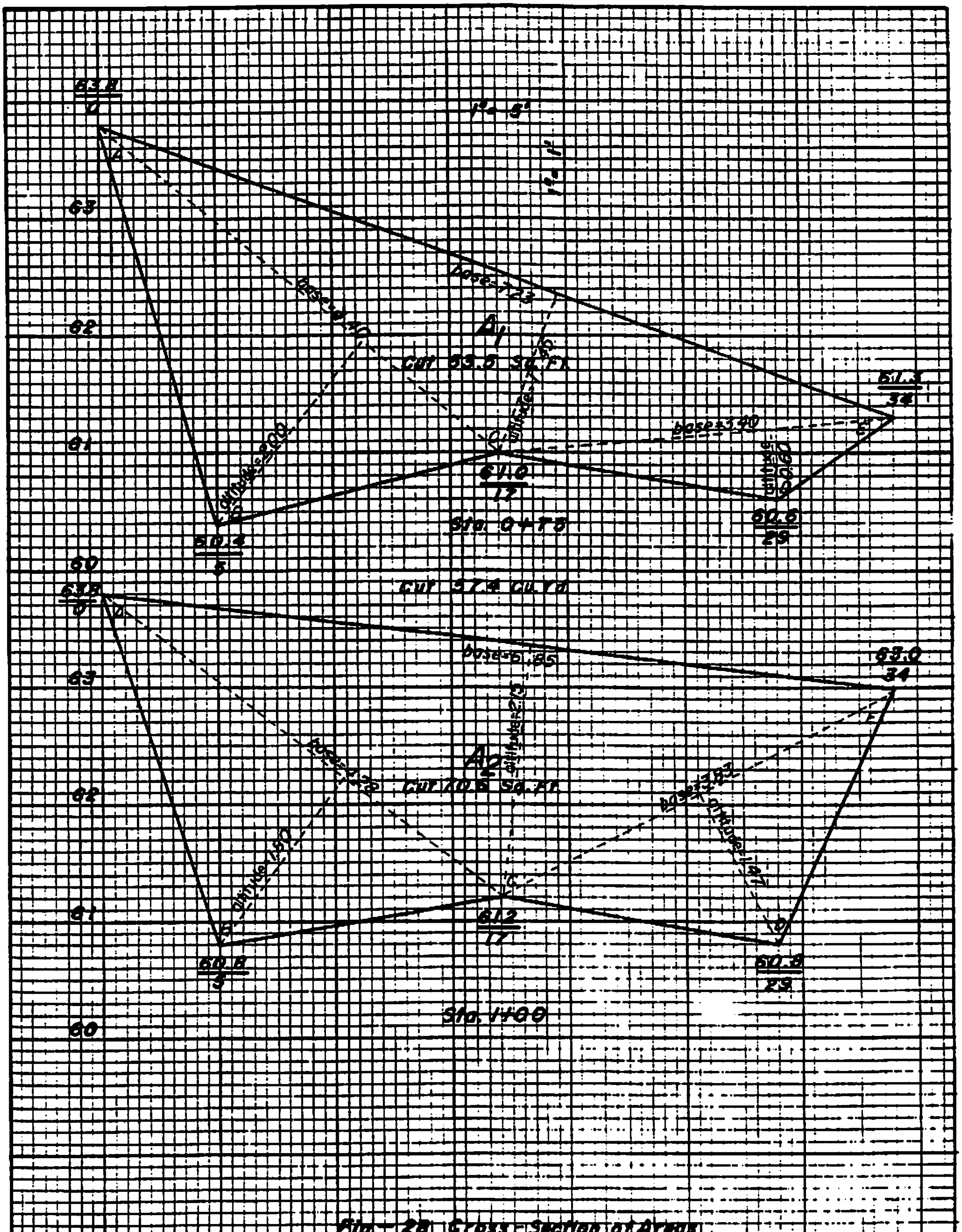

Fig. 28 Cross-Section of Areas

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Volumes of Earthwork:

The most commonly used method of computing volumes of earthwork is by the method of average end areas. In Figure 28 the volume of earth between stations 0 + 75 and 1 + 00 is equal to the average of the end areas multiplied by the distance between them. The volume is equal $A_1 + A_2/2 \times 25$. Since the units of measurements are in feet the volume will be in cubic feet. This is converted to cubic yards dividing by 27.

Figure 29 illustrates a convenient form for the calculation of earthwork. Column 1 is the station number. Column 2 gives the distance between successive stations. Column 3, opposite the station number, shows the area of the cross section. Column 4 is the sum of the two areas. Column 5 gives the volume of earth between the two stations. To obtain the volume, the sum of the areas is multiplied by the distance then divided by 54. This is equivalent to averaging the two areas by dividing the sum by two then multiplying by the distance to obtain the volume in cubic feet and dividing by 27 to convert cubic feet to cubic yards. The individual volumes between stations are then added to get the total volume from beginning to end of line.

Vertical Curves:

At the changes in gradient of the selected grade for railways and highways, curves in a vertical plane are necessary to prevent abrupt changes in direction of the vehicle in a vertical direction. The vertical curve is almost always an arc of a parabloa since it gives a gradual change in the vertical direction of the curve. The maximum allowable change in grade per station commonly governs the sleection of a vertical curve. In computing a vertical curve the tangent offsets to various points on the curve are calculated from the properties of the parabola. Since the plotting of vertical curves by the draftsman is not too often encountered the interested student is referred to a standard textbook on surveying. The example of a vertical curve calculation is shown by Figure 30. Such curves do not mean much plotted to scale on a profile. It can be seen that the offests from the tangent to the curve are small when compared to the length of the curve.

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EARTHWORK CALCULATIONS

STATION	Dist.	Excavation Area	Sum of Areas	Cu. Yds.
0+00		43.4		
	25		93.5	43.3
0+25		50.1		
	25		106.2	49.1
0+50		56.1		
	25		109.6	50.7
0+75		53.5		
	25		124.1	57.4
1+00		70.6		
	25		145.0	67.1
1+25		74.4		
	25		141.5	65.5
1+50		67.1		
	25		132.8	61.5
1+75		65.7		
	25		126.8	58.7
2+00		61.1		
	25		121.6	56.3
2+25		60.5		
	25		112.5	56.7
2+50		62.0		
	25		96.4	44.6
2+75		34.4		
	25		81.0	37.5
3+00		46.6		
	25		101.9	47.1
3+25		55.3		
	25		108.5	50.2
3+50		53.2		
	25		87.6	40.5
3+75		34.4		
	25		74.0	34.2
4+00		39.6		
	25		78.3	36.2
4+25		38.7		
	25		77.4	35.8
4+50		38.7		
	25		85.5	39.6
4+75		46.8		
	25		93.6	43.3
5+00		46.8		
	33		78.4	38.3
5+33		31.6		
				1011.6

$$\text{Cubic yards} = \frac{\text{dist.} \times \text{sum of areas}}{2 \times 27} = \frac{\text{Dist.}}{54} \times \text{sum of areas}$$

Fig. 29– Calculation of Volumes

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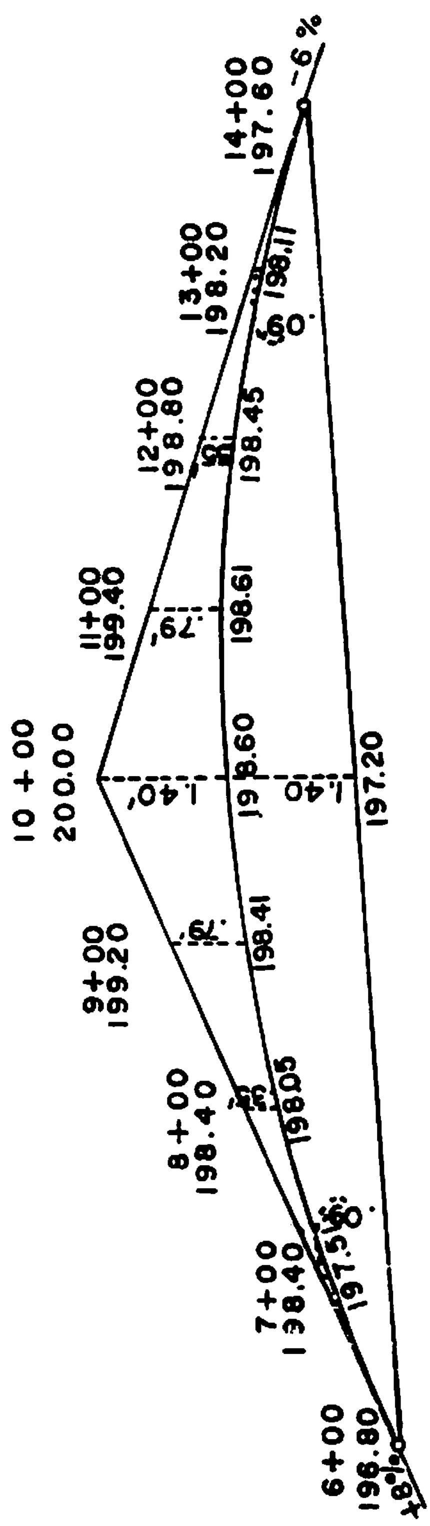

STATION	6=A	7	8	9	10	11	12	13	14=C
Elevation of Tangent	196.80	197.60	198.40	199.20	200.00	199.40	198.80	198.20	197.60
Tangent offset	0.00	.09	.35	.79	1.40	.79	.35	.09	0.00
Elevation of curve	196.80	197.51	198.05	198.41	198.60	198.61	198.45	198.11	197.60

Fig. 30 —Vertical Curve

AREA MAPS

In the section on route surveying and mapping we were interested in long and very narrow strips of land. In this section on area maps we deal with areas where the width and length are comparable. Area maps cover specific areas the size of which may vary from a single tract, such as a farm, to a city, county, state or larger. In the drafting related to plane surveying we are interested only in areas of limited extent where the distortion due to the earth's curvature will not be appreciable.

Kinds of Area Maps:

There are innumerable kinds of area maps such as political maps, city maps, economic study maps, statistical maps, charts for air and sea navigation, highway maps, land survey maps, subdivision maps and many other types. Again the survey drafter is interested only in maps of limited extent such as route survey maps, land survey maps, topographic maps and subdivision maps.

Purpose of Area Maps:

Maps are part of the working equipment of every industry, military organization, educational organization, engineering organization and business. Maps are required for every engineering project except the most simple. Practically every land survey, subdivision survey and topographic survey requires that a drafter construct a map from the field survey notes. Many transfers of property require maps describing the property. Maps are used for the purpose of numerous studies.

Surveys for Area Maps:

Since area maps cover considerable territory it is usually necessary first to run a skeleton control survey. This survey is rather precise. Level parties determine the vertical control. Reference horizontal and vertical control markers are set throughout the area. From these control points the details in the area are obtained. Sometimes the control traverses are run simultaneously with the details. This is the case for the notes for making Plate 9.

Plotting Area Maps:

Sample Plate 9 will be used in discussing the plotting of area maps. In this case the control traverses were run at the same time the detail was obtained. When this method is used it is best to plot all of the traverses and check them for error before plotting any of the detail. It can be seen that some of the traverses form closed figures and these should close when plotted on the map. It will be noted that the traverse for Wilson Road was run first and then the Stagg Road traverse was run. Wilson Road should be plotted first. The second plotted should be Stagg Road since it takes off from a station on Wilson Road. The other traverses

Plotting Area Maps: Continued

all take off from stations on these two roads. The location of the notes in the field book is indicated in the index. The left-hand page shows the survey notes for the traverses and the right-hand page shows sketches with distances and angles to the details being mapped. The calculated bearing of each line is given together with the station numbers. The traverses should be carefully plotted from this information. After all of the traverses have been plotted and checked the detailed information can be plotted. This requires careful reading of the remarks and the labeled sketches. After the detail is completed,culture symbols can be drawn in.

Maps in Public Record:

Many maps showing property sales, easements, rentals and leases are filed in the clerk of court's office. Here they become a matter of public record and are open to inspection by the public. Figure 31 shows a map of the division into seven parts of a piece of property. The map was drawn from the survey field notes. This map was recorded and became a part of the public record.

Survey Plats:

Maps showing the results of the survey of small tracts of land such as lots are referred to as plats. Figure 32 shows a survey plat required for a F.H.A. loan.

City Maps:

City maps show usually the location of streets, public utilities, lots and blocks. The mapping and surveying procedures are usually more accurate than for less valuable country property.

Contents of Maps:

The contents of a map depends on its purpose. All information should be shown on a map that is needed to satisfy its purpose. Sometimes, too much information shown on a map that is not required to serve the purpose of the map only tends to be confusing.

The following information should appear on any type map: a suitable title, the direction of the meridian, a suitable scale, preferably graphical, and a legend showing symbols used other than conventional symbols.

Any map that is to be made a part of the public record should show in addition to general information for maps the following items:

1. The length and direction of each line.
2. The location and kind of corner markers used.

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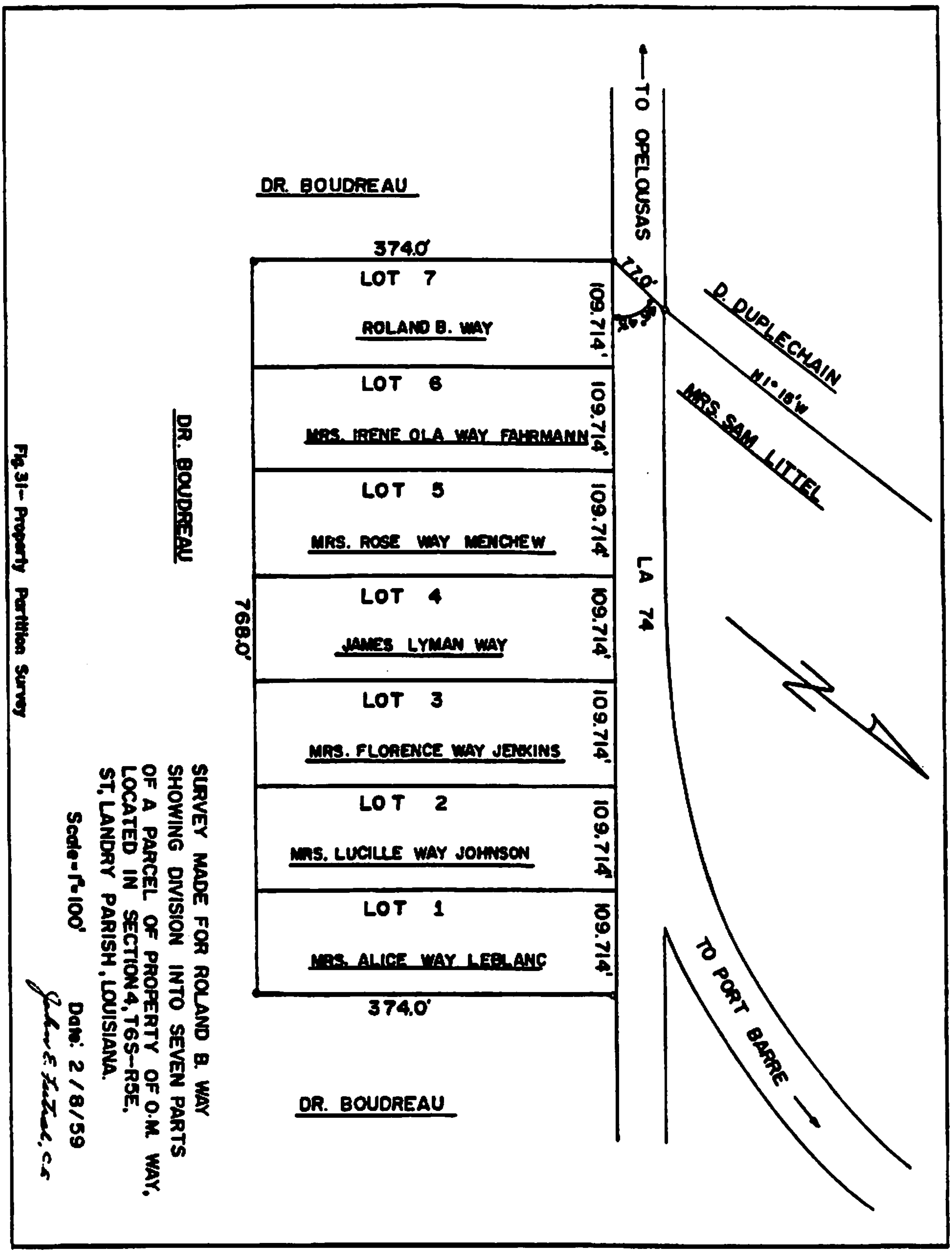

Fig. 31 – Property Partition Survey

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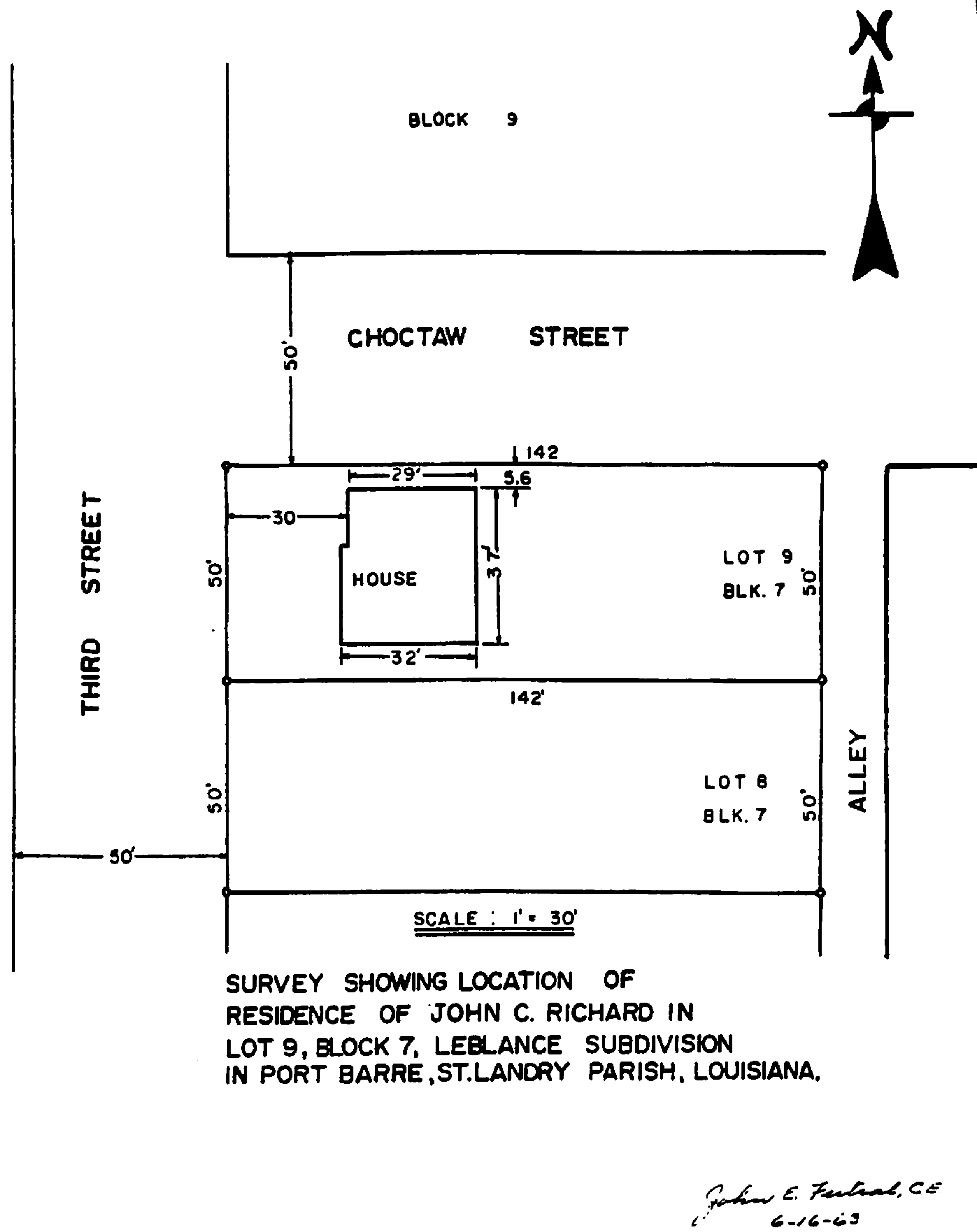

Fig. 32– Survey Plat

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Contents of Maps: Continued

3. The distances and directions to the corner reference marks.
4. The subdivision description of the property such as lot, block and section number. In rural property the county, ward, township and range as well as section should be shown.
5. The name of the property owner and the names of the owners of the adjoining properties.
6. The signature and seal of the surveyor together with his registry number.

Subdivisions:

Subdivisions of property are divisions into smaller parcels than the previous or original survey. A piece of property may be made into a subdivision of a town by dividing it into lots and blocks with streets and utilities and having it incorporated as part of the town. Maps made of these subdivisions then serve as the basis for a legal description of the various lots.

GENERAL DIRECTIONS FOR PREPARING MAPPING PLATE ASSIGNMENTS

These instructions for preparing plates are general. Directions will be given for each plate including the necessary information to complete each plate. The usual size of plates, unless otherwise stated, will be 14 by 20 inches. The size sheet of paper will necessarily be slightly larger. The outside border or lines along which the plate is trimmed will be 14 inches wide and 20 inches long. A one-half inch border will be left all around and inside of the outside border. The inside border will then be 13 inches wide and 19 inches long. The plate title will be enclosed in a rectangle in the lower right-hand side of the plate. The size of the title rectangle will be 2 inches high and 5 inches long. The title will include the student's school, school location, the scale or scales to which the drawings are made, the date the drawing is completed and the student's name.

Some of the drawings will be made with the longer side of the border parallel to the bottom side of the drafting table. Others will be made with the shorter side of the drawing parallel to the bottom side of the drafting table. Directions for each plate are given.

The drawings should first be made in pencil on a good grade of drawing paper. The plotted points should be marked with a needle point and the point circled lightly with the pencil so they may be readily found again when needed. The pencil used should have the hardness of above a 3H good grade drawing pencil. The use of too soft a pencil lead will cause an unsightly and dirty looking drawing due to pencil marks smearing over the paper.

After each plate is completed in pencil it should be carefully checked for measurement of lines and angles.

Inked tracings on a good grade of tracing paper should then be made, striving for neatness and a pleasing appearance.

Accuracy in the plotting of both angles and line measurements is highly essential in the drawings of surveying.

Any necessary erasing on the inked drawing should be done willingly and carefully. The ability to erase and reink neatly is the mark of a good drafter.

Lettering should be done neatly and with great care. Poor and unsightly lettering can spoil a map that is otherwise perfect. Lettering skill can be acquired only by much diligent practice. Mechnaical lettering sets are widely used by most drafting offices and should be used if available.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

GENERAL DIRECTIONS FOR PREPARING MAPPING PLATE ASSIGNMENTS (cont'd)

The student should refer to the reduced-size drawing plates in this manual for the general layout of the drawings. These reduced-size drawings should be used only as a guide. All drawings should be plotted directly from the field survey notes for each plate. Do not attempt to measure angles or distances from the reduced drawing and transfer them to your drawing being plotted or constructed.

This manual should be studied thoroughly before the plates are drawn. The piates are assigned to be made in the order in which they are numbered. Other plates may be assigned by the instructor.

to facilitate the drawing of any needed sketches on the right-hand rectangular-ruled sheet. The small round circle shown to the left of some station numbers indicates where the surveying instrument was set up for the purpose of making angular measurements. The distance between any two stations may be found by taking the difference between station 6 + 27 and station 12 + 42 is equal to 1242 - 627 which is 615 feet.

Column 2 shows the deflection angle at the station measured between the extension of back line and the forward line. These deflection angles are shown right or left depending whether the angle is turned in a clockwise or counterclockwise direction.

Column 3 shows the magnetic bearing which was obtained by taking a compass reading at the station to obtain the direction of the line. Compass readings are taken as a check against mistakes in angular measurements. This will not show small errors as the compass needle can be read to only approximately 15 minutes.

Column 4 is the calculated bearing. This bearing is calculated from the bearing of the back line and the deflection angle to the forward line. The calculated bearing is compared with the magnetic bearing to detect mistakes in reading or recording the deflection angle.

Columns 4 and 5 are for remarks. In these columns are entered any notes necessary to make the details of the survey clear to the people who will use them.

The right-hand cross-ruled page is used for notes and sketches. On this sheet is shown the names of field personnel and their duties. In the notes for Figure 1, Richard is instrument technician and the surveyor's helpers on the chain are Soileau at the head and Carrier at the rear. The date of survey and the general weather conditions are shown. The scale to be used for Plate 1 is 1 inch equals 2000 feet. Point A is located 3/4 inch from the left border and 1.25 inches from the upper border. The notes show the bearing of line AB to be S27°08'E. The protractor is oriented at point "A" and an angle of 27°08' is measured off in the southeast quandrant by making a needle mark at 27°08' from the south towards the east. A line of indefinite length is drawn through point "A" and the needle mark. A distance of 627 feet, using a scale of 1" equals 200 feet, is scaled on the line. This locates point B. Line AB is then prolonged lightly on the drawing paper. The protractor is then oriented at point B and a deflection angle 97°45' to the left is marked with the needle point. Again a line of indefinite length is drawn through points B and the needle mark at 97°45'L. On this line from point B a distance of 12 + 42 - 6 + 27 or 615 feet is scaled to locate point C. The same procedure is followed to locate the other changes in direction of the traverse. Use calculated bearings for plotting.

For Figure 2, point A is located 3/4 inch from the left border and 5 inches from the top border. The notes for Figure 2 are found by the index to be on pages 3 and 4. Only calculated bearings and stations are given and these are used in plotting.

DIRECTIONS FOR PLATE 1
PLOTTING OPEN TRAVERSES AND THE USE OF THE FIELD BOOK

The outside border or trim line is to be 14 by 20 inches. The inside border will be 19 by 13 inches. The size sheet should be large enough to allow mounting on the drawing board so that no marks will appear within the outside border or trim line. The longer side of the border will be vertical on the drawing board. North direction will be parallel to the left border and pointing upward. The title block will be 2 inches high and 5 inches long and is located in the lower right-hand corner. The title block will show the plate number, the student's school and location, the scale or scales used, the date the drawing is completed, the student's name, and any other information wanted by the instructor.

Five open traverses are to be plotted on this plate and are shown on the reduced guide plate as Figures 1 through 5. All initial points of the traverses will be located 3/4 inches from the left vertical border. The first step after the border and title block layout are completed is to draw a light line 3/4 inch from and parallel to the left border. A true north arrow is drawn on this line between Figures 1 and 2. Avoid fancy or flourishing arrows. The trend in modern drawing is towards simplicity. In this and other drawings, the inside border will be referred to only as the border and the outside border will be referred to as the trim line. The initial point of Figure 1 is called point A and the station number is 0 + 00. It is located on the line 3/4 inch from and parallel to the left border and 1.25 inches from the top border.

Figure 1 is a deflection angle open traverse and is to be plotted by the protractor method. The protractor method was discussed in Section 3 and should be referred to as needed.

Information for plotting the deflection angle traverse by the protractor method is given in the field book notes. The contents of the notebook under subject gives notes for Plate 1, Figure 1 to be located on pages 1 and 2. Each double sheet in the notebook is considered as one page and is so numbered.

The notebook will be briefly discussed here in order that the student will become familiar with its role by the drafter. The subject of the survey is listed at the top of the page. In this case it is "Notes for Plate 1, Figure 1." The subject and page numbers of the survey are listed in the contents. The contents show the subject of all surveys in the notebook and the respective pages on which they are located. The contents are shown in order that any survey in the book can be readily located without searching throughout the book.

Column 1 is headed "sta." It lists each station on the traverse. The stations are listed continuously from the beginning to the end of the traverse. Any plus stations are also listed. The notes start at the bottom of the page. This is done

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These are to be plotted by the protractor method. A meridian is drawn through each lettered point as it is located. When point A is located the protractor is oriented to the meridian at point A and an angle of 56°27' is constructed in the southeast quadrant. Along the line with a bearing of S56°27'E a distance of 425 feet is scaled to locate point B. A meridian is now drawn through point B and an angle of 46°52' is constructed in the northeast quadrant. A distance of 595 is scaled on this line to locate point C. In a like manner the other points on the line are located.

Figure 3 is to be plotted by the tangent method of plotting angles. The notes for Figure 3 are shown in the notebook on pages 5 and 6. Use the deflection angles given in Column 2 for plotting. Point A for this figure is located 3/4 inch from the left border and 8.25 inches from the lower border. A table of natural tangents is needed for plotting this figure. Use the 40 scale for scaling the legs of the right angle construction triangle. From point A a distance of 10 units is measured northward to point B. A perpendicular to the meridian of indefinite length is erected eastward at point B. Now, from a table of natural tangents it is found that the tangent of 35°57' is .725 which is multiplied by 10 to obtain 7.25. This number of units is scaled on the perpendicular from B. To locate point C a line is drawn through points A and C. On this line a distance of 474 feet is scaled, using 1 inch equals 200 feet, to locate D. The other points are located in the same manner to complete the plotting of the traverse.

For Figure 4 the notes are located on page 7 in the field book. The scale for all parts of this figure is 1 inch equals 200 feet. Use the calculated latitudes and departures for each line shown in columns 4 and 5 of the notes. Point 1 for Figure 4 is located 3/4 inch from the left border and 4.25 inches from the lower border. Review the method of plotting by latitudes and departures of individual courses and plot the traverse for Figure 4 accordingly.

Point A of Figure 5 is located 3.4 inch from the left border and 0.95 from the lower border. In this figure the angles are plotted by the chord method. Review the discussion dealing with the chord method before attempting this traverse. The notes for Figure 5 are on pages 8 and 9 in the field book. The deflection angles given in Column 2 are to be used except the first line, AC. For this use the calculated bearing given in Column 4 of the notes.

The scale for the traverse is 1 inch equals 200 feet and the scale for the unit measurements in constructing the angles is the 20 scale. A meridian is drawn northward through point A and a distance of 5 units on the 20 scale is measured to locate point B. With the distance from A to B, 5 units, set on the compasses describe the arc DE. Now a table of natural sines is needed and from this table the side of 1/2 of 24°30' or the sine of 12°15' is found to be .212. Three places in the sine is as close as can be plotted. Then 10 x sine of ½ angle to be plotted is equal to 10 times .212 which is 2.12 units. With the compasses set to 2.12 units on the 20 scale describe the arc FG with the center at point B. A line of indefinite length is now drawn through point A and the intersection of arcs DE and FG. On this line a distance of 529 feet is scaled from point A. This locates point C on the traverse. The other points on the traverse are located in a similar manner. This completes the traverse for plate 1.

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Unless otherwise directed by the instructor this plate should be inked on tracing paper. The construction lines are dashed and the traverse lines are solid. Use the reduced size drawing of Plate 1 as a guide as to what should be included on the inked copy of the plate.

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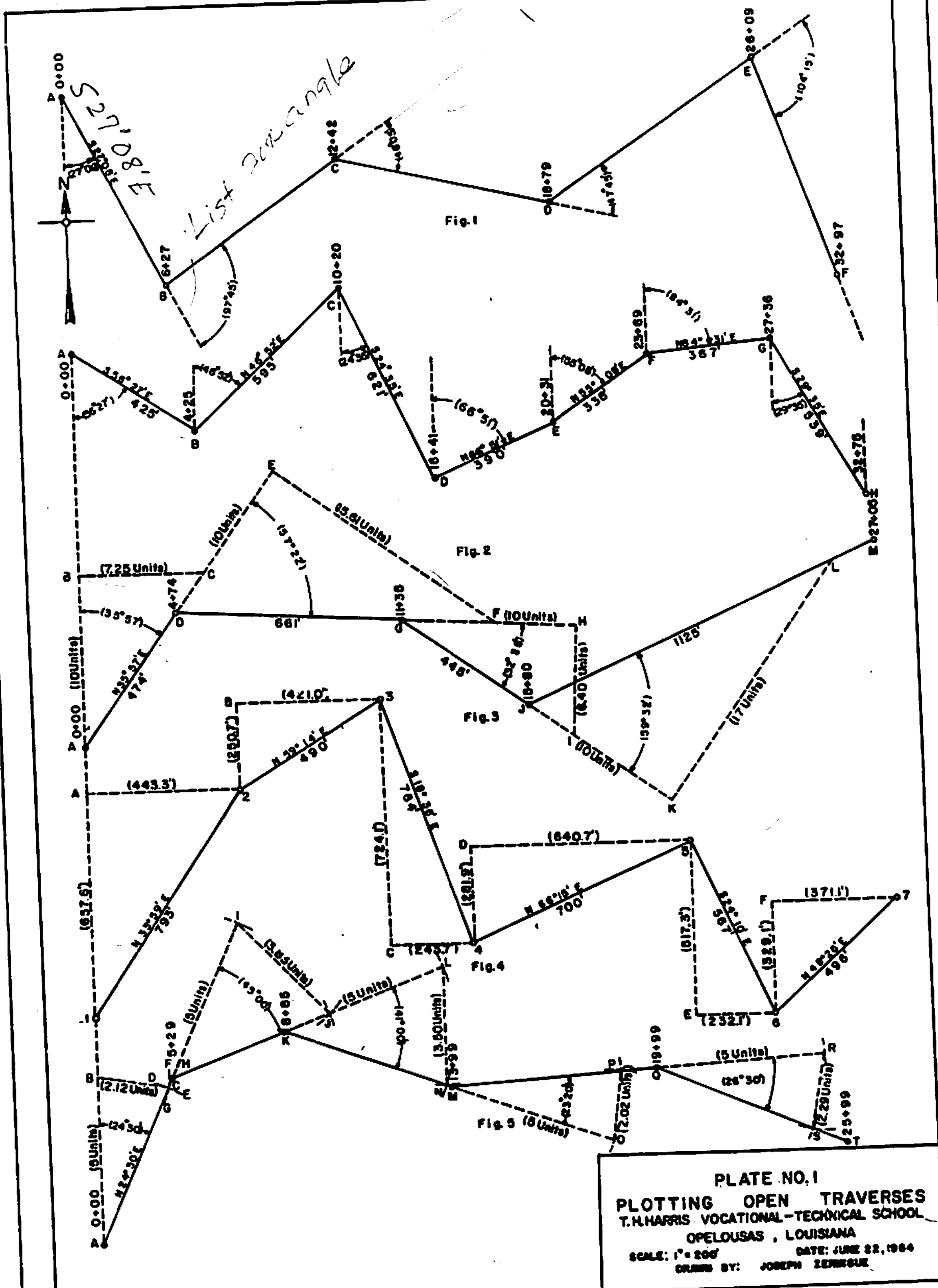

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DIRECTIONS FOR PLATE 2
PLOTTING CLOSED TRAVERSES

The size sheet for Plate 2 and the border dimensions are the same as for Plate 1. However, in this case the short border is placed vertical on the drafting board. The title block is placed in the lower right-hand corner of the inside border. True north is parallel to the left border. The scale to be used is 1 inch equals 100 feet. The notes for plotting are on pages 10 and 11 of the field book. The notes are from a traverse that has been adjusted to give methematical closure, that is with careful plotting, the plotted traverse should return to the point of beginning. The distance between points was measured in the field and the direction of each line was measured by an azimuth from the north. The compass bearing of each line was recorded as a check on mistakes in recording or reading the azimuths. The azimuths were converted to bearings and recorded as a calculated bearing in column 6 of the notes. This traverse is to be plotted by the use of distances and calculated bearings shown in Column 2 and 6 in the notes.

In plotting this traverse start with point M which is located 0.52 inch from the left border and 0.92 inch from the upper border. After point M is located a meridian is drawn south through point M and an angle of 83°56' is laid off in the south-east quadrant from the meridian. A line is drawn through the point established by the angular measurement and point M. This gives the direction of line M to 13, the bearing of which is S83°56'E.

In the notes under the column marked "sta." is shown the station at which the surveying instrument, in this case a transit, is set up. Column 2, marked "obj." gives the object to which the measurement was made. The distances were measured in a forward direction only. From the notes it can be seen that with the transit at M a back azimuth was taken to N and a compass reading also recorded. The instrument was then turned to the forward point 13 and an azimuth and compass reading recorded. The bearings to the points were calculated from the azimuth readings.

After the direction of line M to 13 has been drawn of indefinite length, the distance of 488.32 feet is scaled from M and this establishes point 13. When point 13 has been located a meridian is then drawn through the point, the bearing laid off and point 14 located by scaling the given distance from 13 to 14. The other points are located in the same manner until all of the points have been plotted.

The dashed meridians and angular values given on the sample plate at point 14 are to illustrate again the procedure for plotting bearings.

In plotting always use the field notes for measurements and not values from the sample plate. The sample plates are given only as a general guide and an approximate comparison for the student with a completed plate.

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As soon as each forward point in the survey is located on the drawing the plotted scaled distances and angular values should be checked. Any error in locating a point on the plotted traverse will appear in the plotted points following the error. This will cause the plotted traverse not to return to the point of beginning.

When all of the points have been plotted and checked an inked tracing should be made on tracing paper. All of the lines and figures included on the sample plate should be inked on the tracing. Bearings and distances are shown as indicated on the sample plate.

In the actual practice of tracing a traverse only the traverse with directions and distances of the courses would be shown. The construction lines such as shown at point 14 would not be shown.

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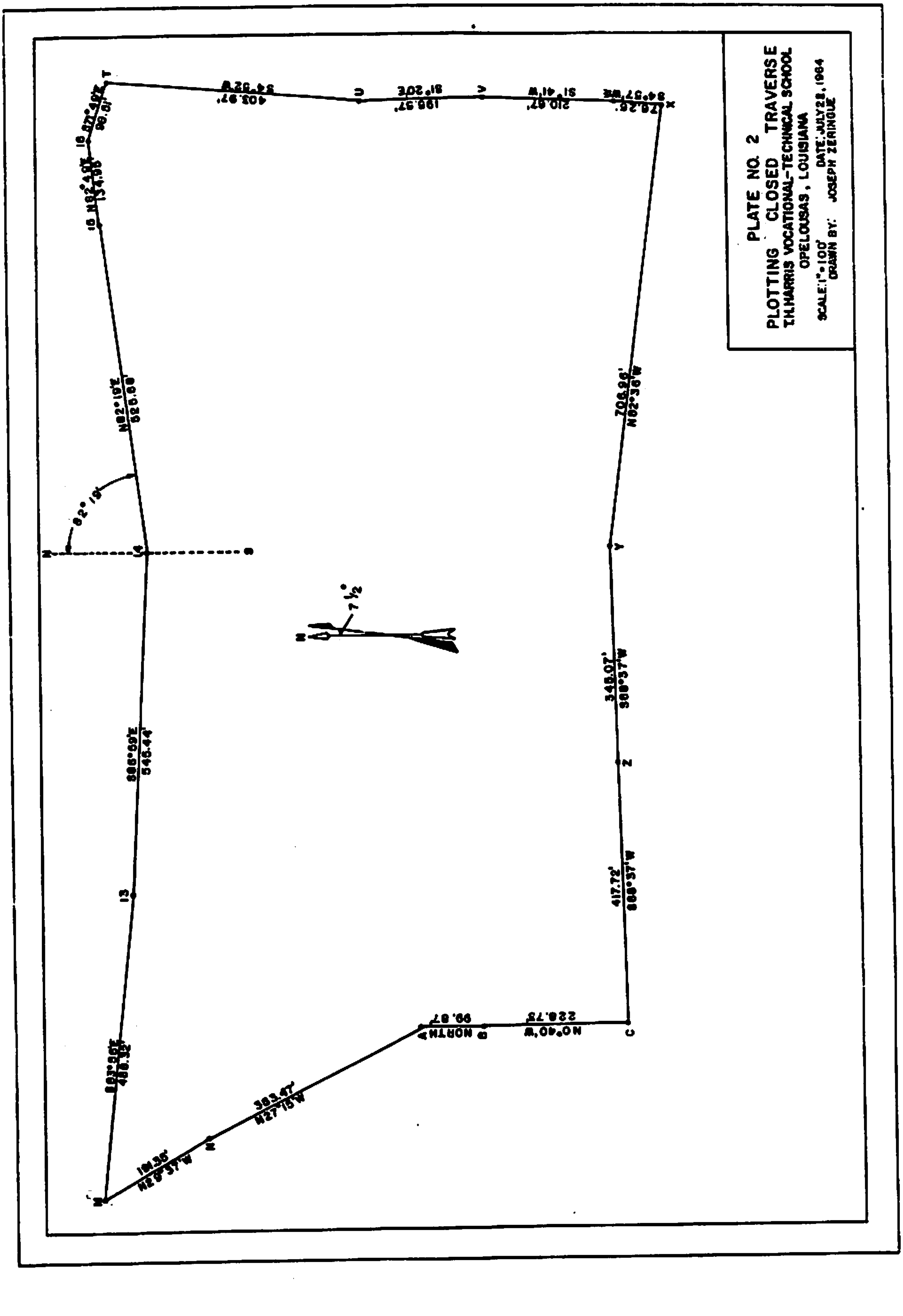


MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 3
PLOTTING CLOSED TRAVERSES

The size of this plate is the same as was used for Plates 1 and 2. The short border is placed vertical on the drawing board. The scale used is 1 inch is equal to 100 feet. The true meridian is parallel to the left border and the magnetic declination is 7½ degrees to the east. The notes to be used for plotting this plate are on page 12 and 13 in the field book.

The notes show the results of a deflection angle survey. In Columns 5 and 6 are the computed total latitudes and total departures. These were computed from the notes of the survey. The origin for the coordinates of the points is located at point A of the survey. Column 5 shows the distance of each point north or south of the origin. Column 6 shows the distances east or west of the origin. From the notes it is seen that the coordinates or total latitude and departure of point M is 507.3 feet north of the origin and 270.2 feet west of the origin.

In plotting this traverse point A is first located on the drawing paper and within the border. Point A is located 3.25 inches from the left border and 6.04 inches from the top border. Through point A a system of rectangular coordinates is constructed placing the dashed lines of the system 250 feet apart to scale as shown on the sample plate. The horizontal lines are labeled respectively 250N, 500N, 250S and 500S in a north-south direction from Point A. These are true east-west lines and are perpendicular to the meridian. The vertical lines are meridian lines and are labeled each 250 feet both east and west of the origin. The purpose of this system of coordinates is to facilitate plotting. This eliminates the necessity of scaling the complete distance from the origin. Each point can be scaled from the nearest line in the rectangular system. The coordinates of point N from the notes are 340.9 North and 175.6 West. In plotting point N a distance of 340.9 is scaled north from the origin and 175.6 west from the origin; this locates point N. Since the rectangular system already drawn shows a line at 250 feet north of the origin, the best procedure is to scale from this already plotted line. It is done by scaling a distance from the 250N line a distance of 340.9 minus 250 which is 90.9 feet north of the line. When the point 340.9 feet north of the origin is located, a light line is drawn west from the located point and a distance of 175.6 feet is scaled to locate point N. The method of locating point W of the survey is illustrated also on the sample plate.

All of the points are located on the drawing by coordinates using information from the notes. The method of plotting the points is as described above.

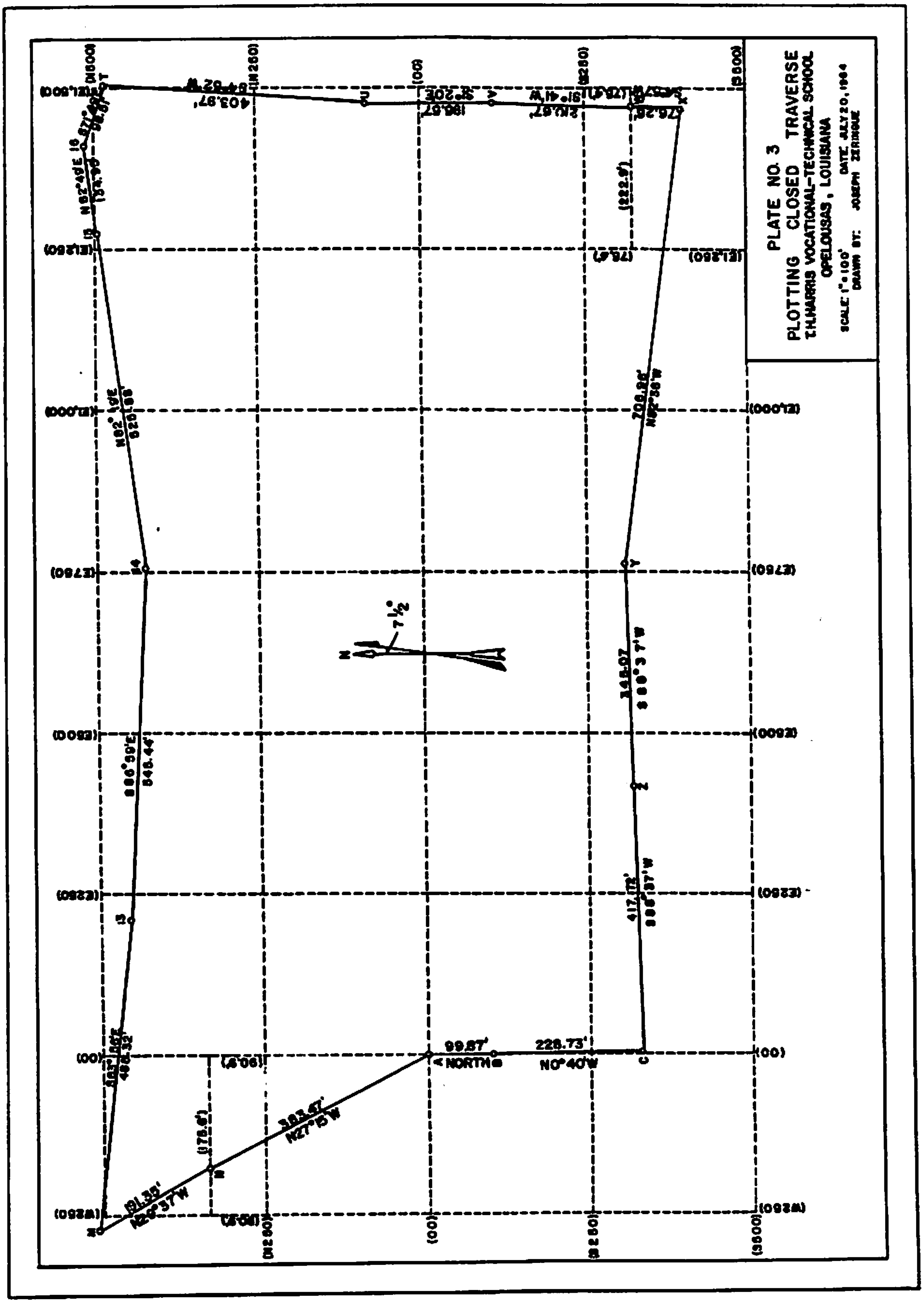
As the points are plotted they are lettered and the bearings and distances are shown for each line on the drawing.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Arrows representing true north and magnetic north are drawn near the center of the plate.

When the drawing is completed an inked tracing should be made using the sample plate as a guide.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING



DIRECTIONS FOR PLATE 4
PLOTTING ROUTE SURVEYS

The sheet for Plate 4 is of standard size. The longer border is placed parallel with the bottom of the drawing board. True north is parallel to the shorter border and is towards the top of the drawing board.

Before attempting to draw Plate 4 the student should review thoroughly Section 7 on Route Surveys with Circular Curves. In this section under the topic of Plotting Route Surveys with Circular Curves are given the directions for plotting the curves on Plate 4.

The scale of the drawing is 1 inch equals 300 feet. The notes for the traverse for Figure 1 are given on page 14 and the notes for the traverse for Figure 2 are given on page 15. The notes for the curves for Figure 1 are given beginning on page 16 of the notebook. The notes for the curves for Figure 2 are given beginning on page 20. The curves for Figure 1 use the chord definition of the degree of curve and Figure 2 uses the arc definition of the degree of curve. Both are plotted in the same manner.

In drawing Plate 4 the first operation is to construct the system of rectangular coordinates. The origin of the system is located 0.75 inch from the left border and 0.85 inch from the top border. The coordinate lines are drawn 1000 feet apart south from the origin and 1000 feet apart east from the origin.

The coordinates, or total latitudes and departures, are given in Columns 5 and 6 of the notes. The traverses are first plotted by the method of coordinates to locate the PI's. The same method of plotting is employed as was used in plotting the points on Plate 3.

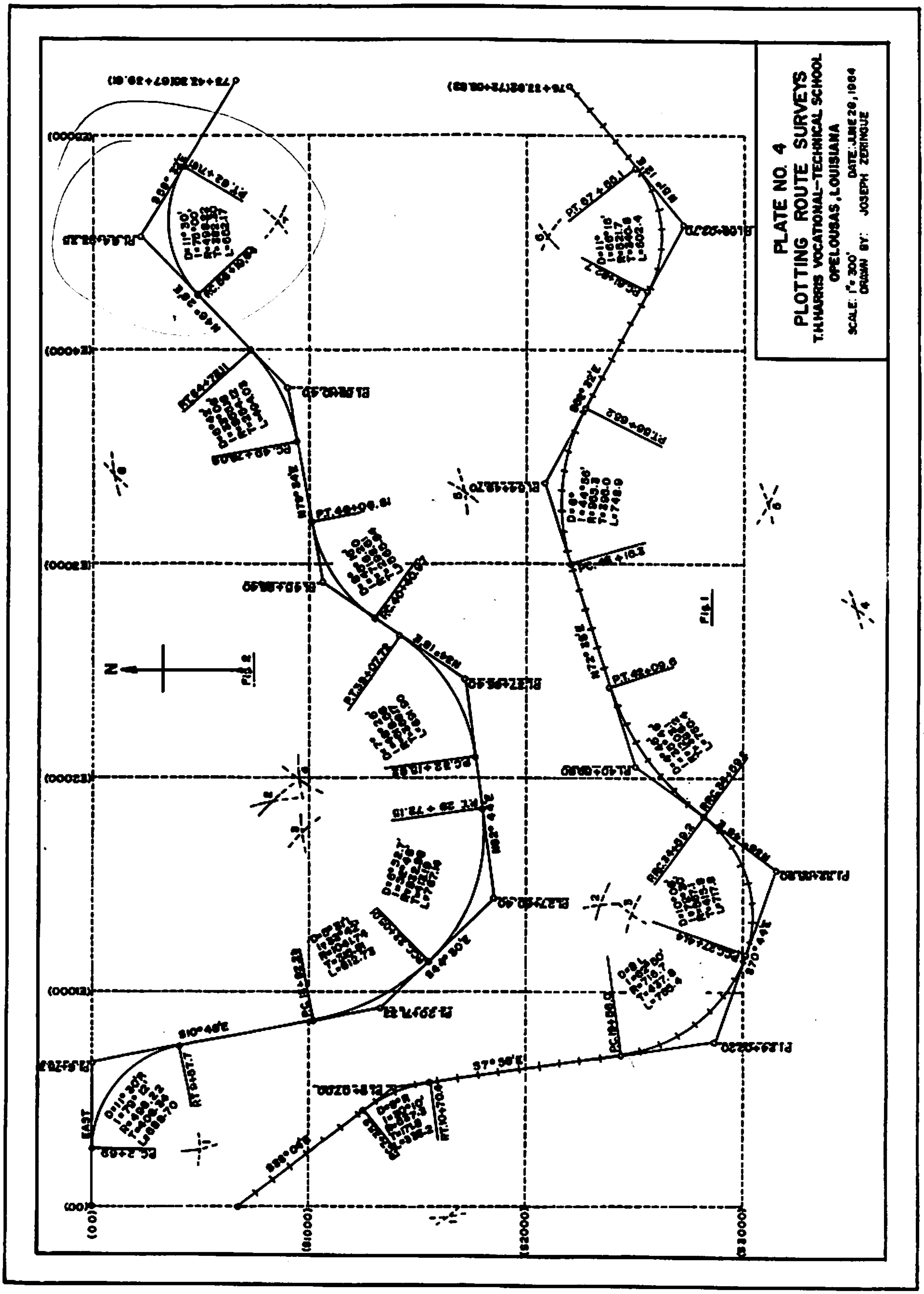
After the traverses have been plotted the curves are then plotted by the method described in Section 7 under the topic of "Plotting Route Surveys with Circular Curves."

It is to be noted that in the final plotting that the stationing in the curve notes is carried continuously from the beginning to end and around the curves. Figure 1 on Plate 4 shows the location for a railway using the chord definition and Figure 4 on Plate 4 shows the centerline of a highway location using the arc definition of the degree of curve.

When the drawing is completed it is to be inked showing all of the curve data as is shown on the sample plate and in the field notes.

207 5499

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING



DIRECTIONS FOR PLATE 5
CONVENTIONAL SIGNS AND SYMBOLS

A standard size sheet and layout is used for Plate 5. The long border is placed parallel to the bottom of the drawing board. There is no scale.

This plate consists of the drawing of certain signs and symbols used in topographic mapping.

The layout of this plate is left to the student using sample Plate 5 as a guide to the arrangement and location of the signs and symbols. Before attempting to draw any but the very simple symbols on the plate, the student should first practice making them until a reasonably good symbol can be made.

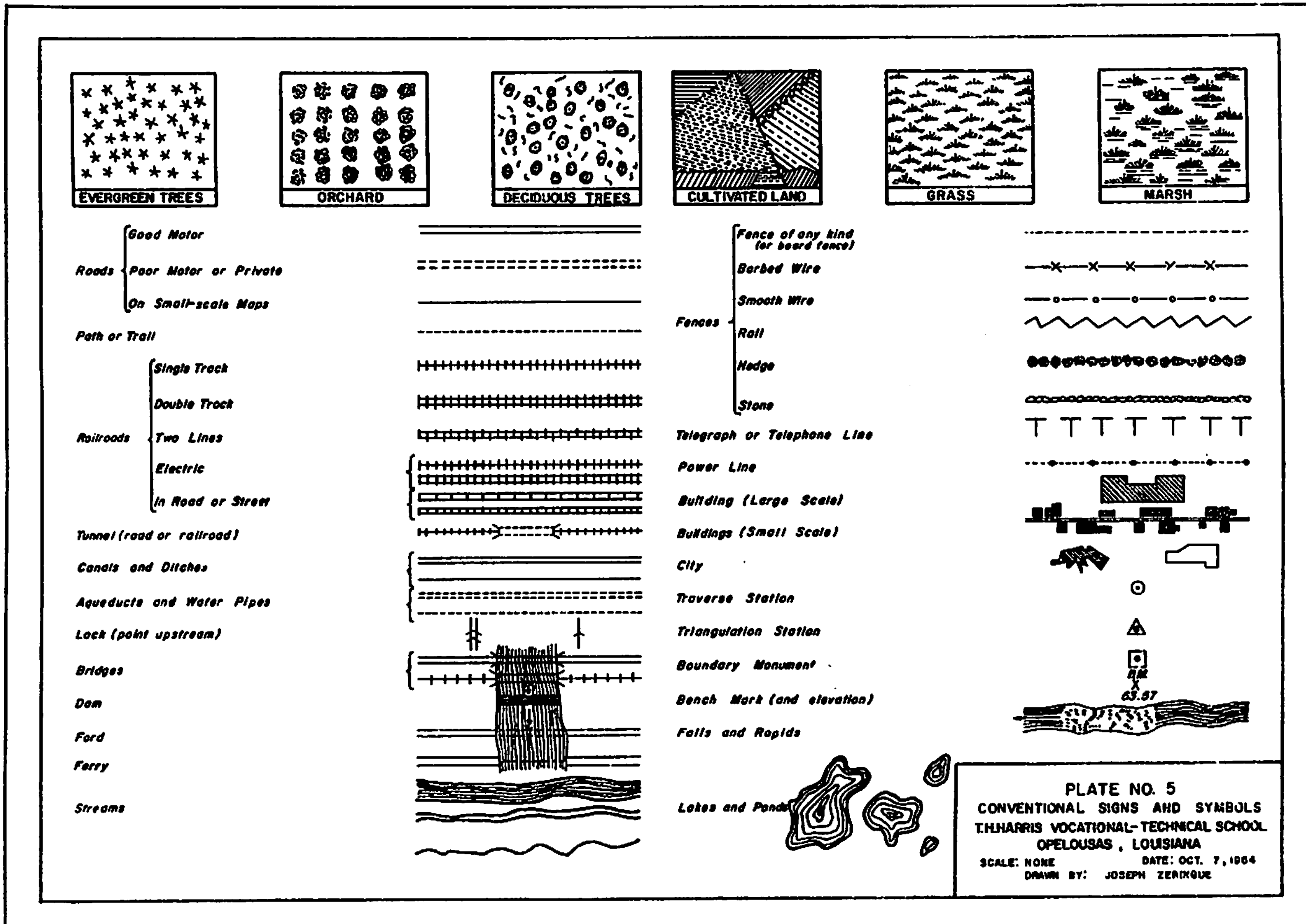
In arranging the distribution of the symbols on a full-size sheet the student can get an accurate estimate from the reduced-size drawing by remembering that the unreduced size of the title block is 2 inches high by 5 inches long.

Symbols and conventional signs were discussed under this topic in Section 8 of the manual.

This plate should be done in pencil and then traced in ink on tracing paper.

Many other signs and symbols not listed may be found in various texts on drawing and surveying.

There are no notes in the field book for this plate.


EVERGREEN TREES
ORCHARD
DECIDUOUS TREES
CULTIVATED LAND
GRASS
MARSH
Roads
Good Motor
Poor Motor or Private
On Small-scale Maps
Path or Trail
Railroads
Single Track
Double Track
Two Lines
Electric
In Road or Street
Tunnel (road or railroad)
Canals and Ditches
Aqueducts and Water Pipes
Lock (point upstream)
Bridges
Dam
Ford
Ferry
Streams
Fences
Fence of any kind (or board fence)
Barbed Wire
Smooth Wire
Rail
Hedge
Stone
Telegraph or Telephone Line
Power Line
Building (Large Scale)
Buildings (Small Scale)
City
Traverse Station
Triangulation Station
Boundary Monument
Bench Mark (and elevation)
BM
63.57
Falls and Rapids
Lakes and Ponds
PLATE NO. 5
CONVENTIONAL SIGNS AND SYMBOLS
T.H.HARRIS VOCATIONAL-TECHNICAL SCHOOL
OPELOUSAS, LOUISIANA
SCALE: NONE
DATE: OCT. 7, 1964
DRAWN BY: JOSEPH ZERINGUE

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 6
PLAN-PROFILE OF PROPOSED ROADWAY

The sheet for this drawing is standard size and layout. The long side of the sheet is placed parallel to the bottom of the drawing board. True north is parallel to the left border and upwards. The notes for this plate are given beginning on page 24. The traverse notes are given beginning on page 24. The traverse should be plotted first using the calculated bearings and the station numbers from the notes.

Station 0 + 00 is located on the drawing 0.75 inch from the left border and 3.2 inches from the top border.

When the traverse is plotted, lines at right angles to the traverse are drawn extending out from the traverse as illustrated by Figure 1, Section 1. At the changes in directions, lines at right angles to each line are drawn in some cases. When the traverse is plotted and the cross lines are drawn, the extremities of the traverse are connected by a straight line and this straight line is labeled "alternate route." The scale for the traverse is 1 inch equals 200 feet.

The student should review the topics of "Cross Sections" in Sections 1 and 9 of the manual.

The next operation is to plot the elevations obtained from the field notes shown beginning on page 25 of the field book. The notes on page 25 show the trace-contour method of obtaining information for plotting contours. This method is discussed under "Topographic Details" in Section 8 of the manual.

The distance out to each contour is located on the ground. This distance out is shown on the sketch on the right-hand sheet. The contour elevation is labeled at each contour end.

In plotting, the distance out from the center line is scaled, a point is located and the elevation of the point is written at the point. The points of equal elevation are then joined by a contour line. The plus distances at the center line in the notes show the distance from the last station where the contour crosses the center line.

The form of notes changes on page 26 of the notes. Here the station numbers are shown on the left-hand sheet and the cross profiles are shown on the right-hand sheet.

Column 1 shows the sta., Column 2 shows the deflection angle, Column 3 shows the calculated bearing and Column 4 shows the elevations along the center line. These same items are shown on the left-hand page of all of the notes for this plate. On the right-hand page beginning on page 26, two figures are shown out in both the left and right direction from the center line. The figure on top of the bar is the distance out and the figure under the bar is the elevation of the point.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

The plotting is done at each station in this manner. The distance out is plotted as a point. The elevation of the point is written at the point. After several stations have been plotted the points of equal elevations are joined by contour lines. Thus at station 11 at a distance out to the left from the center line of 45 feet the elevation is 610 feet, at 145 feet out the elevation is 605 feet and at 470 feet out the elevation is 585 feet.

The top unruled portion of the drawing is known as the plan portion of the drawing. The bottom portion is known as the profile.

The bottom portion is ruled to represent profile paper. Plan-profile paper may be purchased from any engineering supply office. In the drawing horizontal lines are drawn each tenth of an inch apart and each fifth line is drawn heavy. Vertical lines are drawn each half-inch apart and every other line is drawn heavy. The horizontal scale is 1 inch equals 200 feet and the vertical scale is 1 inch equals 10 feet.

In plotting the profile a vertical line is dropped from each point on the traverse where a contour crosses the traverse. The elevation of the contour is plotted on the ruled profile section. Thus at "a" between stations 1 and 2 a vertical line is dropped to the ruled profile paper. The elevation of "a" is between 610 and 615, say 613. This elevation of 613 is plotted on the ruled paper.

When points on the profile paper have been plotted for each point where a contour crosses the traverse, they are connected by a solid line. This gives a profile along the traverse line. The same procedure is used in plotting a profile along the alternate route. The profile of the alternate route is shown as a broken line.

The grade line is then drawn in to show the finished grade of the final roadway. The location of this grade line is discussed in Section 9 under the topic of "Fixing Grades."

The plotting of profiles such as is to be done on Plate 6 is discussed in Section 9 under the topic of "Plotting Profiles." This should be reviewed thoroughly before plotting the profiles on Plate 6.

When Plate 6 has been completed in pencil it should be traced in ink on tracing paper.

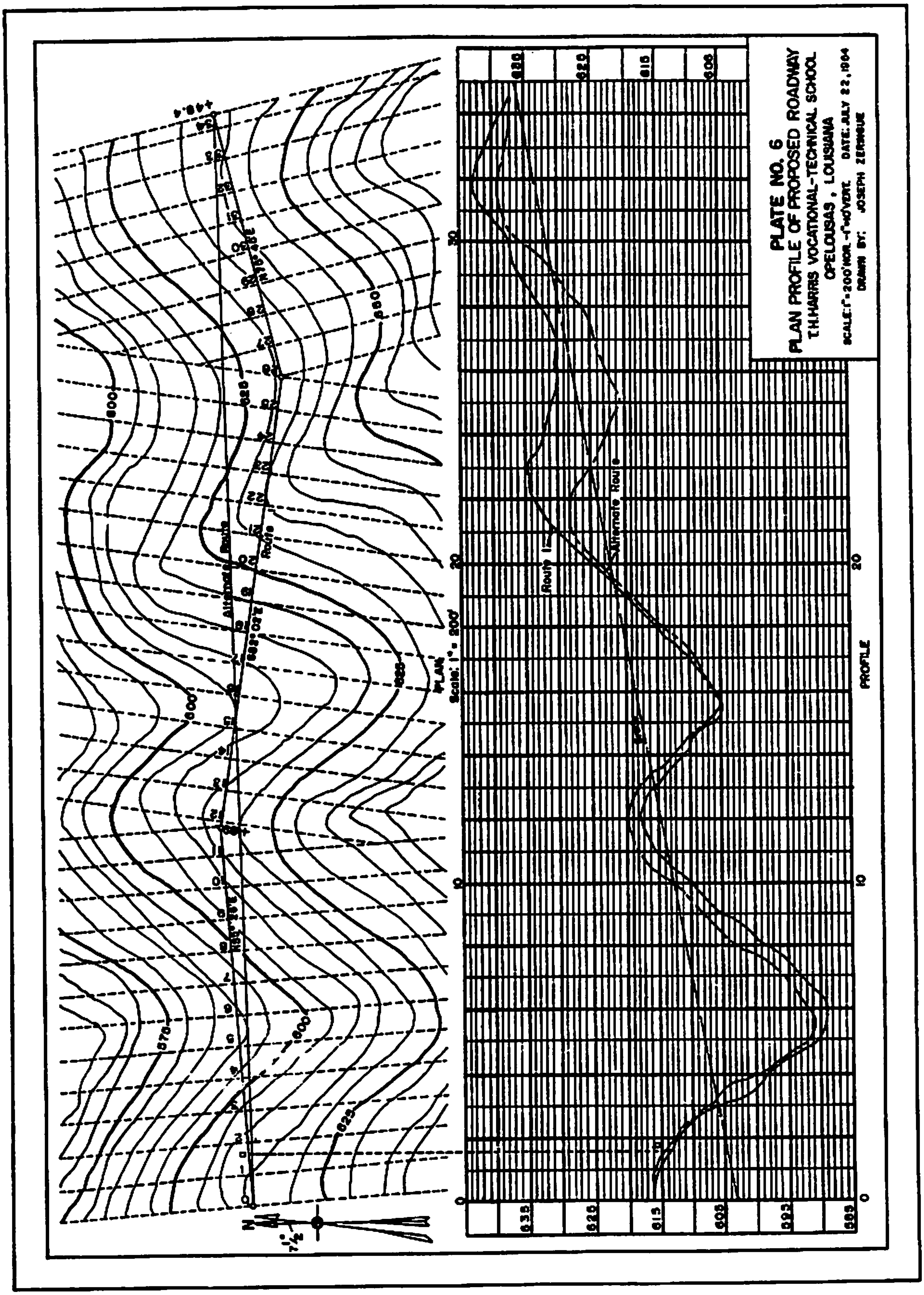


PLATE NO. 6
PLAN PROFILE OF PROPOSED ROADWAY
T.H.HARRIS VOCATIONAL-TECHNICAL SCHOOL
OPELOUSAS, LOUISIANA
PLAN
PROFILE
Route I
Alternate Route

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 7
FEATURES AND CONTOUR MAP

The size sheet for Plate 7 is the regular standard size. Two sample sheets are shown for this drawing. Sample Plate 7P is to be made first. The "P" in this sheet is for preliminary. It is to be made first and then this same Plate 7P is to be completed to make Plate 7. The long size of the sheet is placed parallel to the bottom of the drafting board. North is parallel to the short border and towards the top of the drafting board. Two rectangles are first drawn within the border. The first is one-half inch from the left border and begins one-half inch from the bottom border. That is, the lower left-hand corner is ½ inch from the left and bottom border. The size of the rectangle is 11.60 inches by 7.52 inches with the longer side parallel to the left border. This rectangle is to be divided into six equal portions.

The rectangle next to the right border is 11.60 inches by 10 inches with the longer side parallel to the right border. The lower right-hand corner of this rectangle is located one-half inch from the lower border and one-half inch from the right border. Refer to the sample plate for this construction. The title block is taken out of this rectangle. The left rectangle is for drawing the various land forms and their representation by contour lines. The right-hand rectangle is to be used for the construction of a contour map from field notes.

After the border and rectangle layout within the border is complete, the next step is to plot the control traverse for the construction of the contour map within the right-side rectangle. The coordinate grid is constructed carefully with the origin at the lower-left corner of the rectangle. The grid lines are drawn 500 feet apart each way from the origin. The control traverse is then plotted by coordinates. This traverse is plotted in the same manner as was the traverse for Plate 3.

The field notes for the traverse are shown on page 30 of the field book. On page 31 are shown the calculated total latitudes and departures. These are the coordinates to be used in plotting the traverse. These notes give the location of each point to be plotted. The corners of the traverse are plotted by using the grid system and the notes on page 31 of the field book.

When the control traverse has been plotted the next step is to plot the ground points shown on pages 32 to 49 of the field book. These notes show the field survey notes and the calculated horizontal distance to each point, the azimuth to the point, the elevation of the point and remarks describing the point. A series of observations are taken from each corner of the traverse.

The notes on page 32 show the instrument was located at Station "A." Pages 32 through 34 were taken from station "A." When sufficient detail was obtained at Station "A" the instrument was then moved to Station "B" and observations were taken from Station "B. The heading of each sheet of notes shows the location of the instrument.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

It is to be noted that when the instrument was at Station "C" information could not be obtained to the west of a hill so it was necessary to locate another instrument station. This is shown as Station "I" at the bottom of page 38. The notes to be plotted from this additional Station "I" are shown on pages 48 and 49.

An example of plotting a point is given. Page 32 shows the instrument set at Station "A." Column 1 gives the object sighted. Column 2 gives the azimuth from the north, Column 6 gives the calculated horizontal distance from "A" to the point, Column 7 gives the calculated elevation of the point and Column 8 gives a description of the point. Object 1 shows an azimuth of 115°14', a horizontal distance of 305 feet, an elevation of 450.0 feet and a description of the point as being the waters edge of a lake. In plotting the point the drafting machine is oriented to the north, an azimuth of 115°14' is turned to the right and a distance of 305 feet is scaled along the line from Station "A." This locates the point. The point is labeled A-1 and the point's elevation of 450.0 is written at the point. The elevation can be so written at the point as to make the located point the decimal point of the written elevation. All points from each station are located in the same manner.

When all of the points have been located and labeled the map is then contoured. The points of equal elevation are joined by contour lines following the rules for contouring given in Section 8 and using a contour interval of 5 feet.

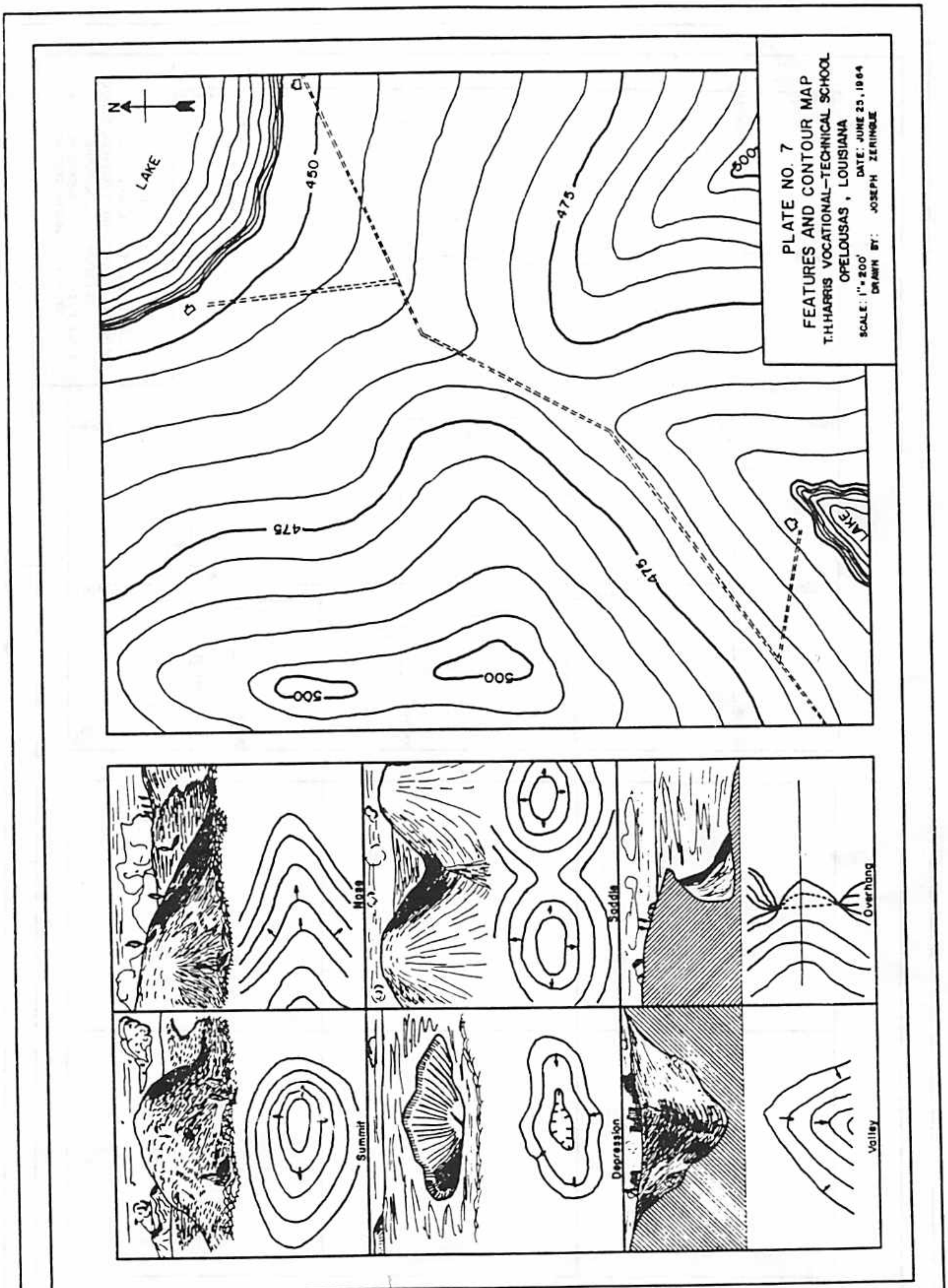
Section 8 should be reviewed thoroughly in a studious manner before attempting to do the contouring.

It is recommended that the contouring of the plate be done by laying a piece of tracing paper over the area to be contoured and copying the points and elevations free hand in ink and using this as a work sheet. This inked copy will allow much erasing and realigning of contours without any erasing of points or written elevations.

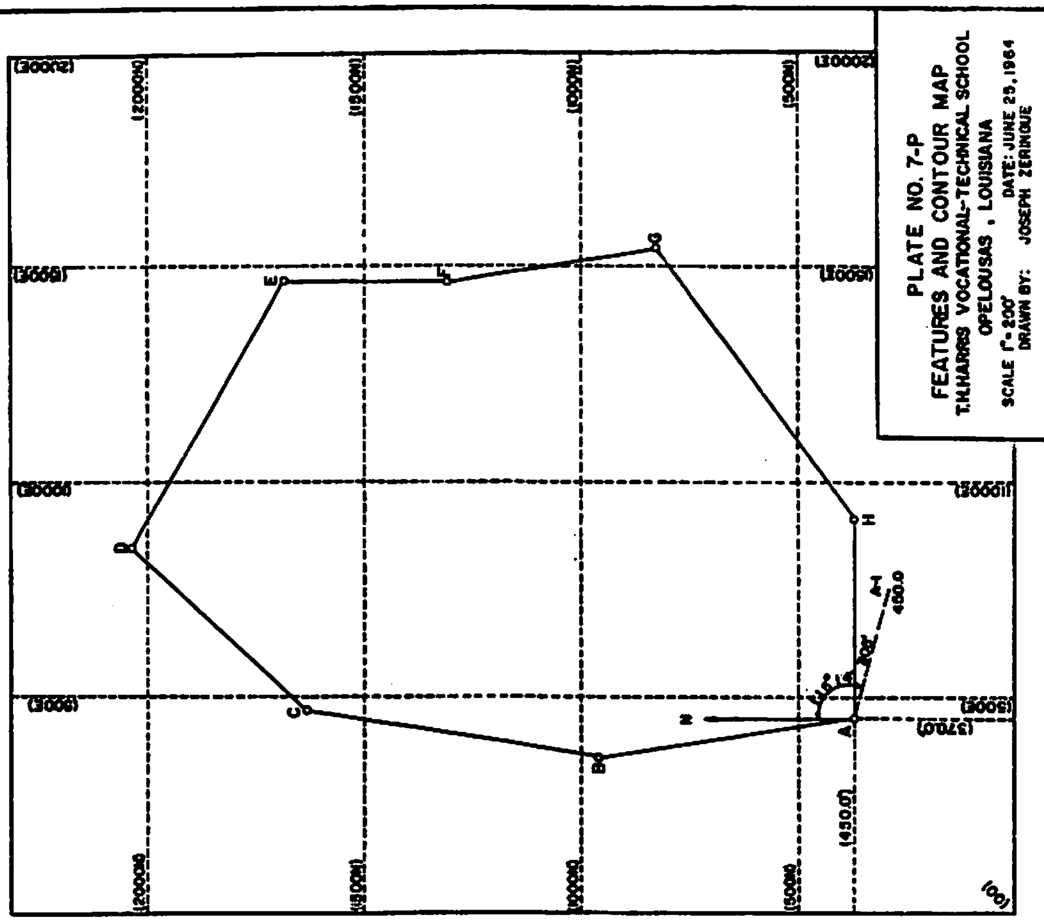
The left-hand portion of the plate showing the various land forms and their representation is to be done freehand using the sample plate as a guide. These should be done several times for practice before attempting to put them on the plate to be inked.

When the plate has been completed it should be traced on tracing paper using ink. Each fifth contour line should be made heavy and the contour value indicated as shown on the sample plate.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING



MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING



MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 8
PLOTTING CROSS SECTIONS

Before attempting to draw this plate Section 9 should be reviewed thoroughly. This plate is to be done on 10 x 10 to the inch cross-section paper 20 inches wide. The length of paper required is approximately 42 inches.

The notes on pages 50-53 show the results of cross sections taken for the construction of a street. The street was excavated to join two existing streets and for drainage. The cross sections were taken from one edge of the excavated street. The sections were taken every 25 feet along the length of the street except for the last section which was at the end. The left-hand sheet was used for running the levels. The right-hand sheet shows the rod reading taken with a level, the middle line shows the distance out to the point from the left edge of the street and the top line shows the calculated elevation of the point. The figures to be used in plotting are the distance out from the left-hand edge of the street and the elevation of the point. The horizontal scale is 1 inch equals 5 feet and the vertical scale is 1 inch equals 1 foot. The horizontal and vertical scales are indicated at each cross section. Assuming that the original grade was uniform from the first point to the last point of each section, they are connected by a dashed line.

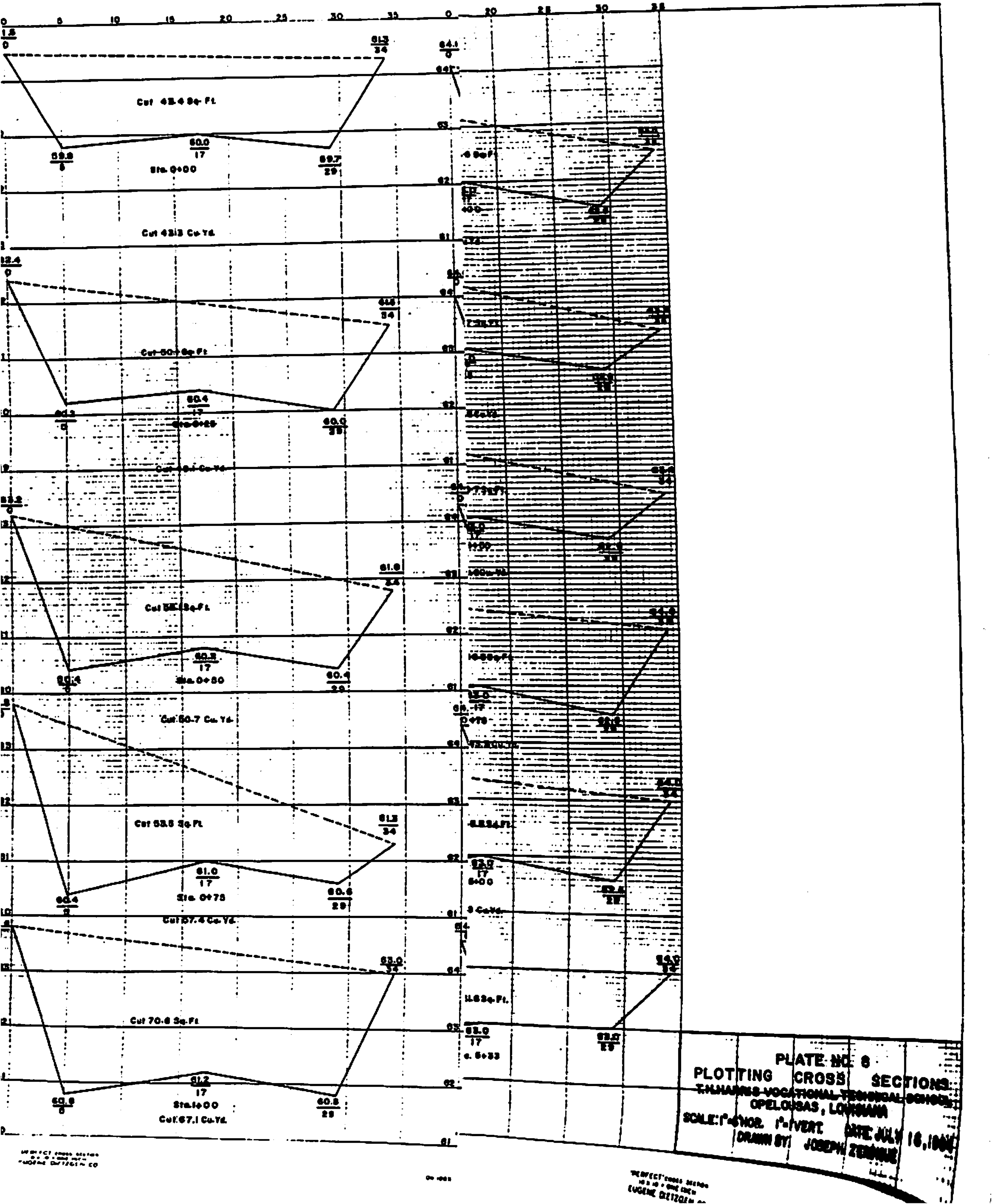
Each section is plotted individually beginning at the top and left-hand side of the sheet. The sections are then plotted under each other and when the sheet is completed to the bottom, another row of sections is then started at the top of the sheet. The elevation is plotted using the vertical scale and the distance out is plotted using the horizontal scale. Sample Plate 8 is to be used as a guide in the arrangement of the plotted sections. The area of each section is written within the section and the volume of earth between each two sections is written between the sections.

Figure 29 shows the calculated areas of the sections, the volume in cubic yards between each two adjacent sections and the total volume of removed dirt. The areas and volumes to be placed on the drawing may be obtained from this source. The cross sections should be plotted lightly in pencil and then the cross sections and other information should be inked as illustrated by the Sample Plate No. 8.

At each plotted point both the elevation and the distance are indicated. In this case the elevation is above the bar and the distance is below the bar.

P DRAFTING & RELATED COMPU
R PLANE SURVEYING

Section 12
Plate 8
Page 2 of 2



MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 9
BAYOU TATE AREA MAP

Before attempting to plot this area map Section 10 should be reviewed thoroughly. The drawing sheet is standard size with the longer border parallel to the bottom of the drawing borad. North is parallel to the shorter border and upward.

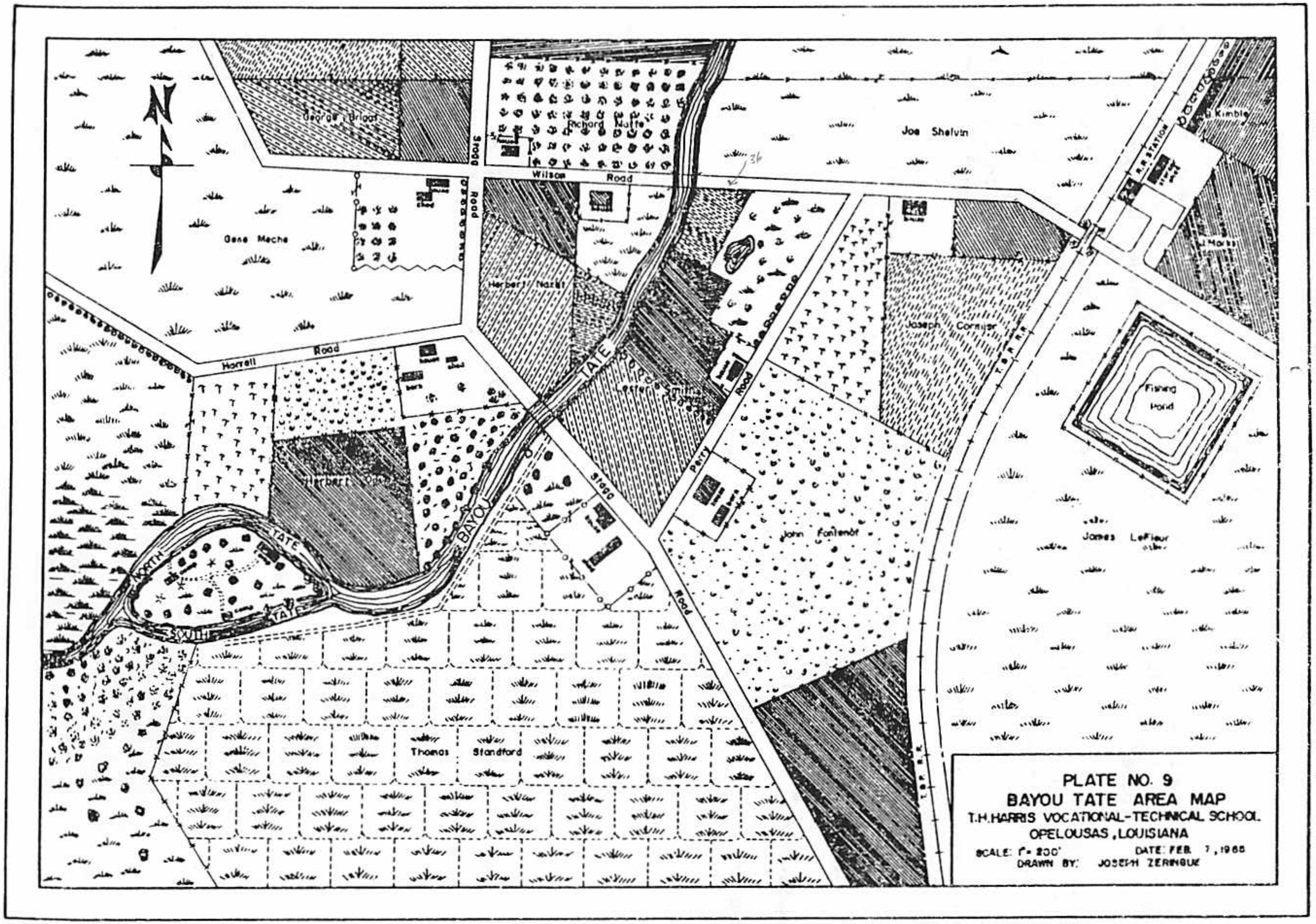
The notes for this plate are on pages 54-74 of the field book. Plot the traverses first, check them against Sample Plate 9 for general correctness, then plot the details by the method described in Section 10. Plot Wilson Road traverse first as the starting point for this traverse is given as being on the north border and 2½ inches from the west border. Use the calculated bearing given in Column 3 of the notes for the directions of the lines and the station numbers given in Column 1 for the distances.

After the traverses are plotted and checked then plot the details along the lines. Study the notes, remarks and sketches carefully as this information is used in plotting the details.

Review Section 8 for culture symbols.

When the drawing is completed, trace the map in ink.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING



410' ∠ S26D 56' E

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 10 and 10A

These are plates which are given completed showing the method of calculating areas by the DMD method, the calculation of the total latitudes and departures and the adjusted bearings and lengths.

Review thoroughly Sections 5 and 6 which describe how the calculations are made. With the information given in Sections 5 and 6 and the use of a calculator, redo and check all of the figures given on Plates 10 and 10A in order to satisfy yourself that you understand the computations done on these plates. This is in preparation for doing the calculations for Plate 11 for which you will be given only the lines, lengths and bearings of a closed traverse.

The field notes for Sample Plates 10 and 10A are given on page 75 of the field book.

The only information needed for these calculations are the line, its length and bearing.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

LINE	LENGTH FEET	BEARING	COSINE	SINE	UNADJUSTED				CORRECTION FEET		ADJUSTED				D. M. D.'s	DOUBLE-AREAS	
					LATITUDES		DEPARTURES				LATITUDES		DEPARTURES			NORTH	SOUTH
					N	S	E	W	LATI-TUDE	DEPAR TURE	N	S	E	W			
B-C	686.4	N9° 28'E	.98638	.16447	677.05		112.89		+.237	+.741	677.29		113.63		113.63	76960.46	
C-D	551.8	N42°57'E	.73195	.68136	403.89		375.97		+.191	+.596	404.08		376.57		603.83	243995.63	
D-E	711.7	S60°05'E	.49874	.86675		354.95	616.87		-.246	+.769		354.70	617.64		1598.04		566824.79
E-F	375.6	South	1.00000	.00000		375.60			-.130	+.406		375.47	0.40		2216.08		832071.56
F-G	491.2	S9° 34'E	.98609	.16620		484.37	81.64		-.170	+.530		484.20	82.17		2298.65		1113,006.33
G-H	782.7	S54°25'W	.58189	.81327		455.45		636.55	-.270	-.846		455.18		635.70	1745.12		794343.72
H-A	462.4	West	.00000	1.00000				462.40	+.160	-.499	0.16			461.90	647.52	103.60	
A-B	595.2	N9° 02'W	.98760	.15701	587.82			93.45	+.206	-.643	588.02			92.81	92.81	54,574.14	
	4657.0				1668.76	1670.37	1187.37	1192.40	1.610	5.030	1669.55	1669.55	1190.41	1190.41		375633.83	3306246.40
						-1668.76		-1187.37									-375633.83
						1.61		5.03	Double Area in Acres = $\frac{2930612.57}{43560}$ = 67.278 Ac							Double Area =	2930612.57 sq ft
											Area in Acres = $\frac{67.278}{2}$ = 33.639 Acres						

ERROR IN LATITUDE = 1.61 South

ERROR IN DEPARTURE = 5.03 West

ERROR OF CLOSURE = $\sqrt{1.61^2+5.03^2} = 5.28$

$\frac{1.61}{4657}$ = .0003457 corr/ft. in Lat.

$\frac{5.03}{4657}$ = .0010801 corr./ft. in Dep.

PLATE NO. 10
CALCULATION OF AREAS
T.H.HARRIS VOCATIONAL–TECHNICAL SCHOOL
OPELOUSAS, LOUISIANA
DATE: FEB. 26, 1965
DRAWN BY: JOSEPH ZERINGUE

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

Sta.	Adjusted Lat.		Adjusted Dep.		Total Lat.		Total Dep.		Adj. Bearing	Adj. Length
	N	S	E	W	N	S	E	W		
A					370.0		450.0		N 8° 58' W	595.30'
	588.02			92.81						
B					958.02		357.19		N9° 31' E	686.76'
	677.29		113.63							
C					1635.31		470.82		N42° 59' E	562.35'
	404.08		376.57							
D					2039.39		847.39		S60° 08' E	712.24'
		354.70	617.64							
E					1684.69		1465.03		S 0° 04' E	375.47'
		375.47	0.40							
F					1309.22		1465.43		S 9° 38' E	491.12'
		484.20	82.17							
G					825.02		1547.60		S54° 24' W	781.86'
		455.18		635.70						
H					369.84		911.90		N89° 59' W	461.90'
	0.16			461.90						
A					370.00		450.00			
	1669.55	1669.55	1190.41	1190.41						

PLATE NO. 10-A
COORDINATE CALCULATIONS
T.H.HARRIS VOCATIONAL-TECHNICAL SCHOOL
OPELOUSAS, LOUISIANA

SCALE: NONE
DATE: MARCH 15, 1965
CALCULATIONS BY: JOSEPH ZERINGUE

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 11
CALCULATION OF AREAS AND COORDINATES

This plate is similar to plates 10 and 10A. No specific directions will be given for this exercise.

Using the forms illustrated by Sample Plates 10 and 10A and the information given in Sections 5 and 6 the student should complete this problem without a sample plate.

The directions to be given are as follows:

1. Draw forms as shown on the sample forms illustrated in the Sample Plates 10 and 10A.
2. From the notes given on page 76 calculate the latitudes and departures of each course.
3. Determine the error of closure.
4. Adjust the latitudes and departures to form a mathematically closed figure.
5. Determine the double meridian distances.
6. Compute the area of the closed figure.
7. Compute the total latitude and departure of each corner of the figure.
8. Compute the adjusted length and bearing of each course.

DIRECTIONS FOR PLATE 12
CROSS SECTIONS

Again this problem will be left to the student. The notes for this problem are given on page 77-80 in the field book. The student is to do the following:

1. Plot the cross sections on ruled cross-section paper as was used for Plate 8.

2. Calculate the areas of the cross sections.

3. Compute the volumes of earth between each two adjacent sections using a form as shown in Figure 29.

4. Compute the total volume of earth along the total line given in the notes by adding the volumes between adjacent sections.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 13
PLOTTING PROFILES

Take Plate 7 and draw a straight line from the northwest corner of the rectangle surrounding the contour map to the northeast corner of the 2 x 5 inch title block. Let the northwest corner of the rectangle be Station 0 + 00. Locate and number the stations from 0 + 00 to the end of the line at the northeast corner of the title block. This is to be done by scaling and marking each full 100-foot station. Use the scale to which the map is drawn.

From information taken from the map along the line drawn, plot a profile of this line using 10 x 10 to the inch cross-section paper. Plot points on the profile at each station along the line and at each point on the line where a contour crosses the line.

The selection of the horizontal and vertical scales is left to the student and instructor.

This problem is similar to the profile plotted in drawing Plate 6.

MAP DRAFTING & RELATED COMPUTATIONS FOR PLANE SURVEYING

DIRECTIONS FOR PLATE 14

The notes for Plate 14 are given on pages 81 and 82 of the field book. The notes show the results of a deflection angle traverse. One of the purposes of this exercise is to give the student practice in converting angles measured in the field into bearings and into azimuths.

The size of the sheet required is 15 inches by 18 inches. The border is drawn one-half inch inside the sheet which gives a working space of 17 inches by 14 inches. The short border is placed vertical on the drawing board. North is parallel to the short border and upward.

Point A is located 1.25 inches from the west border and 2 inches from the north border. Scale: 1" = 100'.

1. Plot the closed traverse by deflection angles.

2. Compute the bearing of all lines from the deflection angles. The bearing of line AB is due south.

3. Compute the azimuths of each line from the north from either the bearings or defelction angles.

4. Enter the bearings and deflections on each line of the drawing.

5. Calculate the interior angles.

6. Complete the set of field notes shown on page 81 of the field book.

7. Complete the map as the instructor may direct.