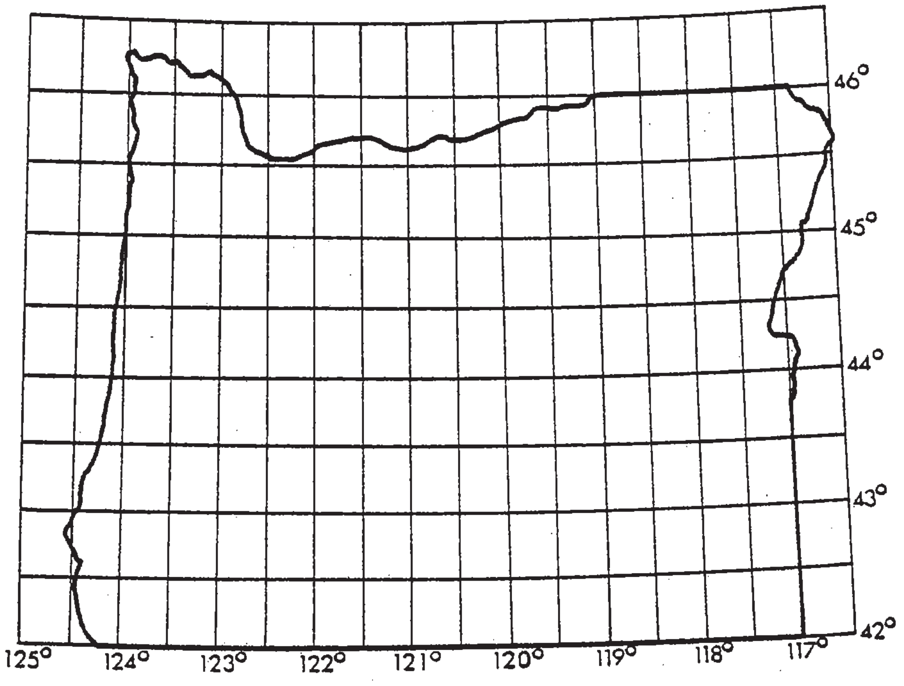


THE GEODETIC COORDINATES OF OREGON

CHAPTER 7

MAP PROJECTION AND COORDINATES

INTRODUCTION

There is nothing new about coordinates. They have been used for centuries to locate positions on the surface of the earth. They were used by ancient surveyors for planning and surveying cities, such as Rome. They were relied upon by cartographers for construction of navigational charts, and by the navigators who used the charts. The township and range pattern developed by the U.S. public land survey is one type of coordinate system; however, not a true plane rectangular coordinate system of the type described in this chapter.

The idea of using plane coordinates for map control is relatively new to cadastral cartography. The major reason for the slow transformation to coordinate based control is that cartographers, like surveyors, have been reluctant to use coordinates in belief that coordinate systems are highly technical and involve the use of many complicated formulas. The fact is, coordinates are based on some rather simple concepts.

The plane rectangular coordinate system described in this chapter is legally called *the Oregon Coordinate System.*[1] To fully appreciate this system, it will be necessary to describe *map projection systems* and the legal requirements for using the Oregon Coordinate System.

The Oregon Revised Statutes designate what map projection is to be used what *spheroid is* to be used, and what triangulation datum is to be used. The following chronological list of developments will help in understanding the statutory requirements; and it will provide you with a proper perspective of coordinate development.

Significant Dates of State Plane Coordinate Development

1772 (87 years prior to Oregon Statehood) J. H. Lambert, a Swiss surveyor and mathematician, developed the *conic conformal map projection.* Contrary to popular belief, Lambert did not develop the rectangular coordinate system.

1841 Bessel computed the shape of the earth. The U.S.C. and G.S. used Bessel's computations until 1880.

1866 Alexander R. Clarke, a British geodesist, developed more precise measurements of the earth. (Clarke's configuration is called *Clarke's spheroid* by ORS 93.330)

1880 The U.S.C. and G.S. adopted Clarke's spheroid.

1924 The International Geodetic Association adopted the *International Ellipsoid.* This configuration was so mathematically close to Clarke's that the U.S.C. and G.S. decided to retain Clarke's spheroid.

1933 Dr. O. S. Adams, senior mathematician for the U.S.C. and G.S., developed the *state plane coordinate system* (as used by Oregon).

1938 The U.S.C. and G. S. developed the mathematical coordinate tables for Oregon.

1945 The *Oregon Coordinate System* was given legal status. [2]

1952 The U.S.C. and G.S. published the *Plane Coordinate Projection Tables* for Oregon.

1959 The Oregon Department of Revenue began using the Oregon Coordinate System for base map control.

LEGAL STATUS OF THE OREGON COORDINATE SYSTEM

The Oregon Revised Statutes contain the technical constants that are important to the system; such as the location of the North and South zones, the required map projection, the required geoid, the location of the standard parallels, the origin of coordinates, the use of "X" and "Y" for coordinate identification and the requirements for noting the system on maps and records.

It is important to study the laws before applying coordinates to cadastral maps.

ORS 93.320 "Oregon Coordinate System; Zones. (1) The system of plane coordinates which has been established by the United States Coast and Geodetic Survey for defining and stating the positions of locations of points on the surface of the earth within the State of Oregon is known and designated as the Oregon Coordinate System.

(2) For the purpose of the use of this system the state is divided into a "north zone" and a "south zone."

(3) The area included in the following counties on June 16, 1945, constitutes the north zone: Baker, Benton, Clackamas, Clatsop, Columbia, Gilliam, Grant, Hood River, Jefferson, Lincoln, Linn, Marion, Morrow, Multnomah, Polk, Sherman, Tillamook, Umatilla, Union, Wallowa, Wasco, Washington, Wheeler and Yamhill.

(4) The area included in the following counties on June 16, 1945 constitutes the south zone: Coos,

Crook, Curry, Deschutes, Douglas, Harney, Jackson, Josephine, Klamath, Lake, Lane and Malheur.

(5) The use of the term "Oregon Coordinate System" on any map, report or survey or other document, is limited to coordinates based on the Oregon Coordinate System as defined in ORS 93.330.

The Technical Constants are provided in the following statute.

ORS 93.330 "Definition. (1) For more precisely defining the Oregon Coordinate System, the following definition by the United States Coast and Geodetic Survey is adopted:

(a) The Oregon Coordinate System, north zone, is a Lambert conformal projection of the Clarke Spheroid of 1866, having standard parallels at north latitudes 44 degrees 20 minutes and 46 degrees 00 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 120 degrees 30 minutes west of Greenwich and the parallel 43 degrees 40 minutes north latitude. This origin is given the coordinates: X = 2,000,000 feet and Y = 0 feet.

(b) The Oregon Coordinate System, south zone, is a Lambert conformal projection of the Clarke Spheroid of 1866, having standard parallels at north latitudes 42 degrees 20 minutes and 44 degrees 00 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 120 degrees 30 minutes west of Greenwich and the parallel 41 degrees 40 minutes north latitude. This origin is given the coordinates: X = 2,000,000 feet and Y = 0 feet.

(2) The position of the Oregon Coordinate System shall be marked on the ground by triangulation or traverse stations established in conformity with the standards adopted by the United States Coast and Geodetic Survey for first-order and second-order work whose geodetic positions have been rigidly adjusted on the North American datum of 1927, and whose coordinates have been computed on the system defined in this section. Any such station may be used for establishing a survey connected with the Oregon Coordinate System."

The requirements for noting the Oregon Coordinate System in land descriptions, is clearly defined in ORS 93.340.

ORS 93.340 "Use of terms in land descriptions. (1) As established for use in the north zone, the Oregon Coordinate System shall be named, and in any land description in which it is used it shall be designated the "Oregon Coordinate System, North Zone."

(2) As established for use in the south zone, the Oregon Coordinate System shall be named, and in any land description in which it is used it shall be designated the "Oregon Coordinate System, South Zone."

(3) When any tract of land defined by a single description extends from one into the other of the coordinate zones mentioned in ORS 93.320, the position on its boundaries may be referred to either of those zones, the zone which is used being specifically named in the description."

The "X' and "Y" identification of coordinates is described in the following statute.

ORS 93.350 "Plane Coordinates. The plane coordinates of a point on the earth's surface, used in expression the position or location of such point in the appropriate zone of the Oregon Coordinate System shall consist of two distances, expressed in feet and decimals of a foot. One of these distances, to be known as the "X-coordinate," shall give the position in an east and west direction; the other, to be known as the "Y-coordinate," shall give the position in a north-south direction. These coordinates shall be made to depend upon and conform to the coordinates, on the Oregon Coordinate System, of the triangulation and traverse stations of the Coast and Geodetic Survey within the State of Oregon, as those coordinates have been determined by that survey."

The following statute should be carefully studied before noting "Oregon Coordinate System" on maps and records.

ORS 93.360 "Coordinates exempted from recordation. No coordinate based on the Oregon Coordinate System, purporting to define the position of a point on a land boundary, shall be presented to be recorded in any public land records or deed records unless that point is within one-half mile of a triangulation or traverse station established in conformity with the standards prescribed in ORS 93.330. However, the one-half mile limitation may be modified by an authorized state agency to meet local conditions; or (2) an electronic distance-measuring device is employed to obtain position of the point in conformity with the standards prescribed in ORS 93.330.

The object of ORS 93.360 is to prevent the misrepresentation of points or monuments, as being accurately tied to the Oregon Coordinate System. 93.360 does not prohibit showing coordinate grid ticks and "X" "Y" intersections on cadastral maps.

ORS 93.370 is another precautionary measure. The statute reflects a long established rule that *any survey measurement cannot overcome or outweigh the physical evidence of a monument or corner. A* corner, as set on the ground, is that corner or monument for which it was established.

ORS 93.370 "If coordinates based on the Oregon Coordinate System are used to describe any tract of land which in the same document is also described by reference to any subdivision, line or comer of the United States public land surveys, the description by coordinates is construed as supplemental to the basic description of that subdivision, line or corner contained in the official plats and field notes of record. In the event of any conflict the description by reference to the subdivision, line or corner of the United States public land survey prevails over the description."

ORS 93.370 should not be hastily evaluated. First of all, the statute is referring to descriptions, not surveys. It is *not* implying that resurveys or retracement surveys should be ignored. A retracement survey that locates an original corner, as it was placed on the ground, would not be subordinate to original plat distances and bearings even if coordinates were used to describe that corner. This is based on a long standing rule that *the location of a corner as it was placed in the ground by the original surveyor is, for all practical purposes, indisputable.*

The following example should clarify ORS 93.370. A deed calls for the four comers of a parcel of land by coordinates. The deed further describes the land as section 7 of a certain township. By comparing the location of the parcel by coordinates, with the location of section 7 by the U.S. public land survey, it appears as though something other than section 7 is being described. At this point one thing is certain, as per ORS 93.370 the parcel is section 7 and nothing else. If the coordinates were from an U.S. dependent survey and they represented the comers as found by that survey, the coordinates must be used; but the parcel of land they represent will be section 7 and nothing else.

Although the statutes are strict as to how the Oregon Coordinate System is to be used, they only *permit* rather than *require* its use, as evidenced by ORS 93.380.

ORS 93.380 "Purchaser or mortgagee not required to rely on descriptions. Nothing contained in ORS 93.320 requires any purchaser or mortgagee to rely on a description of *which* depends exclusively upon the Oregon Coordinate System."

MAP PROJECTION

Plane coordinates must be developed on a plane surface.[3] The development of a plane surface that will represent features of the earth's spherical surface is called map *projection.*

The surface of the earth cannot be developed into a plane without some degree of distortion in land shapes, angles and scale; because the only true *plane* on the earth's surface is at the point of tangency of the plane and spherical surface (position "A" in figure 71).

The distortion resulting from the projection of radials from the curved to the plane surface is evident in figure 71. If the earth were merely a circle, the problem of transformation would be simple; however, the problem is compounded by the fact that the earth is spherical and the distortion exists in every direction at every point of tangency.

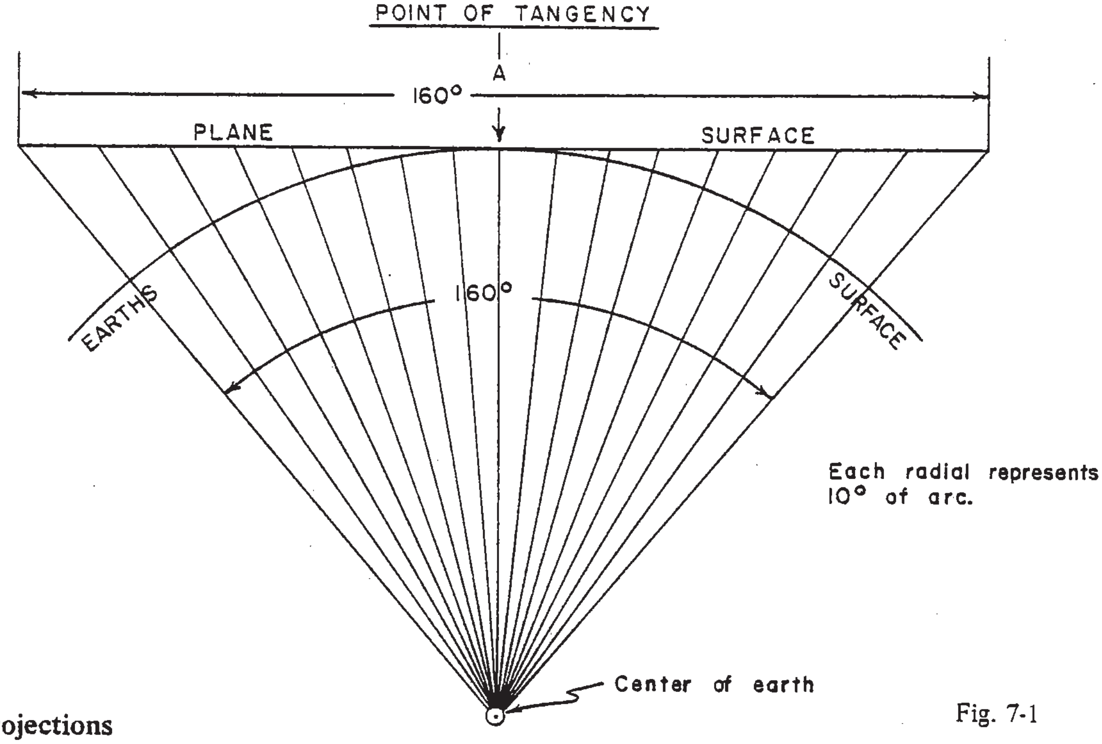
The difference between the geometric relationship on the sphere, as compared to that of the plane, is the difference in scale expressed as a ratio. For example, if we were to produce a world globe with identical geometric relationship to the earth's sphere, the scale factor would be 1.0 (or S.F. 1.0). S.F. 1.0, however, cannot exist when transferring the spherical surface to the plane surface; but, as we shall see, it can be very close to S.F. 1.0.

There are many different types of map projections; each designed for a specific application. There are a number of ways the projections can be categorized; however, they basically fall into three categories

(1) Conformal map projections, (2) *equal-area* projections, and (3) *asimuthal* projections. Each category of projection is broken down by the specific method in which the projection has been developed. The following is a list of some better known projections:

1. CONFORMAL PROJECTIONS
   a. The Universal Transverse Mercator. (a Cylindrical conformal projection)
   b. Lambert's Conic.
   c. Stereographic.
2. EQUAL-AREA PROJECTIONS.
   a. Alber's Conic.
   b. Boone's Conic.
   c. Cylindrical.
   d. Sinusoidal (pseudocylindrical).
   e. Moilweide's (pseudocylindrical).
   f. Eckert's IV (pseudocylindrical).
   g. Flat Polar Quartic (pseudocylindrical).
   h. Lambert's Azimuthal.
3. AZIMUTHAL PROJECTIONS
   a. Stereographic (conformal).
   b. Azimuthal (equidistant).
   c. Lambert's Equal Area.
   d. Orthographic.

It is important to appreciate that no one-map projection can be said to be better than any other. Each has special characteristics that makes it suitable for specific applications.



Azimuthal Projections

Fig. 7-1

Conformal Map Projections

In elementary terms, the conformal map projection is a projection that shows small areas in their proper shape. At any position in a conformal projection, the scale along the parallel and meridian is S.F. 1.0. This category is best suited to cadastral cartography. The mechanics of conformal map projections will be clarified later in this chapter.

Equal-Area Map Projections

The equal-area map projections are projections that maintain a constant ratio of areas, but at the expense of true land shapes. Some equal-area projections, however, are near conformal, i.e., *Alber's Conic.* With this type of projection, the scale in a north-south direction usually differs from the scale in an east-west direction. Some equal-area projections are combined with azimuthal projections, i.e. *Lambert's Equal-Area Azimuthal.* Examples of the cartographic use of equal-area projections may be found in polar maps, statistical maps, and maps of political subdivisions (of a country or continent).

Azimuthal Projections

Basically, azimuthal projections show the azimuth or direction from the central point on the projection to other points on the earth's surface. Many are similar in appearance to equal-area projections; some are categorized as equal-area projections. In an azimuthal projection, the lines radiating from the center of the projection have correct bearings. The azimuthal map projection is ideal for showing polar caps, continents, educational maps and lunar maps.

Other Map Projections

In addition to the conformal, equal-area and azimuthal map projections, there are many special purpose map projections, such as:

1. Cahill's Projection.
2. Goode's Homolosine EqualArea Projection.
3. Gall's Stereographic Projection.
4. Werner's Projection.
5. Miller's Cylindrical Projection.
6. The Gnomic Projection.
7. The Bipolar Conic Projection.
8. Van der Grinten Projection.
9. Goode's Polar Projection.
10. Denoyer's SemiElliptical Projection.
11. Fuller's Polyhedron Projection.
12. Hammer's Projection.
13. Bogg's Eumorphic Projection.

Some of the above map projections are special equal-area projections.

This discussion, thus far, has been to emphasize the broad scope of map projections. However, further details on any but conformal map projections are beyond the scope of this manual. For those interested in pursuing the subject of map projections, there are many excellent books and treatises on the subject. As earlier stated, the main requirement for plane coordinates is to maintain the spherical relationship on a plane at a scale factor as close as possible to 1.0. The *conformal map projection* meets that requirement. The two conformal map projections that are ideally suited to plane coordinates are *The Universal Transverse Mercator* (abbreviated U.T.M.) and *The Lambert Conformal.*

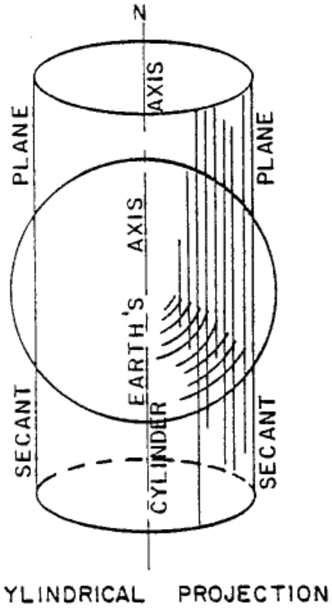
Universal Transverse Mercator

Although the Lambert Conformal map projection is the base for the Oregon Coordinate System, the Universal Transverse Mercator exists on maps of Oregon, such as the U.S.G.S. quadrangle maps. It is therefore important that the cartographer understand the elements of this map projection.

The Universal Transverse Mercator, or U.T.M., is a *cylindrical conformal projection.* It is the best known of all map projections, and it is the map projection used as the base for state plane coordinates in nineteen states.

Mercator used an imaginary cylinder as the developable base for his projection. The cylinder is used because it is round (to coincide with the earth's sphere), and it has a plane surface.[4]

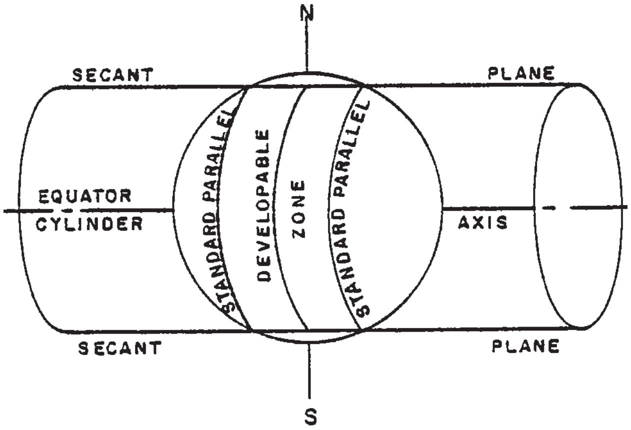
If the anterior-posterior axis of the earth is parallel with the axis of the cylinder, such a figure 7-2, then we have a *cylindrical projection.*



CYLINDRICAL PROJECTION

Figure 7-2

If, on the other hand, the anterior-posterior axis of the earth is at right angles to the axis of the cylinder such as that illustrated in figure 7-3, we have a *transverse cylindrical projection.* The axis of the U.T.M. lies in the plane of the equator; therefore, it is a transverse cylindrical projection.



TRANSVERSE CYLINDRICAL PROJECTION

Figure 7-3

In figures 7-2 and 7-3, the cylinder cuts the earth's sphere rather than lying in *tangent plane*[5] with the earth's sphere. It is therefore known as a *secant plane.* If the cylinder were in a tangent plane with the earth's sphere, there would only be one standard parallel, which would provide only a small developable zone. On the other hand, the secant plane (exaggerated in figures 7-2 and 7-3) provides two standard parallels with a wider developable zone. *Developable zones will* become clearer after reading the section on Lambert's conformal projection.

The developable zone of the U.T.M. extends in a north-south direction. It is therefore very accurate in that direction, but the scale factor varies in an east-west direction. Therefore, the U.T.M. is best suited for plane coordinates in states that extend mostly in a north-south direction. Suprisingly enough, California is on the Lambert system rather than the U.T.M.

Lambert Conformal

The Lambert conformal projection is used in thirty-one states as a base for state plane coordinates (three states use both the U.T.M. and the Lambert Conformal map projections). In contrast to the Universal Transverse Mercator's cylindrical projection, Lambert developed his projection on a conic plane. Therefore, the technical name for Lambert's projection is the Lambert Conic Conformal Projection (C.C.P.).

The Lambert C.C.P. is true to scale in an east-west direction, but its scale factor varies in a north-south direction. It is therefore best suited to states that extend mostly in an east-west direction, e.g. Oregon. The fol-

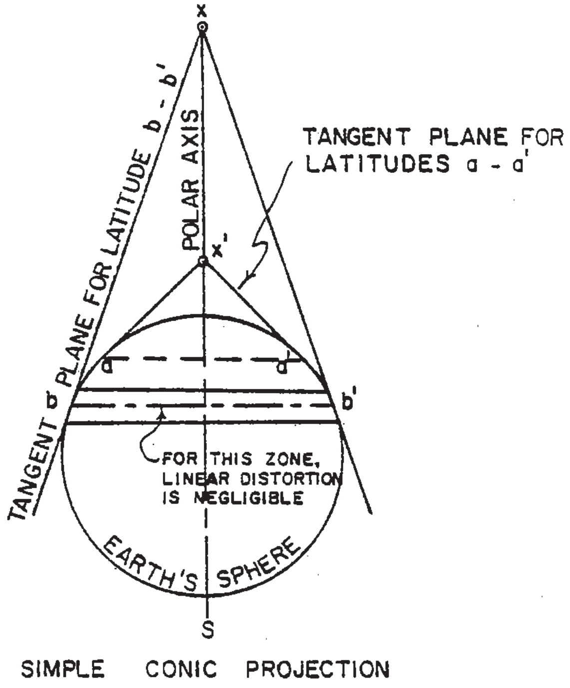


Figure 7-4

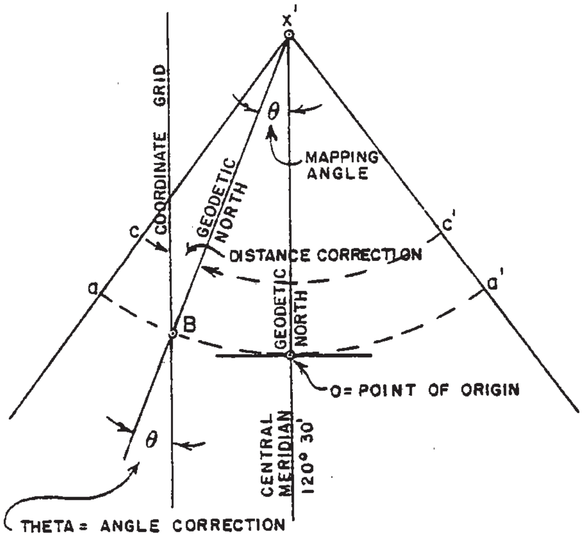
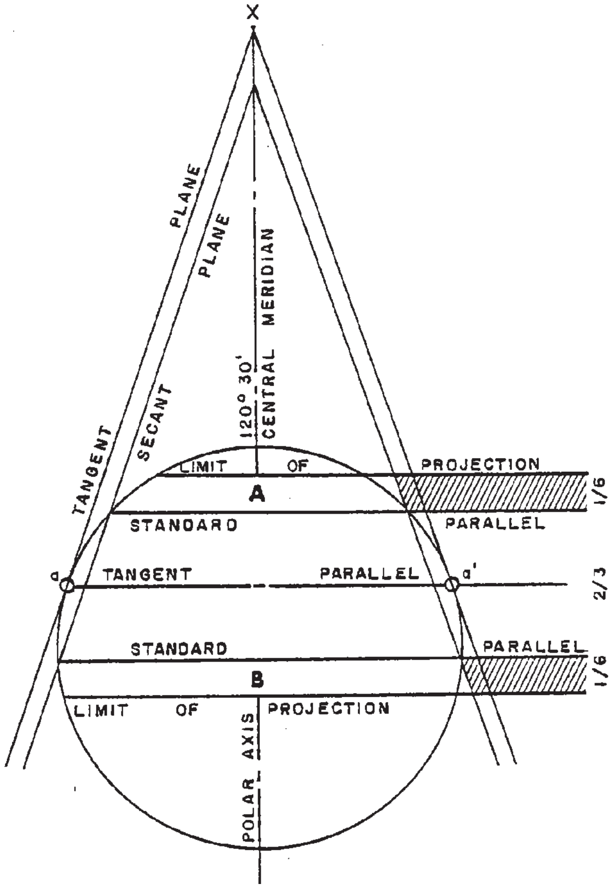


Figure 7-5



CONIC CONFORMAL PROJECTION

Figure 7-6

lowing is a detailed explanation of the Lambert Conic Conformal Projection.

Lambert's goal was to develop a plane that would conform to the surface of the earth so that rectangular coordinates could be projected on that plane. To develop tile idea, consider the diagram in figure 7-4, wherein the circle represents the earth, and triangles x^{1}-a-a^{1} and x-b-b^{1} represent two cones projected on a tangent plane to the earth.

If at any point along a parallel of latitude such as aa^{1}, tangents are drawn in the various meridian planes. These tangents, or elements, intersect the polar axis of the earth at some point (x^{1} to define the cone x^{1}-a-a^{1} In a similar manner, tangents may be drawn from the extremes of any other parallel of latitude such as b-b^{1} to define a second cone xbb^{1}. Obviously, in any small region adjacent to these parallels the surface of the earth and that of the corresponding cones are nearly coincident.

In figure 7-5 the cone x^{1}-a-a^{1} was developed. With the point of origin “0”, a system of rectangular coordinates can be superimposed over the developed plane.

At point “0” there is no distortion, either linear or angular. The central meridian points to geodetic (true) north; the grid north and geodetic north coinciding at point “0”. Along the parallel of latitude aa^{1} there is no distortion in linear distances; however, at any point such as “B” there will be angular distortion “0” (theta), since the geodetic meridian converges at the pole (x^{1}); whereas the coordinate grid lines are parallel. On any parallel of latitude, such as cc^{1}, there will be distortion in angles and correction in distance. These are the basic elements of Lambert's projection.

Thus far, the conic projection has been developed on a tangent plane; therefore, it is not a conformal projection. As pointed out in the section on the Universal Transverse Mercator, a tangent plane only provides a small developable zone. To provide a developable zone accurate enough for state plane coordinates, the conic projection must be developed on a secant plane; that is, a plane that cuts the earth's sphere at two points as illustrated in figure 7-6. Figure 7-7 illustrates the scale factors of the projection in figure 7-6.

Instead of only one parallel of latitude (such as a-a′, in figure 7-4) along which there is no distortion, there will be two standard, parallels within the limits of projection as determined by the two ends of the secant plane where angular and linear errors may be disregarded and the rectangular coordinates may be used without appreciable error. (The same basic principle of secant planes and developable zones also applies to the U.T.M.)

In areas "A" and "B", the scale factor will be greater than true. In the areas between the standard parallels the scale factor will be slightly less than true.

To relate figures 7-6 and 7-7 to the Oregon Coordinate System, examine the map of Oregon in figure 7-8.

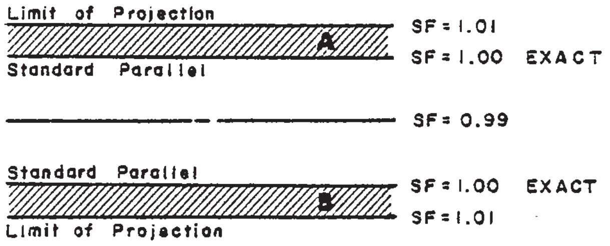


Figure 7-7

Each zone of the Oregon Coordinate System is a separate Lambert Conic Conformal projection. The south zone has standard parallels at north latitudes 42°20′ and 44°00′. The central meridian is at longitude 120°30′. Theoretically, the limits of projection would lie at north parallels 41°55′ and 44°25′; however, the U.S.C. and G.S. tables, for the south zone, begin at north latitude 41°40′ and run to north latitude 45°00′.

The scale factors at the standard parallels are 1.0 (or exact). The scale factors of the north limit of projec-

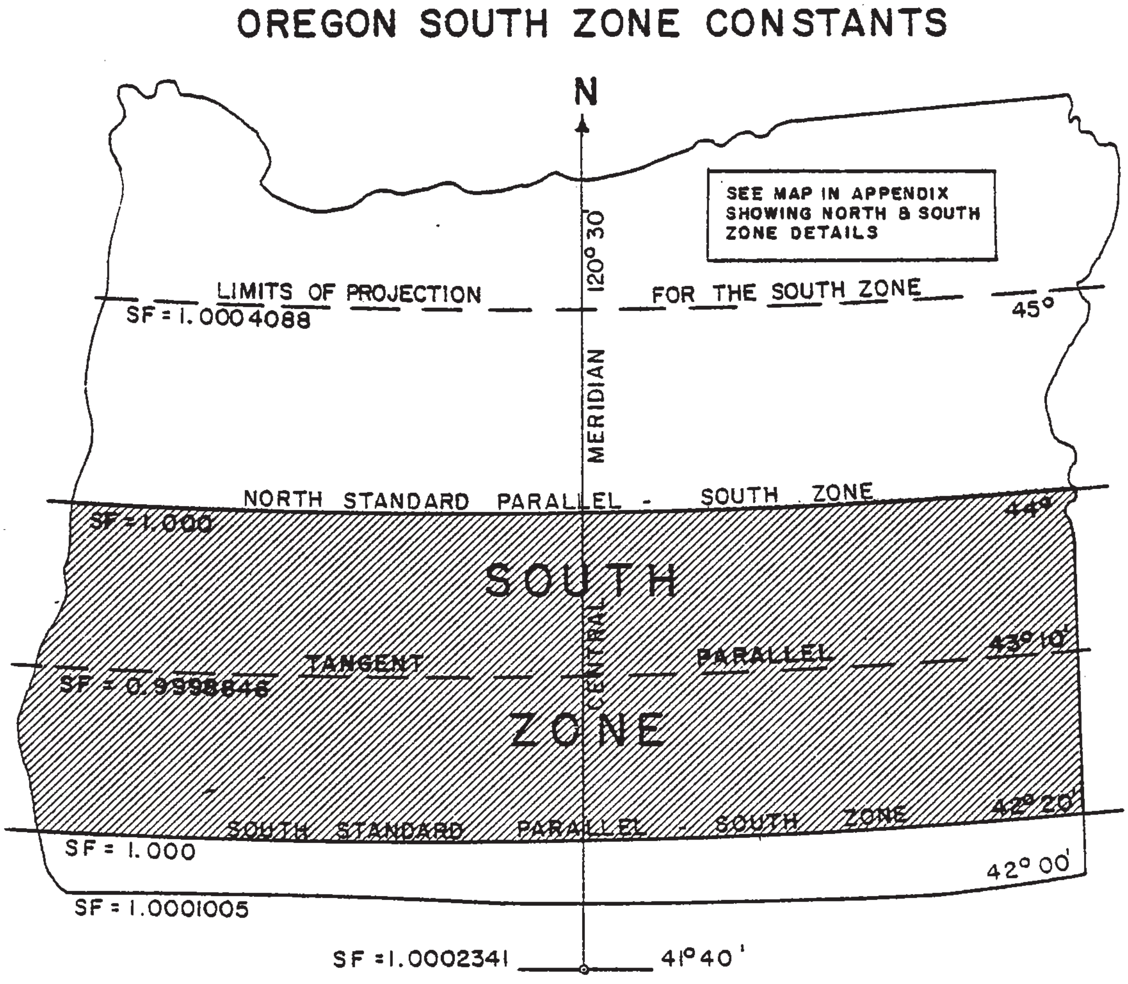


Figure 7-8

POINT OF ORIGIN – SOUTH ZONE

tion is S.F. = 1.0004088. The scale factor of any south zone factor may be found in table 17 under the column marked “Scale Expressed as a Ratio.”

CLARKE’S SPHEROID

The earth, because of its bulges and flat spots, is not a true sphere. The large deformations from the true sphere are called oblateness.

The true geometric shape of the earth is an ellipsoid. Clarke’s mathematical configuration is called Clarke’s Spheroid (ORS 93.330). A configuration of the surface of the earth that is everywhere normal to the direction of gravity and coincides with mean sea level is called the geoid.

The methods used to determine the true shape of the earth are complex and beyond the scope of this manual. The important point to remember is that any map projection not based on the true shape will not be accurate.

Clarke’s spheroid has withstood more recent computations; however, new satellite measurements will soon furnish more accurate measurements of the ellipsoid. If the new configuration is considerably different from Clark’s Spheroid, it may be used when the Oregon Coordinate System is revised in the 1980s.

COORDINATE PRINCIPLES

Rectangular coordinates, as used in higher mathematics and state plane coordinates are *cartesian coordinates.* Cartesian coordinates are two coordinates that locate a point on a coordinate plane. The coordinates of a cartesian coordinate system are measured from intersecting straight-line axes along lines parallel to the axes.

Figure 7-9 is an illustration of the important elements of cartesian coordinates.

The system of perpendicular straight lines is called the *graticule of the coordinate plane or coordinate grid.*

The horizontal lines of the coordinate grid run parallel to a line called the X-Axis. The vertical lines of the grid run parallel to a line called the Y-Axis. The X-Axis and the Y-Axis are called the *coordinate axes.* The point of intersection of the coordinate axes is called *the point of origin.* In a cartesian coordinate system the point of origin has the coordinates X=O, Y=O. As we shall see in the discussion on the Oregon Coordinate System, the point of origin can be assigned other coordinate values.

The pair of values that define a particular point in a coordinate system such as point “A” in figure 7-9 are called *coordinates of that point.* A coordinate is made up of an “X” value called the *abscissa,* and a “Y” value called the *ordinate.* In cartesian and state plane coordinate systems, the abscissa should be shown first; however, this rule is not always adhered to. *Every point* on a coordinate system has only *one set of coordinates,* and each pair of coordinates represent only *one point in the coordinate plane.*

The numbers that follow the X and Y letters of the coordinates are called *constants of that point.* In figure 7-9, point “A” has the constants 3 and 1.5.

The distance between the lines of the coordinate grid, as designated by the numbers along the axes, is called the *numerical grid scale* (abbreviated N.G.S.).

In a cartesian coordinate system the coordinate axes divide the coordinate plane into *quadrants.* In figure 7-9, X and Y coordinates in the first quadrant are *positive* or plus values. X and Y coordinates in

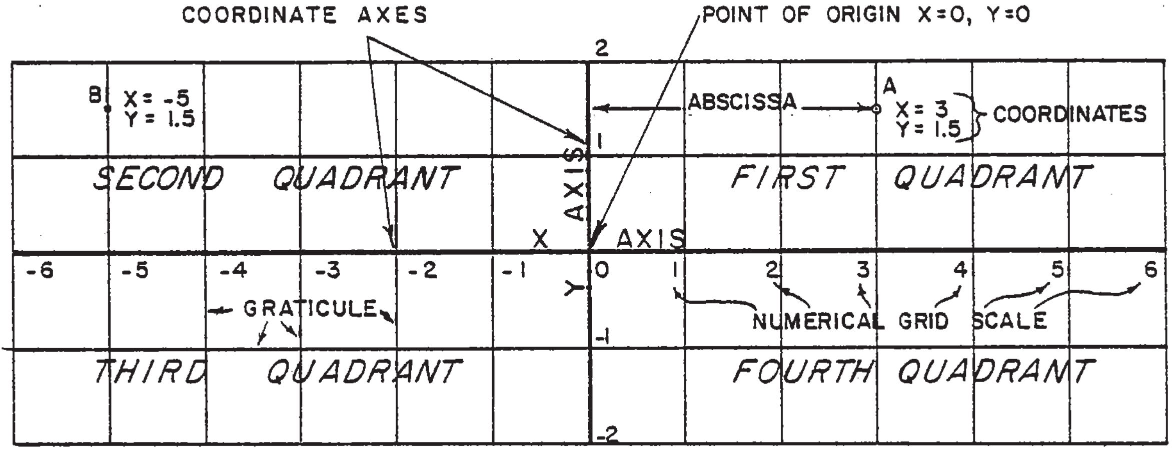


Figure 7-9

the third quadrant are *negative* or min*us* values. In the second quadrant the X values are *negative* and the Y values are *positive.* In the fourth quadrant the X values are *positive* and the Y values are *negative.* Negative constants are to be preceded by a minus sign (–). Positive constants are not preceded by a sign (as in mathematics).

One of the major differences between the Oregon Coordinate System and regular cartesian coordinate system is that the Oregon Coordinate System has no negative values.

To plot a coordinate point, the abscissa is measured from the y-axis and the ordinate from the x-axis. The intersection of the two measurements is the *coordinate point.*

The beauty of plotting by coordinates is that all measurements are made in vertical and horizontal directions; there is no need to plot lines by bearings. Another positive feature is that measurements are made from the nearest grid lines; therefore, distances can be plotted by only making one measurement in each direction.

THE OREGON COORDINATE SYSTEM

All of the elements of a cartesian coordinate system, except for negative values, exist in the Oregon Coordinate System.

To develop the idea of the Oregon Coordinate System, consider the pair of lines in figure 7-10. The y-axis of the system is called the central meridian. It is the meridian used in both the north and south zones. The central meridian is located at longitude 120°30’.

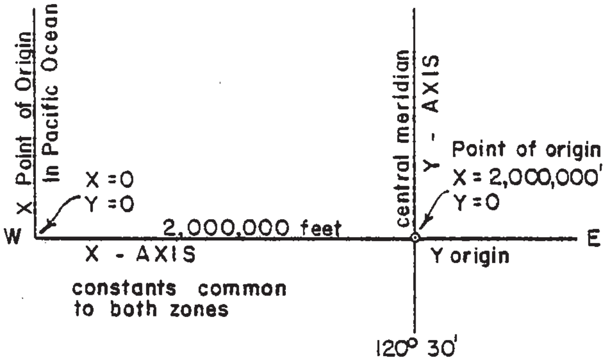


Figure 7-10

To eliminate negative values the x point of origin (zero) is in the Pacific Ocean and each Y point of origin lies south of, and out of the pertinent zone. Therefore, each zone can be said to lie in the NE (or first) quadrant of a cartesian coordinate system, where all values are positive. All coordinates then are either measured north or east. The coordinate grids, however, are measured east and west of the central meridian, where x = 2,000,000 feet.

All northerly coordinate grid lines are grid north and are parallel with the central meridian. The only grid line that runs to geodetic north in the entire system is the central meridian (120°30’). All horizontal grid lines are parallel with the X-Axis and are at right angles to grid north.

Figure 7-11 represents a coordinate grid with a numerical grid scale of 1,000 feet. This is the N.G.S. for a 1” 100 scale cadastral map. The zone is the North Zone.

The point of origin and the XY axes of the Oregon Coordinate System He far to the east and south of the map; however, we still need an XY axis. Because all measurements will be made in an easterly direction, a reference axis is established with a reference point of origin at point 0. The coordinates for point 0 are X = 1,300,000 and Y = 566,000; therefore, point 0 is 700,000 feet west of the central meridian and 566,000 feet north of the point of origin of the zone.

This grid is constructed by measuring grid points at 1,000-foot intervals north and east of point 0, and by drawing a rectangular grid network from these points. To locate a coordinate point on this grid, for example, X 1,303,175 and Y 568,201, locate the grid intersection nearest to the given coordinates. In this case point A at X 1,303,000, Y 568,000. Next measure 175 feet grid east along the grid parallel Y = 568,000. Then running parallel with the y-axis, measure 201 feet grid north to point B, which is the given coordinate point X 1,303,175, Y 568,201.

The rule for labeling coordinates is to use the letters X and Y added to the constants, with the X value (or abscissa) written above the Y value (the ordinate) as shown at point B in figure 7-11. The Highway Division of the Oregon State Department of Transportation uses the letters N (for north) and E (for east) to identify the X, Y coordinates. The letter N designates the Y coordinate and the letter E designates the X coordinate. The Highway Division also labels the ordinate before the abscissa, as shown at point C in figure 7-11. The B.P.A. uses the standard XY identification.

Geodetic north can be converted from grid north by using simple trigonometric formulas and the projection tables in the addendum. The tables may also be used to establish geodetic coordinates (latitude and longitude). The procedures for determining theta (0) and geodetic coordinates may be found in Chapter 9 on Computations.

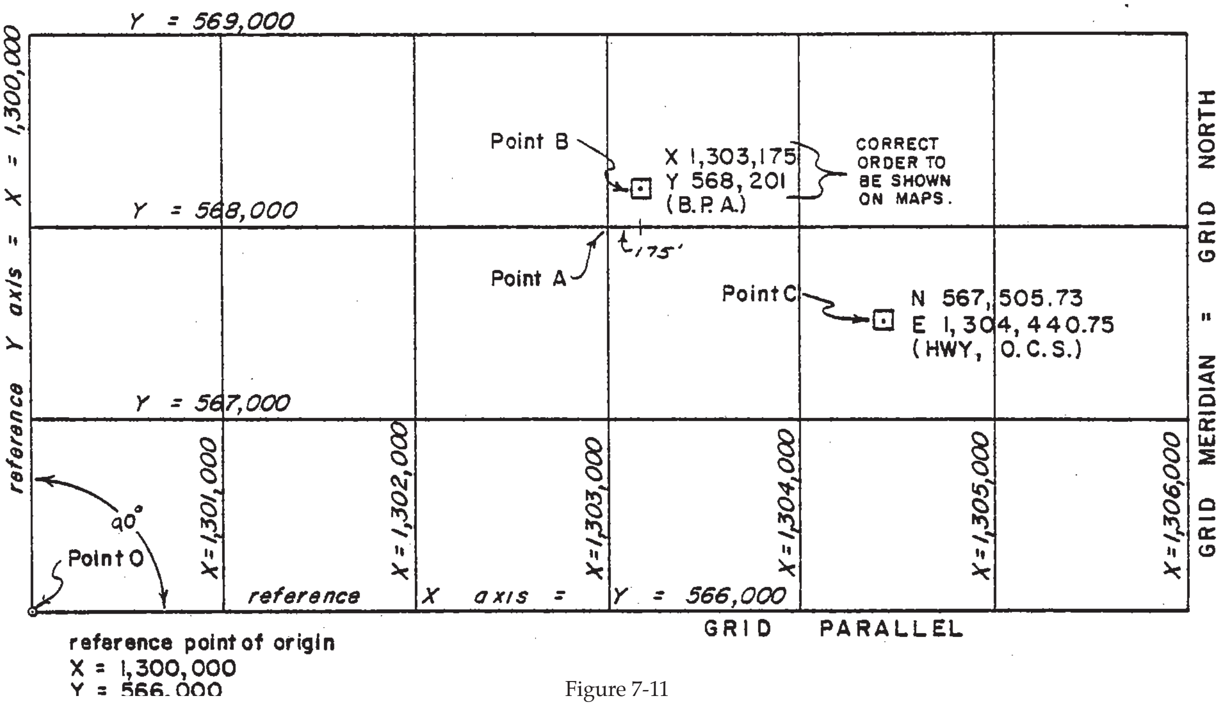


Figure 7-11

When converting grid bearings to geodetic bearings, or geodetic bearings to true bearings, theta must be used carefully. The following diagrams indicate the sign relationships between angle 0 and quadrant bearings. The formulas for converting bearings are shown in each quadrant. (Fig. 7-12)

Figure 7-12 applies to quadrant bearings (N 45°30′ E is a quadrant bearing in the NE quadrant). When azimuths are used, all angles are measured clockwise from south and approximate values of the geodetic (true) azimuth are determined by the formulas:

$$\text{Grid} - \theta = \text{Geodetic Az (W of } 120°30'\text{)}$$
$$\text{Grid} + \theta = \text{Geodetic Az (E of } 120°30'\text{)}$$

The above formulas are illustrated in figure 7-13.

The geodetic azimuth of a line is its true azimuth. The difference between grid and geodetic azimuth of any line passing through a single point is nearly constant. It is represented by theta, as shown opposite the longitudes in tables 16 and 18.

The Rectangular Grid

It would be logical to assume that establishment of the Oregon Coordinate System would mean that the grid intersections are located and monumented on the ground. However, there is an infinite number of

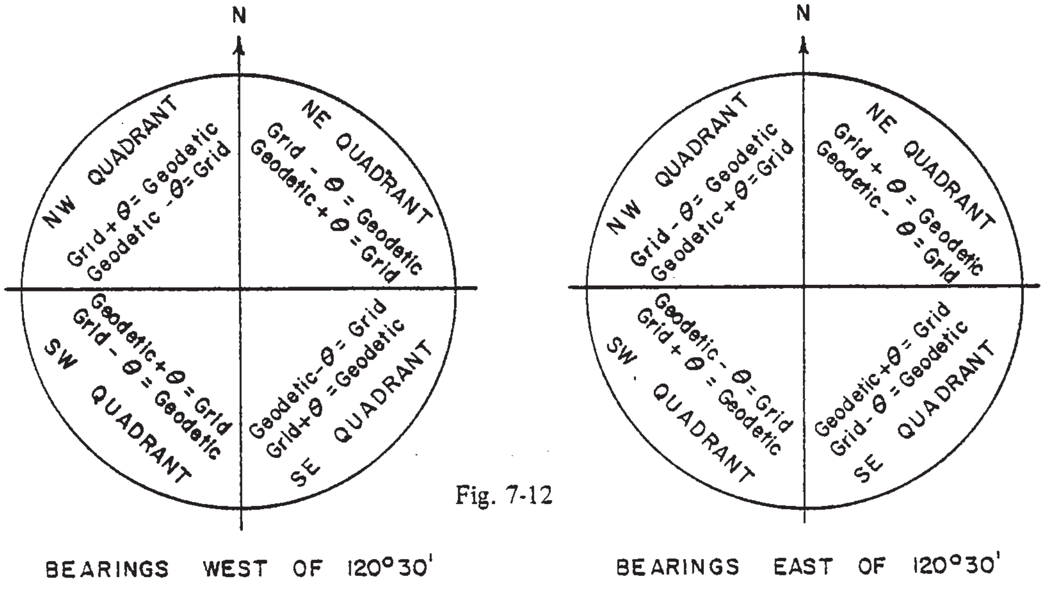


Fig. 7-12

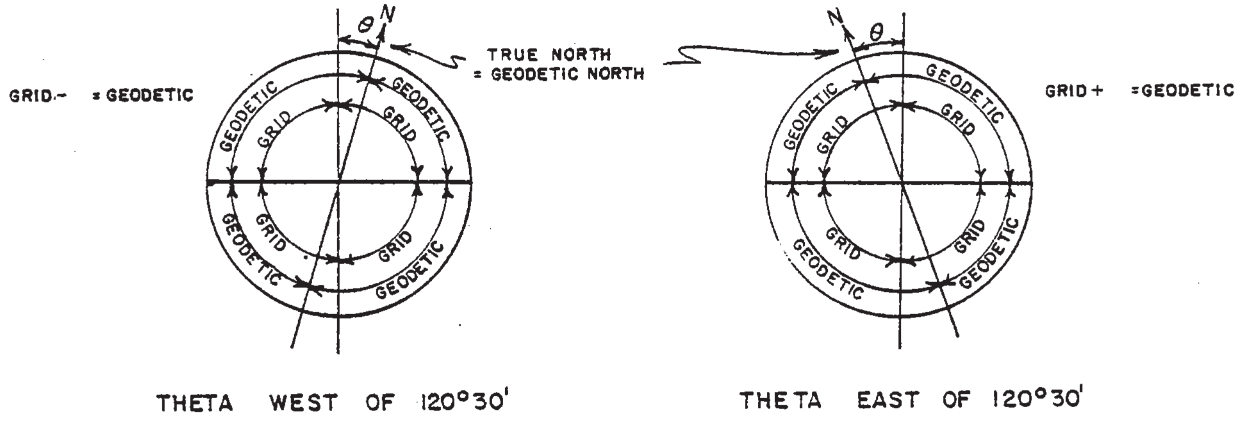


Figure 7-13

N.G.S.'s and an infinite number of grids; therefore, it would be impossible to monument a grid with a numerical grid scale satisfactory for all purposes. Such a project would be financially impossible. Therefore, the grid is not monumented.

Instead of attempting to monument a grid, triangulation networks have been established and monumented. Each triangulation station is tied to the Oregon Coordinate Grid and the geodetic grid. These triangulation stations are used by surveyors and cartographers to tie comers, monuments and lines to the coordinate system.

The U.S.C. & G.S. has established a national system of triangulation which provides stations for nearly every locality; and it allows for expansion of surveys over great distances, while still providing correct azimuths throughout the survey. By checking other triangulation points, the surveyor can avoid closing the survey to the beginning point of the survey. Many triangulation monuments have been set by organizations other than the U.S.C. & G.S., e.g. the Oregon State Department of Transportation, U.S. Army Corp. of Engineers, the U.S.G.S. and U.S. Forest Service.

For applying coordinates to cadastral cartography, see Chapter 11 on "Basic Map Control."

LOCAL COORDINATES

Often surveyors establish coordinate systems that are not oriented to the Oregon Coordinate System. These coordinate systems are called local *coordinate systems.* Cartographers must always study each survey to determine whether or not the coordinate system is local or on the Oregon *Coordinate System.*

If a local coordinate system is used, the methods for plotting are the same as with the Oregon Coordinate System; however, it is important to try to establish a tie to the Oregon Coordinate System so that the local coordinates can be converted to that system. Some local coordinates are difficult to plot because the local grid was not projected as a conformal map projection; however, the scale factor is usually so close to 1.00 that the coordinates can be made to fit control.

If difficulty is experienced with a local coordinate system, it is best to plot the survey information by *direction methods* (bearings, angles and distances).

Most surveys made today will be on the Oregon Coordinate System rather than local coordinate systems.

ENDNOTES

[1] ORS 93.320.

[2] ORS 93.320 to 93.380.

[3] A plane surface is a flat surface.

[4] We think of a plane surface as being flat, which a cylinder is not. But when unrolled, a cylinder becomes a plane surface.

[5] The plane surface in fugure 7-1 is lying in a tangent plane with the earth's surface.