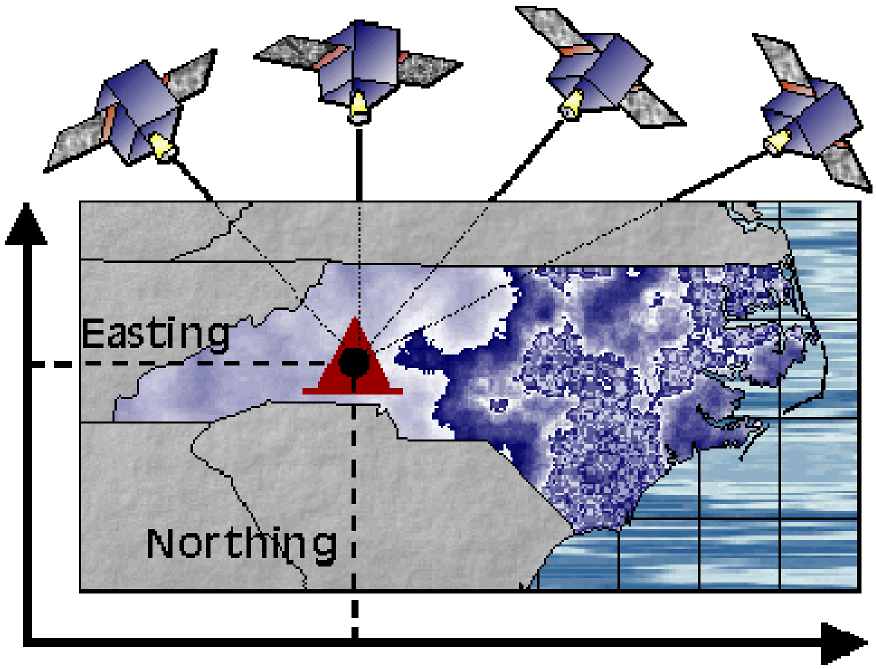
DEVELOPMENT & APPLICATION OF THE STATE COORDINATE SYSTEM



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North Carolina Geodetic Survey
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STATE OF NORTH CAROLINA
Beverly Eaves Perdue, Governor

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First in Geodetic Surveys

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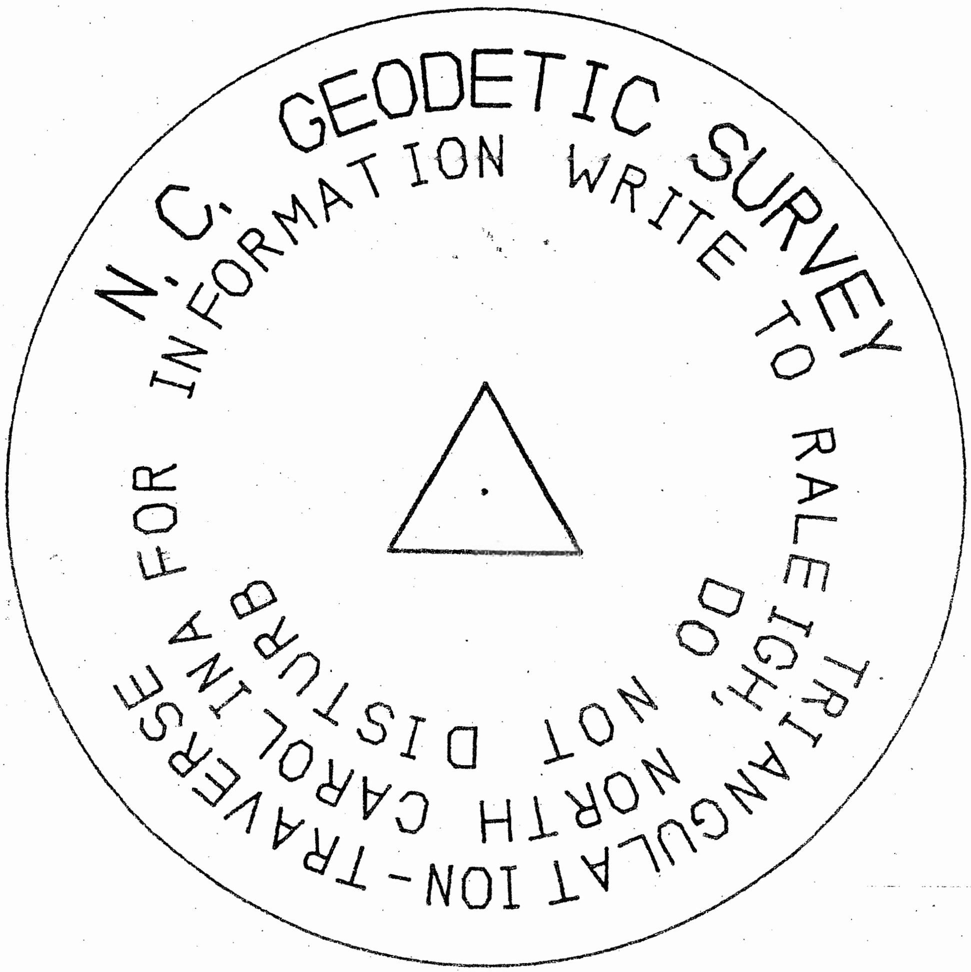
NORTH CAROLINA GEODETIC SURVEY



DEVELOPMENT AND APPLICATION

OF THE

STATE COORDINATE SYSTEM

NC GEODETIC SURVEY

DEVELOPMENT AND APPLICATION
OF THE
STATE COORDINATE SYSTEM

INTRODUCTION

The Geodetic Survey Section is the official representative of the Office of State Planning in the field of Geodesy. The general purpose of the Section is to establish precisely located monuments on the North Carolina Grid System and Bench Marks referenced to a vertical datum (NGVD 1929 and NAVD 1988).

This manual has been prepared in the hope that all who are interested in the North Carolina Grid System - land surveyors, engineers, planners, instructors, students - will become familiar with the computations involved. State plane coordinates are really nothing more than an adaptation of the latitude and departure practices which have been in use for centuries. Most of the computation procedures are arithmetical, not mathematical.

The information in this booklet can be broken roughly into four sections. (1) In the first part a short history is presented and general development and application of the system is discussed. Much of the information in this section is composed of excerpts from the papers listed in the bibliography. (2) The second part is an example of the computations necessary to coordinate a typical small property survey. (3) The new vertical datum (NAVD 88). (4) The final part consists of the Projection Tables, Magnetic Declination Tables and inserts.

We hope the discussion and examples in this paper are presented in such a manner that you will have no difficulty in using the State Coordinate System in your profession and thereby enjoy the many advantages it offers. Should you have any questions, please always feel free to contact the North Carolina Geodetic Survey by either of the following methods:

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DEVELOPMENT AND APPLICATION OF THE STATE COORDINATE SYSTEM

The chief purpose of this book is to explain the various degrees of development and practical application of the State Coordinate System.

A brief history of the development of the system could be of interest to you. Rectangular coordinate systems are probably as old as the surveying profession. The Romans employed such systems in the layouts of their cities and military encampments. In the United States, public land surveys were defined in rectangular coordinates. In 1932, O.B. Bestor and George F. Syme, two North Carolina Highway Engineers, initiated the idea of a State grid system which they hoped would eliminate the large amount of computations needed to make accurate surveys of large areas. They presented their idea to Dr. O.S. Adams of the U.S. Coast and Geodetic Survey, who undertook a feasibility study for a State plane coordinate system utilizing the geodetic data derived from the National Network. As a result of his studies, the Lambert conformal conic projection was developed for those States with greatest extent in the East - West direction.

After the system for North Carolina had been established, a study was made to select a projection suitable for states with greatest extent in a North - South direction. The transverse Mercator projection was chosen for these states. Projection tables have now been computed for all the states.

Projections adopted for the State Coordinate Systems are conformal. That is, the scale at any particular point is the same in any direction and small figures on the surface of a sphere retain their original forms on the map. On the Lambert projection, the basic line is a parallel of latitude and the scale changes in a North - South direction. The transverse Mercator projection is quite similar mathematically to the Lambert except the basic line is a meridian of longitude instead of a parallel of latitude and the scale changes in an East- West direction.

In setting up the State systems, it was necessary to decide on the minimum scale ratio to be tolerated. A curved surface cannot be projected on a plane without some distortion, but this distortion can be kept small by limiting the width of the zone. In the case of the Lambert projection, the zone can be any length in an East- West direction, and in the case of the transverse Mercator any length in a North - South direction. By keeping the width of the zones under 158 miles, and reducing the scale along the basic line, the scale ratio can be kept within one part in 10,000, an amount that can be neglected in most survey operations.

The scale ratio of one part in 10,000 was adopted as a maximum, and in most of the State coördinate zones the scale factor does not exceed this figure. Except in South Brunswick County, where it approaches one part in 5,000, the scale factor in North Carolina is never less than one part in 7,900.

State plane coordinates are available for all stations in the horizontal control network of the United States. The establishment of State plane coordinate systems not only simplifies the use of the control data, but it gives a permanent general grid useful for many purposes. County boundaries, property boundaries, intersection of roads and streets, and any prominent feature of a region can be accurately located with definite Northing (y) and Easting (x) coordinates. Any point which is referenced to the national control network could be relocated, if the marker should be destroyed. This is a very important characteristic and one which should be given due consideration by all surveyors and engineers. Until 1987, the N.C. State Plane Coordinate System was based on the North American Datum of 1927.

In 1978, the National Geodetic Survey (NGS) began the process of developing the data needed to perform a complete adjustment of the National Survey network. In 1987 NAD 83 was officially adopted as the official survey datum in N.C. (see GS 102).

The last total adjustment was done in 1927 (work was actually completed in 1930, but the adjustment was labeled NAD 27), since that adjustment, the technology has advanced rapidly (EDM's, GPS) and it became obvious to NGS that a new adjustment was needed.

Some of the weaknesses of the NAD 27 adjustment were:

1. The old adjustment (1901) did not include the Atlantic Seaboard control.

2. Length control was significantly deficient for the 1927 adjustment.

3. A number of Azimuths (Polaris observations) used in 1927 have been found to be of inferior accuracy.

4. The control in Alaska was connected to the datum during World War II by means of a single area of triangulation along the Alaska Highway.

5. In some areas of North America, relative horizontal tectonic (ground) movement as great as 5 cm per year has been observed.

The goals of the new adjustment were to:

1. Remove distortions in the network
2. Develop a new datum that is:
    a. suited for worldwide use, not just for North America
    b. Earth-centered

With the above criteria in mind, the GRS 80 (Geodetic Reference System) ellipsoid was developed. NAD 27 was based on Clark's ellipsoid of 1866, which had as its datum point a control station in Kansas named Meades Ranch. Clark's Ellipsoid worked best in North America. GRS 80 does not have a datum point, but instead is an earth-centered ellipsoid that can be used worldwide.

A comparison of the two ellipsoids shows us that: (Figure 1)

Clark Ellipsoid of 1866	GRS 80
a = 6,378,206.4 meters	a = 6,378,137 meters
b = 6,356,583.8 meters	b = 6,356,752.314140347 meters
f = 1/294.9786982	f = 1/298.2572221
Datum Point: Triangulation station Meades Ranch	Datum Point: None (Mass center of the Earth)

In addition to changing ellipsoids, other changes include all values being published in metric values and all azimuths oriented from North. Published Azimuths in the NAD 27 adjustment were oriented from South.

It should be noted if you convert the Metric values to English units (feet) in North Carolina, the official conversion (GS 102 1.1) is the U.S. Survey foot (1 meter = 39.37 inches or 1 meter = 3.2808333333........ feet). The use of the wrong (International foot) conversion factor will create an error up to approximately 4 feet in the coordinate value. Note that the states adjoining North Carolina have in some cases adapted a different feet/meters conversion.

South Carolina = International Foot
Virginia = US Survey Foot (Note: Some counties in the state use the International Foot Conversion)
Tennessee = US Survey Foot

GS 102-1.1

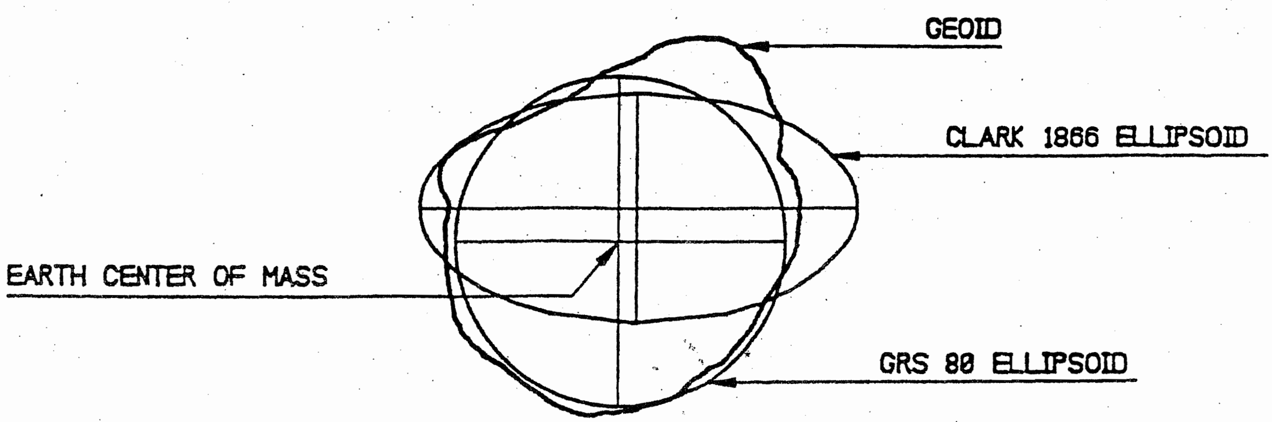
In North Carolina the official conversion for

feet/meter = US Survey Foot

1 meter = 3.2808333333.......ft
1 meter = 39.37 inches exactly
NOTE: <u>DO NOT ROUND OFF</u> this conversion, use at least 9 significant figures. LARGE errors can be introduced if you round off the conversion.

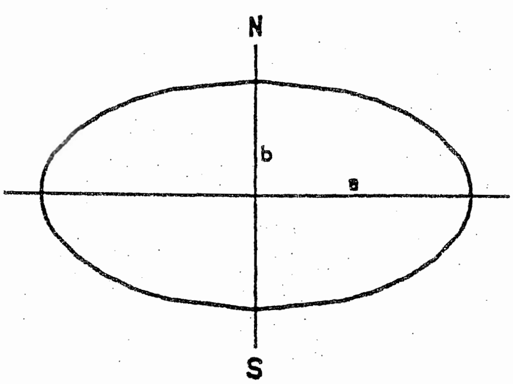
THE GEOID AND TWO ELLIPSOIDS

(FIG. I)



NAD PROJECT

THE ELLIPSOID



a : SEMI MAJOR AXIS

b : SEMI MINOR AXIS

f : $\frac{a - b}{a}$: FLATTENING

THE DATUM

NAME: NAD 83

ELLIPSOID: GRS 80 (GEOCENTRIC)

a = 6378137. METERS

$$f = \frac{1}{298.257222l}$$

Comparison of North American Datum of 1927
and North American Datum of 1983

	NAD 27	NAD 83
Reference Ellipsoid	Clarke Ellipsoid of 1866	GRS 80
Datum Point	Triangulation Station Meades Ranch	None (Mass Center of Earth)
Longitude Origin	Greenwich Meridian (BIH Zero Meridian)	Greenwich Meridian (BIH Zero Meridian)
Azimuth Orientation	From South	From North
Adjustment	25,000 points Several Hundred Baselines Several Hundred Astro Azimuths	250,000 points App. 30,000 EDM Baselines 5,000 Astro Azimuths Doppler Point Positions Very Long Baseline Interferometry
Best Fitting	North America	World-Wide
Geodetic Elements	Latitude Longitude Azimuth Elevation (Only certain points)	Latitude Longitude Azimuth Elevation (All points, plus accuracy statement: scaled, trigometric bench mark)
Information Published on State Plane Coordinate Data Sheets	x coordinate y coordinate Grid Azimuth Mapping Angle (Theta)	Easting Northing Grid Azimuth Mapping Angle (Theta) Scale Factor
New Elements		Geoid Height (See page 21 and 22)
Units	Feet	Meters
Data Format	Paper Copy	Paper Copy Microfilm (from NGS) Microfiche (from NGS) Digital Data Base (In N.C. NCGS Database w/software)

As noted in the previous table, there are significant differences between NAD 27 and NAD 83. The Geodetic Zone constants (Central Meridian, Standard Parallels and Latitude Origin) for North Carolina did not change, and N.C. retained its single Lambert zone.

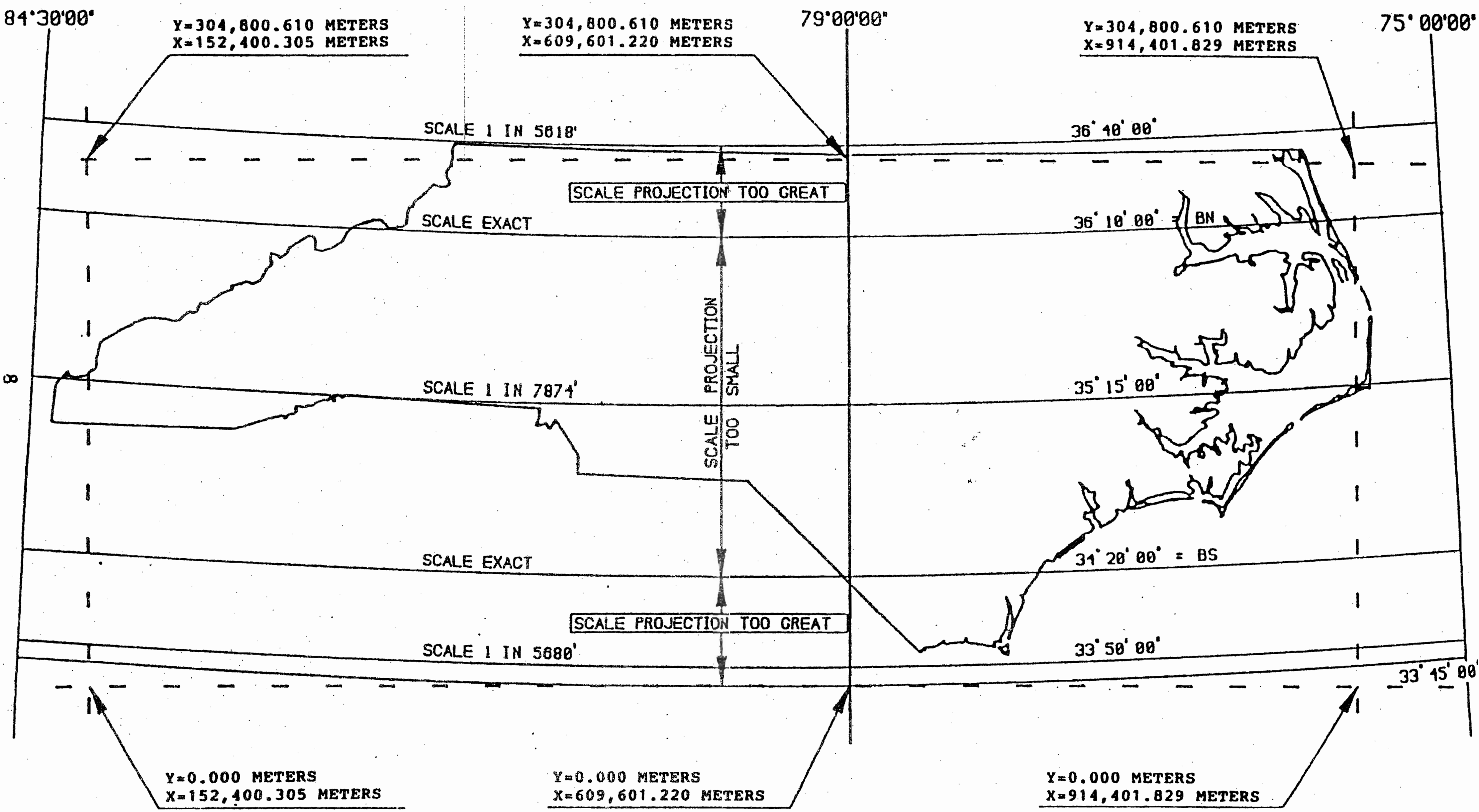
North Carolina Single Zone

	NAD 27	**NAD 83**
Projection	Lambert	Lambert
Latitude of Origin	33 degrees 45'	33 degrees 45'
Central Meridian	79 degrees 00'	79 degrees 00'
Standard Parallel 1	34 degrees 20'	34 degrees 20'
Standard Parallel 2	36 degrees 10'	36 degrees 10'
False Easting	2,000,000.00 Feet	609,601.22 Meters (2,000,000.00 Feet)
False Northing	0.00 Feet	0.00 Meters

As you can see on page 6, there have been some significant changes between NAD 27 and NAD 83, but the basic computations to connect to the N.C. coordinate system remain the same. See pages 31-40 for a step by step worksheet of a typical property survey that has been tied to grid monuments.

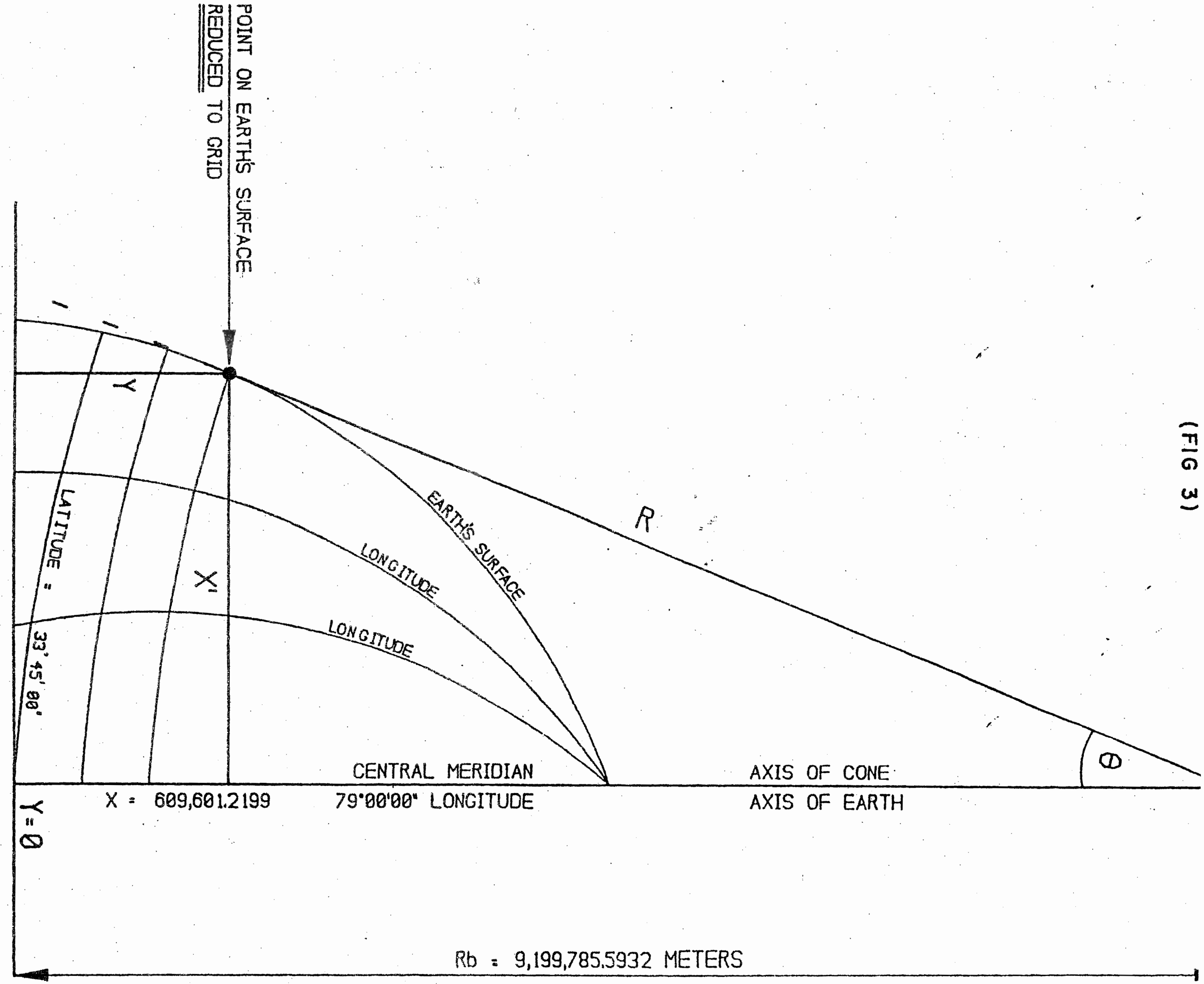
If you are interested in more indepth information concerning NAD 83, a list of NGS literature is listed on page 79 of this booklet.

(FIG 2)



BS = SOUTHERN STANDARD PARALLEL
BN = NORTHERN STANDARD PARALLEL

FOR MORE INFORMATION SEE PAGE 47



POINT ON EARTH'S SURFACE
REDUCED TO GRID
Y
X'
R
EARTH'S SURFACE
LONGITUDE
LONGITUDE
LATITUDE = 33°45'00"
CENTRAL MERIDIAN
AXIS OF CONE
AXIS OF EARTH
X = 609,601.2199
79°00'00" LONGITUDE
Y=0
θ
Rb = 9,199,785.5932 METERS

(FIG 3)

North Carolina is one of about 35 states which has adopted laws (GS 47-30 and GS 102), establishing the State Plane Coordinate System as a basis for property surveys. Since the laws do not contain mandatory clauses, the use of the State system has been limited to areas where control is readily available. In areas where horizontal control points are available, the State system should be used to supplement the description of land surveys. The State plane coordinates then provide means for accurate recovery of a boundary point should the monument become completely destroyed. Once a strong control network has been established in an area and the property corners are tied to this control, there is a no more precise or positive way of relocating the lost corners of the coordinate method.

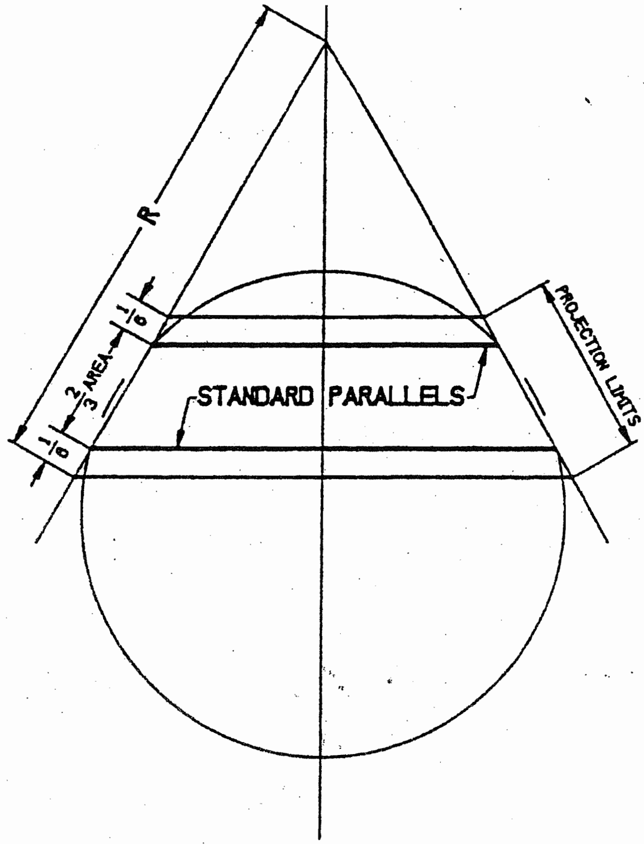
Many Federal and State agencies have made extensive use of the State systems. One of the most widespread applications of the State systems was that of the Tennessee Valley Authority. The TVA employed several State coordinate systems as the basis for computing and plotting practically every survey and map produced by that organization. Also, the N.C. Land Records Management program has based all of its 100 county maps on the N.C. Coordinate system.

In more recent years the State systems have been used extensively in connection with the interstate Highway Program. The National Geodetic Survey has cooperated with other states in the establishment of geodetic markers along many miles of interstate routes. Most of this was in the form of traverse surveys, combined with triangulation to connect to established control. All surveys have been reduced to the State Coordinate Systems.

A state-wide system of coordinates has many advantages over several local systems. When there are several local systems in use in a state, it often causes a great deal of confusion and difficulty in transforming coordinates from one system to another. Another advantage of the state system is the simplicity with which the scale in any part of the grid may be determined over a wide area and then applied to the survey values. One of the important characteristics is the small number of separate grids required to cover most states. North Carolina and several other states are fortunate to be covered by a single grid.

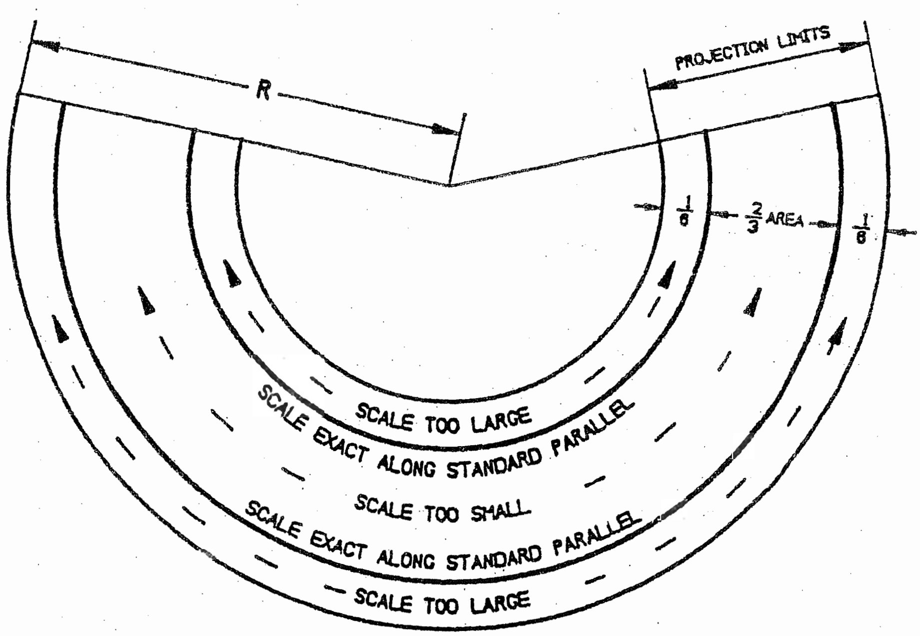
Since North Carolina is based on the Lambert Projection, discussion and explanation of example computations will be limited to that system.

The Lambert conformal conic projection with two standard parallels can be looked upon as a cone - the axis of which coincides with the axis of the earth and which intersects the earth. This cone intersecting the sphere is shown on page 12. The meridians on the earth are represented by the elements of the cone and they intersect in a point at the apex of the cone. When the conical surface is split along an element, it can be unrolled in a plane and the parallels become arcs of concentric circles. The developed cone in a plane is shown on page 12.



LAMBERT CONFORMAL CONIC PROJECTION SPHERE AND INTERSECTING CONE

(FIG 4)



LAMBERT CONFORMAL CONIC PROJECTION DEVELOPED CONE IN A PLANE

Page 8 shows the relation between the Latitudes and the Longitudes, State Coordinates and scale factors for the State of North Carolina. In the State Coordinate System the values of the Easting increases to the eastward and the Northing increases to the northward. An arbitrary Easting of 609601.22 meters was given to all points along the Central Meridian (79 degree Longitude) so that all Easting within the system are positive. The zero Northing was given to the point on the 79 Meridian at the 33° - 45'- 00" Latitude, a point further south than any position of the State. This enables all points within the State to have positive Northing coordinates.

Page 15 shows the relation between True North (Longitude lines solid) and Grid North (Grid Azimuth lines dotted). The sketch is not drawn to scale, but just illustrates the relation. You will note at the Central Meridian (79° - 00'-00") that the Geodetic Azimuth (or True North) and the Grid Azimuth are equal. The angle formed between the geodetic (Longitude solid lines) and the Grid meridians (dashed lines) is the Theta angle, often referred to as the mapping angle, or convergence angle. The Theta angle is positive to the east of the Central Meridian and negative to the west of the Central Meridian. This (+) or (-) angle sign is very important in your mathematical calculations <u>when</u> it is used. The rule is, Grid Azimuth equals Geodetic (True) Azimuth (-) Θ + 2nd Term.
On page 14 an example of computing a theta angle is shown. The ratio of theta (mapping angle) to the longitude difference from the Central Meridian equals 0.577170255241; or, in simple terms, one second of Longitude equals 0.577170255241" of Theta angle. Therefore to compute a Theta angle from the Central Meridian, simply subtract your longitude from the Central Meridian (79° 00' 00").

Multiply the difference by 0.577170255241 to obtain the theta angle. If you are east of the central meridian the theta angle will be positive, if you are west of the central meridian the theta angle will be negative.

Central Meridian = 79° 00' 00"

0.577170255241 = ratio of theta (mapping angle) to the longitude difference from the Central Meridian (in N.C.)

(Central Meridian - Longitude) (0.577170255241) = theta

Example

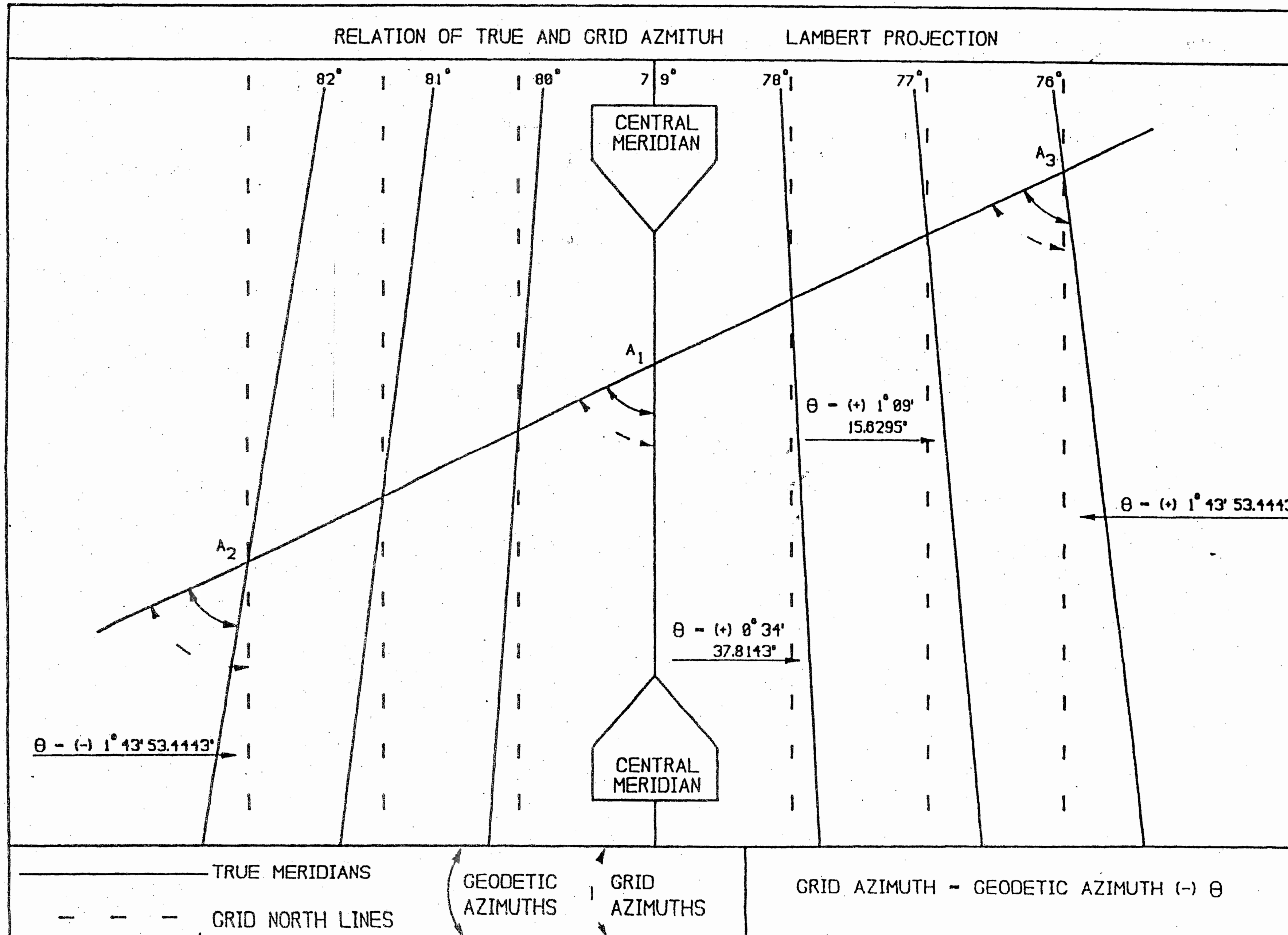
You are located at Latitude = 35° 19' 43.46521"
Longitude = 79° 56' 04.82641"

[(79° 00' 00") - (79° 56' 04.82641")] 0.577170255241 = theta

(- 0° 56' 04.82641") 0.577170255241 = theta

<u>Theta = (- 0° 32' 22.08")</u>

(FIG 5)


RELATION OF TRUE AND GRID AZMITUH LAMBERT PROJECTION
82°
81°
80°
79°
78°
77°
76°
CENTRAL MERIDIAN
A1
A2
A3
θ = (+) 1° 09' 15.8295"
θ = (+) 1° 43' 53.4443"
θ = (+) 0° 34' 37.8143"
θ = (-) 1° 43' 53.4443"
CENTRAL MERIDIAN
TRUE MERIDIANS
GRID NORTH LINES
GEODETIC AZIMUTHS
GRID AZIMUTHS
GRID AZIMUTH = GEODETIC AZIMUTH (-) θ

The "second term" in the formula is a very minor correction which may be neglected in most surveys spanning 10 miles or less (lines projecting east-west are most affected). The second term should be considered when true First and Second Order/Class 1 grid control is being established. Although the correction for individual traverse sections up to a mile long (on an east-west direction) may only yield tenths of a second, the values accumulate as the traverse expands. However, on the other hand, if the total traverse continues throughout in one direction, an adjustment for position closure will likely compensate for the neglecting of this correction.

The second term correction is a flattening value to apply to individual observed (geodetic) directions and/or azimuths to produce grid.

The formula:

1. NAD 27 coordinates are in feet;
   $$\text{2nd term} = 2.361\ (10^{-10})\ (X_2 - X_1) \left[Y_1 - Y_0\ (+)\ \frac{Y_2 - Y_1}{3} \right]$$

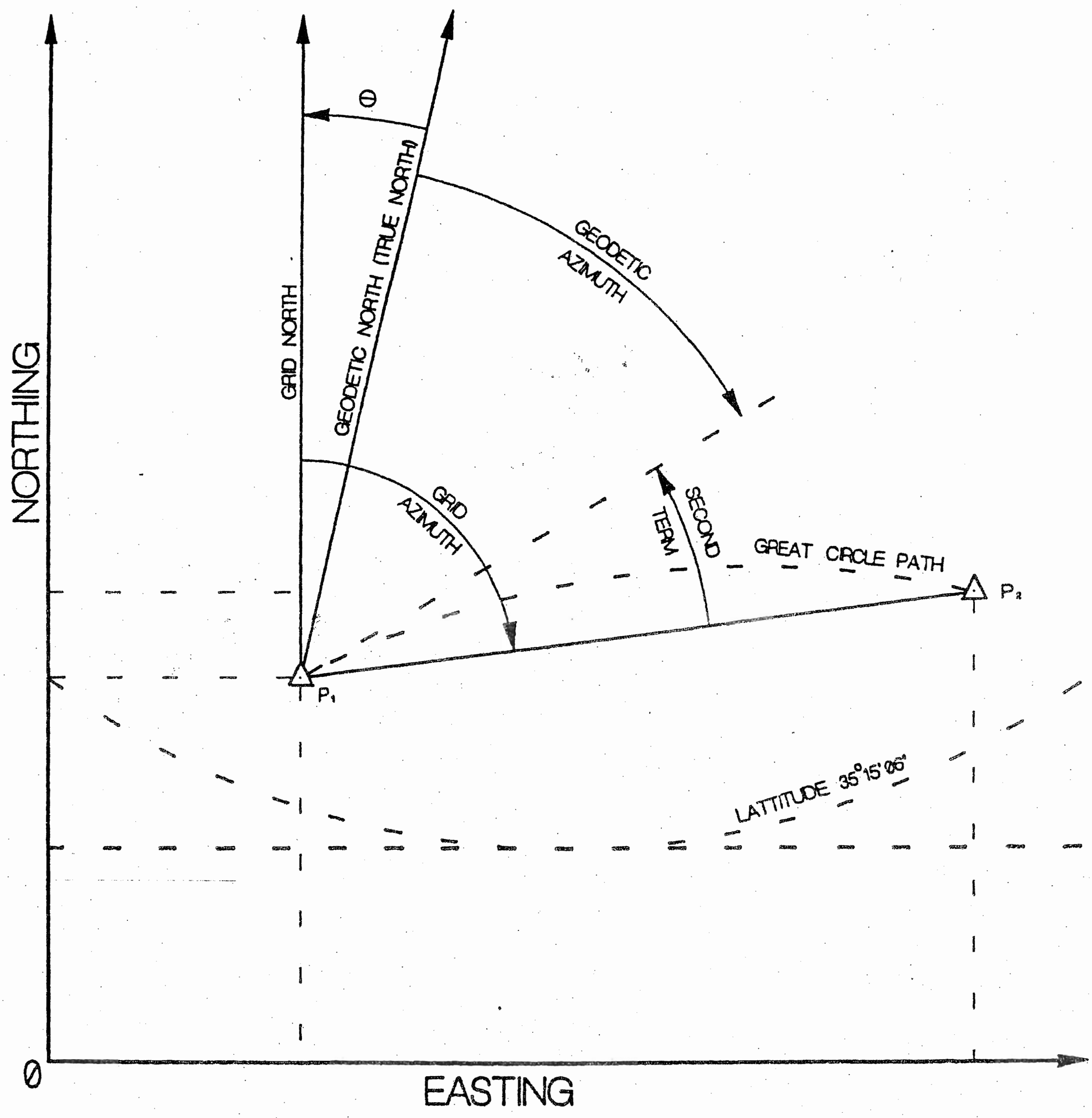
2. NAD 83 coordinates are in meters;
   $$\text{2nd term} = 25.4135\ (10^{-10})\ (X_2 - X_1) \left[Y_1 - Y_0\ (+)\ \frac{Y_2 - Y_1}{3} \right]$$

will yield second terms to 95% or greater accuracy, where X = east coordinates, Y = north coordinates, and Y0 = 546552 feet for NAD 27 and 166580 meters for NAD 83.

Y0 is the northing coordinate of latitude 35° 15' 06" at the 79th degree Meridian.

The second term is best visualized by drawing a geodetic (curved) line over or under a straight (grid) line between two points, the curved line is always concave to the Y0 line, and the second term is the angle between the curved and straight line at point # 1. The second term as computed above would be the correction at point one, on the direction or azimuth to point two. Therefore to correct angles in this way, a second term would have to be computed and applied at every occupied point to every point observed.

GEODETIC AZIMUTH OF DISTANT POINTS



Θ = THETA

Slope Lengths Reduced to Horizontal

If ground lengths are not taped horizontally, but instead are measured with an EDM, as is the case with the North Carolina Geodetic Survey and most other agencies or firms, then they must be reduced from slope length to horizontal distances. In most cases this can be accomplished in one of two ways; either by using vertical angles or differences in elevation. When vertical angles are observed, the horizontal distance is equal to the slope distance times the cosine of the vertical angle, or HD = L Cos VA. In the cases where differences of elevation are available, the reduction is accomplished using the formula $HD = \sqrt{(L)^2 - (\Delta h)^2}$ where the Δh is the difference in elevation between the measured stations. Of course, there are other formulae for reducing slope distances as well as computer software and total stations that internally reduce distance to horizontal.

The North Carolina Geodetic Survey reads reciprocal observations (vertical angles taken from both ends of each line) and carries elevation from station to station throughout the entire traverse. Results of experiments in this area indicate that if the heights of instruments and targets above ground are accurately measured along with the vertical angles, elevations can be computed for each station with a probable error of not more than one tenth of a meter (0.10) per mile or thirty-three hundredths of a foot (0.33) per mile of traverse. Since one minute in vertical angle per 1,000 feet of slope distance will cause 0.29 feet difference in vertical elevation, it is important that care be taken in all measurements and observations for vertical angle elevations. At the present time, elevations determined by GPS (Global Positioning System) are considered to have the same accuracy as trigometric elevations. At some time in the near future, elevations derived via GPS will increase in accuracy.

The computation for elevation from reciprocal observations are obtained from the formula $h_2 - h_1 = D \sin \frac{1}{2} (z_2 - z_1)$ (A.B.C.). In this formula h_1 is the elevation above NGVD 29/ NAVD 88 of station #1, whose elevation is known; h_2 is the elevation of station #2; D is the slope distance between the stations; Z_1 is the zenith angle from station #1 to station #2 and Z_2 is the zenith angle from station #2 to station #1. The A.B.C. in the formula are correction factors whose value is nearly unity and may be omitted from most computations and will not be covered herein.

Horizontal Distances Reduced to the Ellipsoid

The reduction of distances to the ellipsoid is one area that differs from the method used with NAD 27. When NAD 27 was developed, the geoid (NGVD 29/NAVD 88) and the ellipsoid (Clarke Ellipsoid of 1866) were about the same (within about 2 meters). With the advent of satellite positioning (GPS) and space coordinates, a new earth-centered ellipsoid was developed.

In order for this ellipsoid NAD 83 (GRS 80) to best fix the earth, GRS 80 and the geoid (NGVD 29/NAVD 88) could not be the same because it was developed for the whole earth. The difference between GRS 80 and the geoid is known as the geoid height (see figure 6 and 7). In N.C. the geoid height varies from -29 meters to -38 meters.

Since the geodetic data determined by the National Geodetic Survey (the Latitude and Longitude of points) are based on the ellipsoid, your survey must also be first reduced to the ellipsoid base before being reduced to grid.

The formula for reduction to the ellipsoid is:

$$\text{Ellipsoid Distance} = \text{Horizontal Distance} \times \left(\frac{R}{H + \text{Geoid Height} + R} \right)$$

or

$$\text{Ellipsoid Distance} = \text{Horizontal Distance} \times \left(1 - \left[\frac{H + \text{Geoid Height}}{R} \right] \right)$$

H = Elevation (NGVD 29/NAVD 88)

Geoid Height = In the above application, an average geoid height is best used throughout a project. The average geoid height for NC (-33 meters) would be adequate for most boundary surveys.

R = Mean Radius of the Earth (In N.C. use 6370944 meters as mean radius).

By use of the above formula, we can set up a table as follows:

Table of Ellipsoid Factors

Elevation = H (meters)	Ellipsoid Factor	Elevation = H (meters)	Ellipsoid Factor
25	1.00000126	1100	0.99983252
50	0.99999733	1200	0.99981682
100	0.99998948	1300	0.99980113
200	0.99997379	1400	0.99978543
300	0.99995809	1500	0.99976974
400	0.99994239	1600	0.99975404
500	0.99992670	1700	0.99973834
600	0.99991100	1800	0.99972265
700	0.99989531	1900	0.99970695
800	0.99987961	2000	0.99969125
900	0.99986391		
1000	0.99984822		

Note: The values computed for this table were obtained by using an average geoid height of - 33 meters.

In most land surveying projects, if the surface on which the traverse is measured is fairly regular so that variations in elevations are not large, a mean elevation and a mean geoid height for the entire traverse may be used.

For example, if the elevation of the beginning and ending control markers were 390 meters and 610 meters above NGVD 29/NAVD 88, and the traverse varied between those elevations, then the average elevation of the project would be 500 meters. From the table on page 19, the ellipsoid factor would be 0.99992670. Each horizontal line in the project should be multiplied by this factor for reduction to the ellipsoid.

<u>Example</u>
NAD 83 Sea Level Factor Computation
(Ellipsoid)

Your project is between:

NCGS Elwood:	NCGS Village:
MSL (NGVD 29) = 56.161 meters	MSL (NGVD 29) = 58.253 meters
Geoid Height = -32.43	Geoid Height = -32.44
Scale Factor = .9998793	Scale Factor = .9998793

$$\text{Ellipsoid Reduction Factor} = \frac{\text{Mean Radius}}{\text{Elevation (MSL)} + \text{Average Geoid Height} + \text{Mean Radius}}$$

Average elevation (MSL) of area you are working in = 57.207 m

$$\frac{56.161\text{ m} + 58.253\text{ m}}{\div 2}$$

Average Geoid Height = ELWOOD Geoid Height = -32.43
Village " " = <u>-32.44</u>
Average = -32.44

$$\text{Ellipsoid Reduction Factor} = \frac{6370944}{57.207\text{m} + (-)32.44 + 6370944}$$

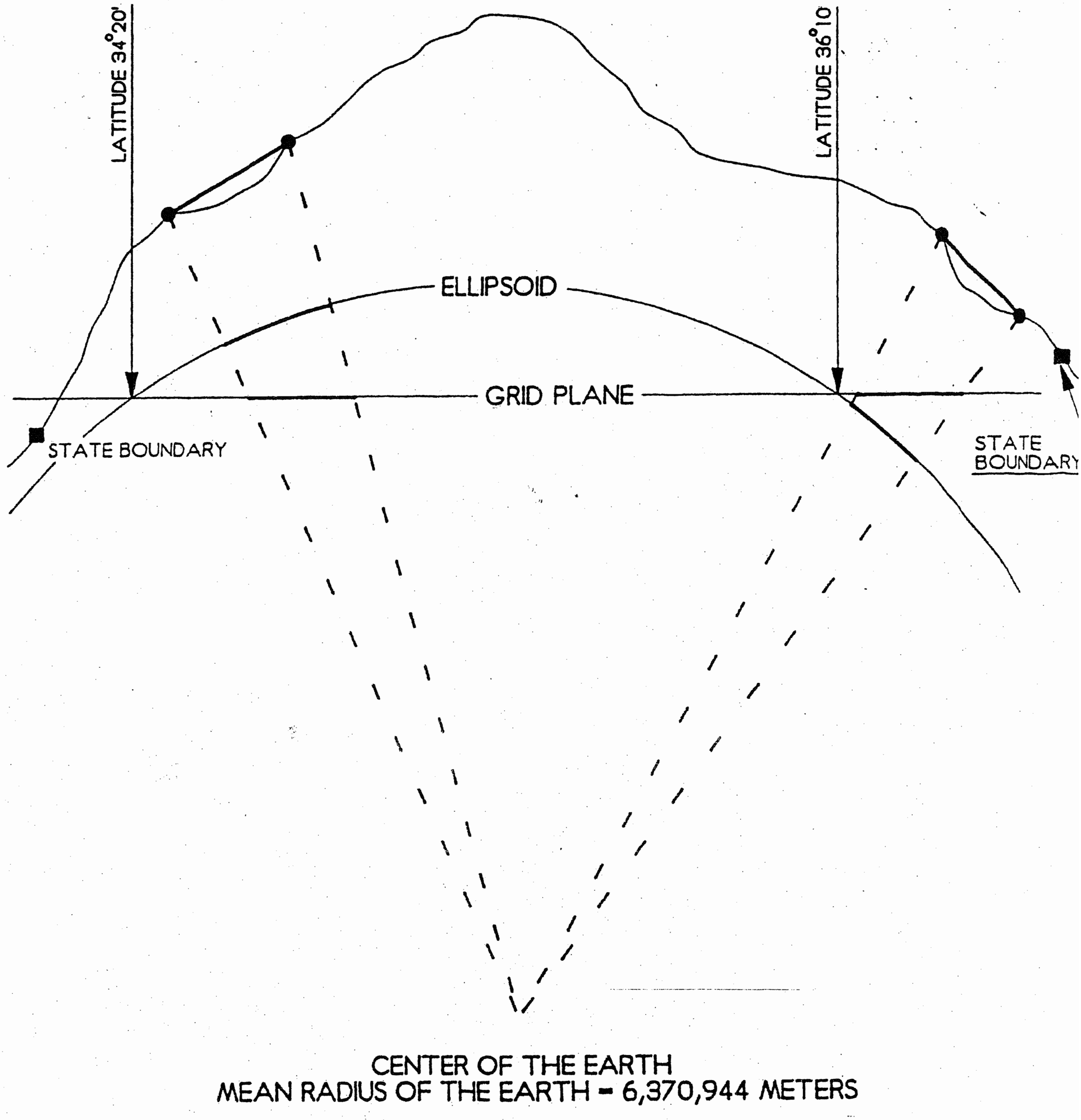
Ellipsoid Reduction Factor = <u>.9999961</u>

* Scale Factor = ELWOOD = .9998793 (Obtained from station
<u>VILLAGE</u> = <u>.9998793</u> data sheet or NC
Mean = .9998793 Projection Tables)

Combined Factor = (Ellipsoid Factor) x Scale Factor

.9998754 = (.9999961) x (.9998793)

* See pages 23-24 for definition of Scale Factor.

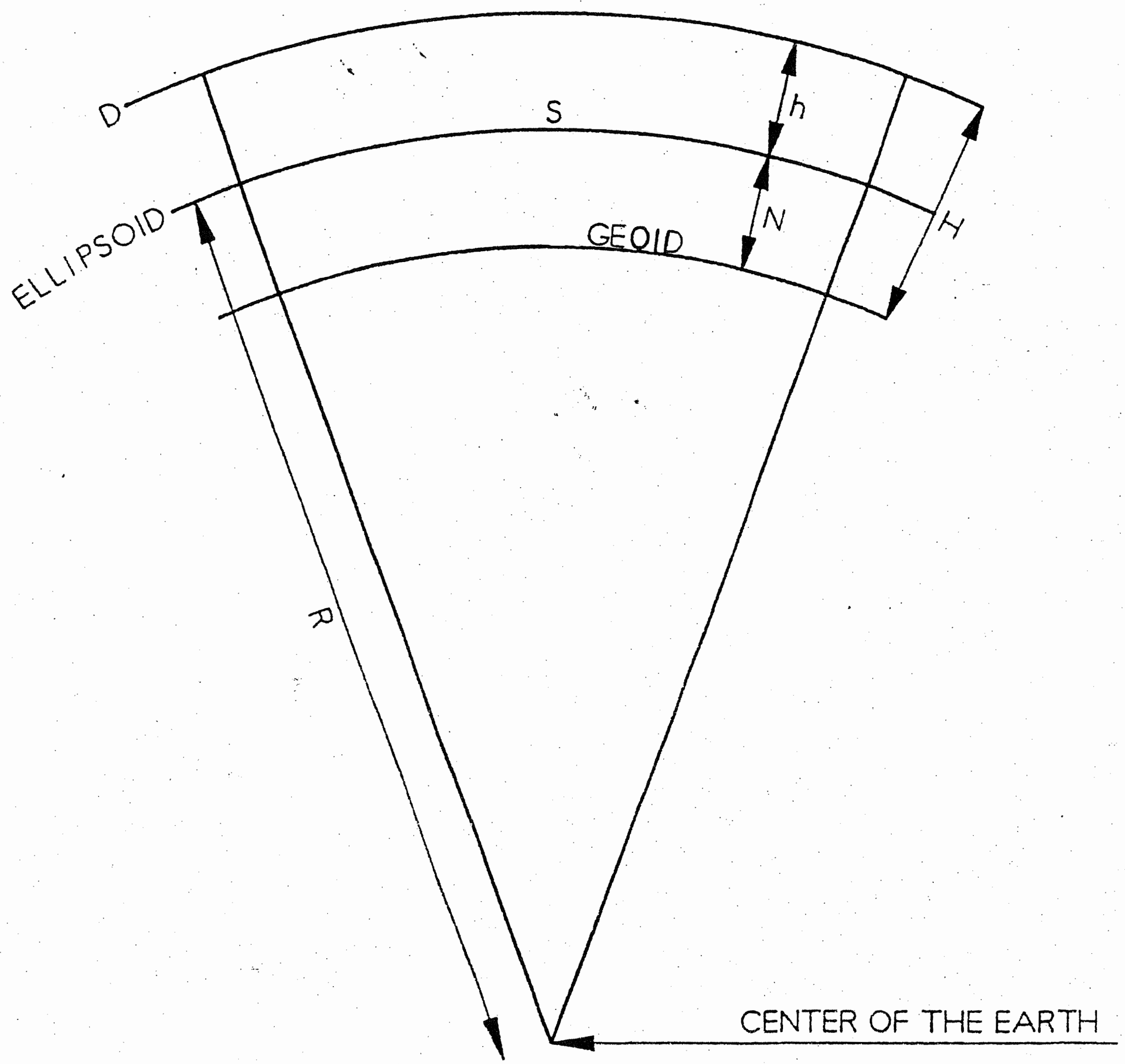


Distances measured on the curved surface of the earth can not be projected onto a flat plane surface without some distortion. Scale factors significantly reduce this distortion.

The Earth's curved surface approximates a spheroid. In order to convert the spherical coordinates (survey points on the ground) to plane rectangular coordinates, it's necessary to mathematically project these points from the spheroid to an imaginary developable surface - one that can be unrolled and laid flat into a plane surface (a grid plane) without much distortion of shape or size.

REDUCTION TO THE ELLIPSOID

(FIG. 7)



$$S = D\left(\frac{R}{R + N + H}\right)$$

WHERE

S = GEODETIC DISTANCE
D = HORIZONTAL DISTANCE
H = MEAN ELEVATION
N = MEAN GEOID HEIGHT (h - H)
R = MEAN RADIUS OF THE EARTH
IN N.C. 6370944 METERS
h = ELLIPSOID HEIGHT

Geodetic Lengths Reduced to Grid Lengths

The geodetic (Ellipsoid) lengths are further corrected for scale differential between the actual length and the same length as represented on the State Plane or grid. This is accomplished by application of a scale factor taken from the NAD 83 NC Projection Tables on pages 51-55.

From observation of the figures on pages 8 & 12 and the Projection Tables, it is seen that for lines along or near the Standard parallels of 36° 10' and 34° 20' Latitude the scale factor is unity and therefore no correction is applied to the Ellipsoid distances; Ellipsoid distances falling between the Standard parallels must be further reduced to the grid; and that those Ellipsoid distances falling outside of the Standard parallels must be increased up to the grid.

If the latitude extent of a survey is not great, a mean scale factor may be used. The approximate mean latitude of a project can be determined from the published latitudes of the beginning and tying geodetic control markers or scaled from a map. For example, if the latitude of the beginning control marker is 35° 51' 01.1715" and the latitude of the ending control marker is 35° 52' 19.7654", the approximate mean latitude of the project would be about 35° 51' 40". From the Projection Tables (pages 51-55), interpolation between 35° 51' = .99992699 and 35° 52' = .99993007 gives a scale factor of 0.9999290. Each Ellipsoid distance of the project should be multiplied by this factor to obtain grid lengths.

The ellipsoid factor of 0.99992670 as derived previously and the scale factor of 0.9999290 from above may be combined by multiplying them together to obtain a combined factor of 0.9998557. This combined factor may then be multiplied by each horizontal distance to obtain grid lengths for your entire traverse.

Using this combined factor of 0.9998557, the horizontal distance will be shortened by about 0.15 of a foot per thousand feet of traverse. If the traverse is 10,400.00 feet long, the length after both the Ellipsoid and scale factors are applied would be 10,398.50 feet, or a reduction of 1.50 foot.

For more detailed information about data reductions and grid or geodetic computations refer to one or more of the U.S. Department of Commerce (NOAA) Special Publications, such as NOAA Manual NOS NGS 5 "State Plane Coordinate System of 1983".

<u>Geodetic Control Information</u>

In addition to our own geodetic control, we strive to maintain and update data files for the following agencies:

National Geodetic Survey - NGS (formerly U.S. Coast & Geodetic)

U.S. Geological Survey - USGS

N.C. Department of Transportation - NCDOT

Army Map Service - AMS

Tennessee Valley Authority - TVA

Army Corps of Engineers - USCE

We will be glad to furnish you with data when available in digital (floppy disk) form. The free Searcher program that is included will enable you to maintain a data base of all the geodetic control in your area on your PC. On page 59 is an example of Searcher, along with a current price list of control data which has been inserted into this booklet. If you obtain Searcher we recommend that you update your data base yearly. To do this, return your data files on floppy disk to our office and request an update. You will only be charged for any new marks that have been added.

When data is not available in digital form, or the request is for printed material, hard copies will be provided. In either case cost estimates can be provided when an order is placed.

The discussion of geodetic data above referred to all published and preliminary adjusted data available. Most of you are aware that our PRELIMINARY positions are available while NGS is making final adjustment and publishing our horizontal and vertical control projects. We are now using a Least Square Adjustment set up by NGS (Program ADJUST) which computes positions only on the new NAD 83 (North American Datum of 1983). These preliminary values will be available in LATITUDE, LONGITUDE, and METRIC COORDINATES, and very likely will be close to, if not the same as, final adjusted values. However, when either NAD 27 or NAD 83 preliminary positions are used for any surveying, mapping, or survey-related projects, it should be so noted (along with the date of the preliminary data) on the resulting instrument of the survey.

We are receiving so many calls for data that our office staff is often backlogged with individual requests. To avoid lengthy phone conversations, it is preferred that data requests be mailed or faxed in, or either called in to be mailed out the next working day. If descriptions and/or position data must be read over the phone (<u>only a maximum of 3 stations will be permitted</u>).

Please be aware that the basic policy of this section is that we stand ready to consult with any surveyor, engineer, community or individual about surveying matters and to furnish, or assist in obtaining the basic data which exists throughout North Carolina.

Feel free to write or call us any time at:

North Carolina Geodetic Survey
512 N. Salisbury Street
Raleigh, N.C. 27604
Telephone (919) 733-3836
FAX (919) 733-4407

North Carolina no longer has a National Geodetic Survey Mark Maintenance representative as this federal program has been phased out. However, our agency has initiated a cooperative agreement with NGS to continue a Mark Maintenance Program in North Carolina. We are extremely interested in preserving all survey marks in our state and encourage you to contact us whenever any survey marker is destroyed or disturbed, or in danger of becoming unusable for whatever reason. As we maintain and share recovery information for all survey marks, please feel free to use the inserted " Survey Mark Recovery Index" form to report on any such mark you may visit.

Classification Definitions

The Standards and Specifications as set forth on pages 28-30 are primarily for use in geodetic control surveys such as those performed by NCGS. It is highly desirable that all geodetic, or other precise engineering surveys referenced to the National Geodetic Control Networks, adhere to these standards whenever possible.

These standards and specifications are suggested by the National Geodetic Survey for geodetic control traverse and are not to be confused with or used in place of those defined by the North Carolina Society of Surveyors and/or the North Carolina Board of Registration for use in land surveying. We assume that all Registered Land Surveyors in the State are familiar with and adhere to the general specifications and classifications of their profession.

CAUTION: The North Carolina Geodetic Survey (NCGS) does provide both horizontal and vertical positions supplied by other governmental and private agencies; however, NCGS and the National Geodetic Survey only verify, compute, adjust and maintain original field records for control published in the National Network's National Geodetic Reference System (NGRS). One of the main benefits of having surveys included within the NGRS network is the ability to continually upgrade and correct the network as new surveys are interconnected within the system. Non-NGRS control surveys may or may not agree with NGRS control within the same area at the time they are established, and may become outdated if the national network is upgraded. A few local networks (including some recent GPS surveys) do exist where adequate connections or adequate constraints to the local NGRS control were not made. Therefore, if and when you use Non-NGRS control and/or data (even if it is classified as higher order) you are advised to close your survey into any NGRS control that may exist within 2000 feet. This should both assure you that the marks have not been moved and that their coordinates agree with each other.

STANDARDS FOR THE CLASSIFICATION OF GEODETIC CONTROL
AND PRINCIPAL RECOMMENDED USES

HORIZONTAL CONTROL
(Traditional Surveying Methods)

Classification	Relative Accuracy Between Directly Connected Adjacent Points (At Least)	Recommended Uses
First-Order	1 Part in 100,000	Primary National Network. Metropolitan Area Surveys. Scientific Studies.
Second-Class I strengthens the National	1 Part in 50,000	Area Control which Network. Subsidiary Metropolitan Control.
Second-Class II	1 Part in 20,000	Area Control which contributes to, but is supplemental to, the National Network.
Third-Class I	1 Part in 10,000	General Control Surveys Referenced to the National
Third-Class II	1 Part in 5,000	Network. Local Control Surveys.

(Standards and Specifications for Geodetic Control Networks
FGCC September 1984.)

(Global Positioning System)

Survey categories	Order	Base error e (cm)	(95 percent confidence level) Minimum geometric Accuracy standard Line-length Dependent error p (ppm)	a (1:a)
Global-regional geodynamics; deformation measurements....	AA	0.3	0.01	1:100,000,000
National Geodetic Reference System, "primary" networks; regional-local geodynamics; deformation measurements...	A	0.5	0.1	1: 10,000,000
National Geodetic Reference System, "secondary" networks; connections to the "primary" NGRS network; local geodynamics; deformation measurements; high-precision engineering surveys...	B	0.8	1	1: 1,000,000
National Geodetic Reference System, (Terrestrial based); dependent control surveys to meet mapping, land information, property, and engineering requirements............	(C)			
	1	1.0	10	1: 100,000
	2-I	2.0	20	1: 50,000
	2-II	3.0	50	1: 20,000
	3	5.0		1: 10,000

Geometric Geodetic Accuracy Standards
and
Specifications for using GPS Relative
Positioning Techniques
Version 5.0 (Aug. 1, 1989)

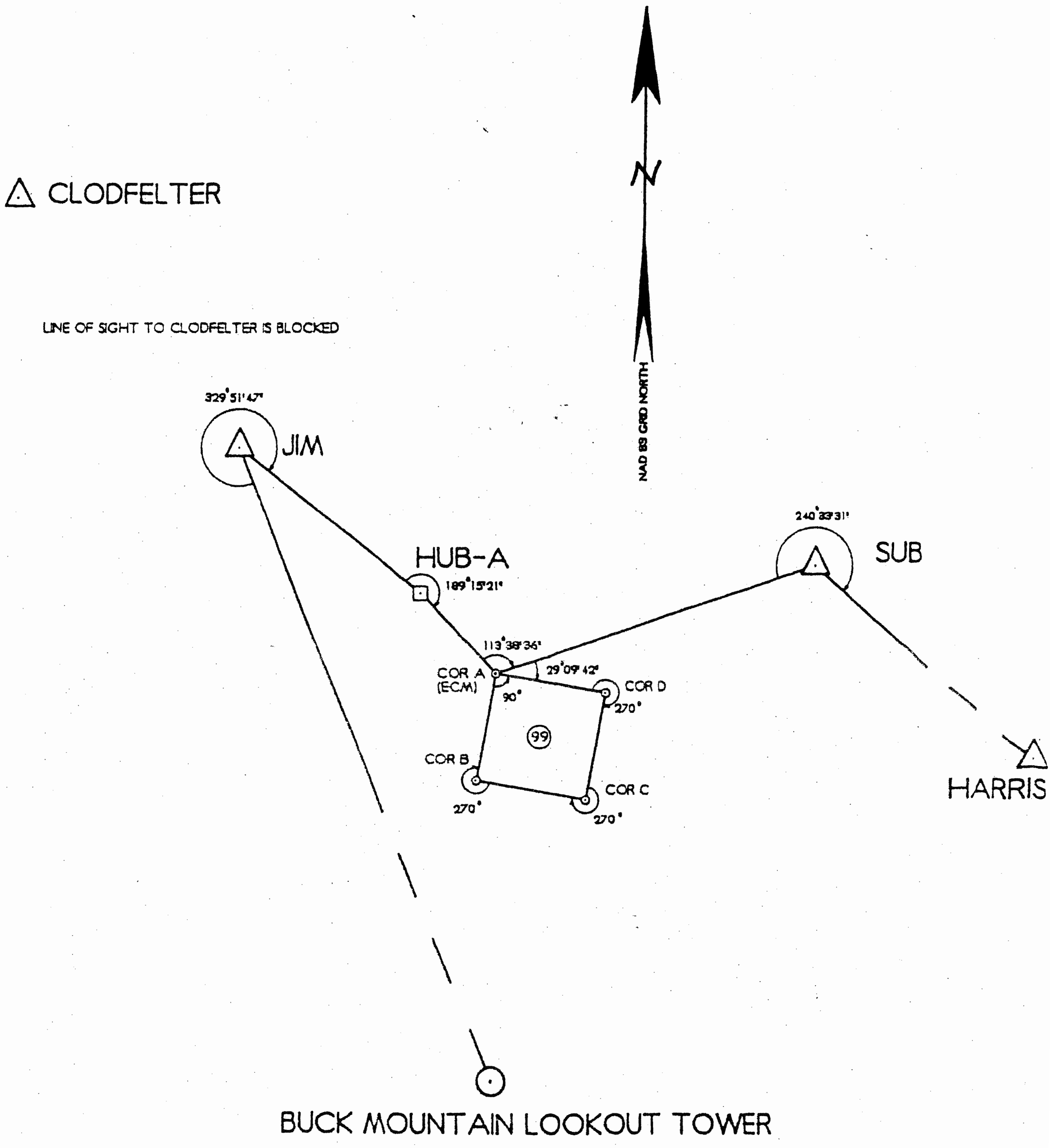
Vertical Control

Classification	Relative Accuracy Between Directly Connected Points or Benchmarks	Recommended Uses
First-Class I	3 MM $\sqrt{K}$	Basic Framework of the National Network and Metropolitan Area Control. Regional Crustal Movement Studies.
First-Class II	4 MM $\sqrt{K}$	Extensive Engineering Projects. Support for Subsidiary Surveys.
Second-Class I	6 MM $\sqrt{K}$	Secondary Framework of the National Network and Metropolitan Area Control. Local Crustal Movement Studies. Large Engineering Projects. Tidal Boundary Reference. Support for Lower Order Surveys.
Second-Class II	8 MM $\sqrt{K}$	Densification within the National Network. Rapid Subsidence Studies. Local Engineering Projects. Topographic Mapping.
Third-Order	12 MM $\sqrt{K}$	Small-scale topographic mapping. Establishing gradients in mountainous areas. Small Engineering Projects. May or may not be adjusted to the National Network.

(K is the distance in Kilometers between points.)

(Standards and Specifications for Geodetic Control Networks
FGCC, September, 1984)

COMPUTATIONS FOR A TYPICAL LOT SURVEY



1. Since the line of sight between NCGS "Jim" and "Clodfelter" is blocked, the grid azimuth is obtained by computing an inverse between "Jim" and the coordinated position of Buck Mountain Lookout Tower, which is about 0.75 miles away and visible from the ground at "Jim".

NAD 83 Coordinates (Meters)

Jim	Northing = 184809.724 m	Easting = 518664.028 m
Buck Mountain Lookout Tower	Northing = 184232.329 m	Easting = 518892.835 m

To inverse between any two points Grid Bearing = $\tan^{-1} \dfrac{X_2 - X_1}{Y_2 - Y_1}$

$$\text{Grid Bearing} = \tan^{-1} \frac{518892.835 - 518664.028}{184232.329 - 184809.724}$$

$$\text{Grid Bearing} = \tan^{-1} \frac{228.807}{-577.395}$$

$$\text{Grid Bearing} = \tan^{-1} - 0.396274647$$

$$\text{Grid Bearing} = -21^\circ\ 37'\ 02''$$

Az (from North) = 180° - 21° 37' 02" = 158° 22' 58" (S 21° 37' 02" E)

2. Using the adjusted field angles as turned, grid azimuths and grid bearings are computed for the project.

Grid Azimuth Jim to Buck Mt. L/T	158° 22' 58" (S 21° 37' 02" E)
	329° 51' 47"
	488° 14' 45" - 360 = 128° 14' 45"
Grid Azimuth Jim to Hub A	128° 14' 45" (S 51° 45' 15" E)
	180°
	308° 14' 45"
	189° 15' 21"
Grid Azimuth Hub A to ECM (Cor A)	137° 30' 06" (S 42° 29' 54" E)
	180°
	317° 30' 06"
	113° 38' 36"
Grid Azimuth ECM (Cor A) to Sub	71° 08' 42" (N 71° 08' 42" E)
	180°
	251° 08' 42"
	240° 33' 31"
Grid Azimuth Sub to Harris	131° 42' 13" (S 48° 17' 47" E)

To check our Azimuth tie, we must inverse between Sub and Harris.

Sub	N = 184704.115	E = 519186.888
Harris	N = 184527.934	E = 519384.605

$$\text{Grid Bearing} = (\tan)\ \frac{519384.605 - 519186.888}{184527.934 - 184704.115}$$

Grid Bearing = (tan) - 1.122237926

Grid Bearing = - 48° 17' 47" (S 48° 17' 47" E)

Az (from North) = 180° - 48° 17' 47" = 13° 42' 13"

Published Az = 131° 42' 13"
Survey Az = 131° 42' 13"
Error = 0° 0' 0.0'

(Note: In most practical situations some Azimuth error will occur. practical method of adjusting for angular error would be to distribute error equally among all angles.)

3. In this problem it is assumed that all measured distances are slope and can be reduced to horizontal by one of two ways; either by using vertical angles or difference of elevation. When vertical angles are observed, the horizontal distance (HD) = L (Cos VA), where L is the slope distance and VA is the vertical angle.

When differences in elevation are available, the reduction is accomplished using $HD = \sqrt{(L)^2 - (\Delta h)^2}$ where Δh is the difference in elevation between the two measured stations.

4. To reduce horizontal distances to the ellipsoid, we use the formula:

$$\text{Ellipsoid Dist.} = \left(\frac{\text{Mean Radius}}{\text{Elevation} + \text{GeoidHeight} + \text{MeanRadius}} \right) * \text{HD}$$

or

$$\text{Ellipsoid Dist.} = \frac{\text{HD} * (1 - \text{Elevation} + \text{GeoidHeight})}{\text{Mean Radius}}$$

(Note: See page 19-22 for more details)

Since the average elevation for this small project is about 156 meters (Mean elevation of two control points: Jim 147.5 m and Sub 164.1 m), the average geoid height of this project is -30.3 m (Mean geoid height of two control points: Jim -30.3 m and Sub - 30.3 m). Using this average elevation of 156 meters and average geoid height of -30.3 m , the ellipsoid reduction factor can be obtained by using the above formulas.

$$\text{Ellipsoid Factor} = \frac{6370944}{156 + (-30.3) + 6370944}$$

Ellipsoid Factor = .9999803

This factor multiplied by each horizontal distance of the survey will reduce the distance to the ellipsoid base.

5. To reduce the ellipsoid distances to grid lengths we must use a scale factor from the published control data sheets or from the projection tables on pages 51-55.
The scale factor to be used can be obtained if the mean latitude of the project is known. The mean latitude of the project can be obtained by averaging the published latitudes of the beginning and ending control points or by scaling the mean latitude from a USGS topographic map. For this project the mean latitude is:

Jim: 35° 24' 42.71580"
Sub: 35° 24' 39.45944"

Mean Latitude = 35° 24' 41"

From the projection tables using a latitude of 35° 24' 41" = .9998764

or

If the NCGS control data sheets are available, you can obtain the scale factor from these sheets, and average the factors from the beginning and ending NCGS control.

From the control sheets:

Jim	NAD 83 Scale Factor	= 0.9998765
Sub	NAD 83 Scale Factor	= 0.9998764
Average	NAD 83 Scale Factor	= 0.9998764

This factor multiplied by each ellipsoid distance will reduce the distance to the grid base.

It might be noted that if you multiply the:

Ellipsoid Factor X Scale Factor = Combined Factor

This combined factor can be multiplied by each horizontal distance to obtain a grid distance.

For this project: Ellipsoid Factor = .9999803
Scale Factor = .9998764

Combined Factor = .9998567

Line	Horizontal Dist. (Meters)	X Combined Factor	= Grid Distance (Meters)
Jim to Hub A	212.295	.9998567	212.264
Hub A to Cor A (ECM)	99.010	.9998567	98.996
Cor A (ECM) to Sub	305.702	.9998567	305.658

LATITUDE = COS (AZ) X (DIST) DEPARTURE = SIN (AZ) X (DIST)

	AZIMUTH	DISTANCE (GRID)	LATITUDE (NORTHING)	DEPARTURE (EASTING)
JIM			(NAD 83) 184809.724m	518664.028m
	128°14'45"	212.264m	-131.399	166.704
HUB-A			184678.325	518830.732
	137°30'06"	98.996m	-72.989	66.879
COR A			184605.336	518897.611
(ECM)	71°08'42"	305.658m	98.781	289.256
SUB			184704.117	519186.867
	TOTAL DISTANCE	616.918m	(NAD 83) 184704.115m	519186.888m
			ERROR -0.002	-0.021

$$\text{TOTAL ERROR} = \sqrt{-0.002^2 + -0.021^2}$$

$$\text{TOTAL ERROR} = \sqrt{0.0004450}$$

$$\text{TOTAL ERROR} = 0.021\text{m}$$

$$\text{ERROR OF CLOSURE} = \frac{\text{TOTAL DISTANCE}}{\text{ERROR}}$$

$$\text{ERROR OF CLOSURE} = \frac{616.918}{0.021}$$

$$\text{ERROR OF CLOSURE} = \frac{1}{29{,}377}$$

BUCK MOUNTAIN LOOKOUT TOWER,

MONTGOMERY COUNTY

NAD 83 =>	LATITUDE = 35 24 24.05413	LONGITUDE = 079 59 55.51900	
SPC 83 =>	NORTHING = 184232.329 Meters	EASTING = 518892.835 Meters	
NAD 27 =>	LATITUDE = 35 24 23.55000	LONGITUDE = 79 59 56.34400	
SPC 27 =>	NORTH(Y) = 604368.460 Feet	EAST(X) = 1702325.156 Feet	
GRID SHIFT (NAD27 - NAD83)	NORTH = -67.106 feet	EAST = -75.753 feet	
NAD83 CONVERGENCE (Θ) = -0 34 35.23		NAD83 SCALE FACTOR = 0.9998762	
ELEVATION (NGVD 29) meters		GEOID90 GEOID HEIGHT IS -30.32 meters	
PID = EZ3772			

THIS IS A TRAVERSE STATION.

THE STATION IS LOCATED 6-1/2 MILES NORTHWEST OF TROY AND 3 MILES SOUTH OF ELDORADO, ON LAND OWNED BY THE UNITED STATES FOREST SERVICE AND ON THE HIGHEST POINT OF BUCK MOUNTAIN.

IT IS A FOUR LEGGED STEEL STRUCTURE ABOUT 100 FEET IN HEIGHT. THE POINT OBSERVED ON WAS THE CENTER OF THE AIR VENT ON THE TOP OF THE CAB.

A TRAVERSE CONNECTION WAS MADE FROM TRIANGULATION STATION BUCK TO THE CENTER OF THE BASE OF THE LOOKOUT TOWER AND THE DISTANCE WAS FOUND TO BE 13.910 METERS.

TO REACH THE STATION FROM THE JUNCTION OF STATE HIGHWAYS 109 AND 27 AT THE NORTHWEST CORNER OF THE COURTHOUSE SQUARE IN TROY, GO NORTHWEST ON HIGHWAY 109 FOR 7.1 MILES TO A SIDE ROAD LEFT AND A SIGN BUCK MTN. TOWER, TURN LEFT AND GO 0.65 MILE TO THE STATION AS DESCRIBED.

******************************** RECOVERY TEXT ********************************

RECOVERED BY CGS in 1967. SOME OF THE OLD STEEL MEMBERS AT THE BASE OF THE TOWER HAVE BEEN RECENTLY REPLACED, WHICH MAY POSSIBLY HAVE AFFECTED THE COLLIMATION, OTHERWISE THE TOWER IS IN GOOD CONDITION AND AS DESCRIBED.

AIRLINE DISTANCE AND DIRECTION FROM NEAREST TOWN 0.8 MILE SOUTHEAST OF UWHARRIE. 6.5 MILES NORTHWEST OF TROY.

******************************** RECOVERY TEXT ********************************

RECOVERED AS DESCRIBED.

******************************** RECOVERY TEXT ********************************

Last Recovery: 92 GOOD

HARRIS, MONTGOMERY COUNTY

```
NAD 83 =>  LATITUDE = 35 24 33.80665       LONGITUDE = 079 59 36.14466
SPC 83 =>  NORTHING =  184527.934 Meters     EASTING =  519384.605 Meters

NAD 27 =>  LATITUDE = 35 24 33.30179       LONGITUDE =  79 59 36.97103
SPC 27 =>  NORTH(Y) =  605338.189 Feet       EAST(X) = 1703938.500 Feet

GRID SHIFT (NAD27 - NAD83)    NORTH = -67.208 feet    EAST = -75.825 feet

NAD83 CONVERGENCE (Θ) = -0 34 24.04       NAD83 SCALE FACTOR = 0.9998764
  ELEVATION (NGVD 29)                           GEOID90 GEOID HEIGHT IS
      167.7 meters (±0.3 m)                             -30.32 meters
                              PID = EZ3787
```

HARRIS IS LOCATED APPROXIMATELY 6.7 MILES WNW OF TROY, AND 0.6 MILE ESE OF UWHARRIE COMMUNITY. TO REACH STATION FROM INTERSECTION OF SR 1150 WITH NC 109 AT UWHARRIE, PROCEED EASTERLY ALONG NC 109 FOR 0.7 MILE TO STATION ON THE LEFT, APPROXIMATELY 250 FEET SE OF INTERSECTION WITH DIRT ROAD LEADING TO BUCK MOUNTAIN.

STATION MARK IS A STANDARD N. C. BRASS TRAVERSE DISK, STAMPED HARRIS 1974, SET IN THE TOP OF A CONCRETE CYLINDER, THE TOP OF WHICH IS FLUSH WITH THE SURFACE OF THE GROUND.

MARK IS 23.0 FT NE OF C/L OF NC 109
23.1 FT NW OF NE END OF CONCRETE CULVERT UNDER NC 109
113.0 FT N OF CENTER OF TOP OF TELEPHONE JUNCTION BOX WITH POLE WITH ALUMINUM REF. TAG
68.5 FT ESE OF SE END OF CONCRETE CULVERT UNDER ABANDONED DRIVEWAY

10.0 FT W OF 12 IN GUM WITH ALUMINUM REF. TAG
27.0 FT SSE OF 8 IN OAK WITH ALUMINUM REF. TAG

JIM, MONTGOMERY COUNTY

NAD 83 =>	LATITUDE = 35 24 42.71580	LONGITUDE = 080 00 4.81876	
SPC 83 =>	NORTHING = 184809.724 Meters	EASTING = 518664.028 Meters	
NAD 27 =>	LATITUDE = 35 24 42.21129	LONGITUDE = 80 0 5.64495	
SPC 27 =>	NORTH(Y) = 606262.713 Feet	EAST(X) = 1701574.362 Feet	
GRID SHIFT (NAD27 - NAD83)	NORTH = -67.190 feet	EAST = -75.870 feet	
NAD83 CONVERGENCE (Θ) = -0 34 40.59		NAD83 SCALE FACTOR = 0.9998765	
ELEVATION (NGVD 29) 147.5 meters (±0.3 m)	PID = FA1873	GEOID90 GEOID HEIGHT IS -30.32 meters	

JIM IS LOCATED APPROXIMATELY 7.0 MILES WNW OF TROY, AND AT SE EDGE OF UWHARRIE COMMUNITY. TO REACH STATION FROM INTERSECTION OF SR 1150 WITH NC 109 AT UWHARRIE, PROCEED EASTERLY ALONG NC 109 FOR 0.2 MILE TO STATION ON THE RIGHT, APPROXIMATELY 150 FEET EAST OF A ONE STORY YELLOW FRAMED HOUSE.

STATION MARK IS A STANDARD N. C. BRASS TRAVERSE DISK, STAMPED JIM 1974, SET IN THE TOP OF A CONCRETE CYLINDER, THE TOP OF WHICH IS FLUSH WITH THE SURFACE OF THE GROUND.

MARK IS 23.4 FT SSW OF C/L OF NC 109
138.4 FT E OF NE CORNER OF YELLOW HOUSE
199.2 FT SE OF CENTER OF TOP OF TELEPHONE JUNCTION BOX (LARGER)
22.1 FT NE OF 8 IN PINE WITH ALUMINUM REF. TAG
20.5 FT N OF 6 IN PINE WITH ALUMINUM REF. TAG
57.4 FT NNW OF 15 IN TWIN TRUNK OAK WITH ALUMINUM REF. TAG

******************************** RECOVERY TEXT ********************************

Last Recovery: 83 GOOD

SUB, MONTGOMERY COUNTY

NAD 83 =>	LATITUDE = 35 24 39.45944	LONGITUDE = 079 59 44.05158
SPC 83 =>	NORTHING = 184704.115 Meters	EASTING = 519186.888 Meters
NAD 27 =>	LATITUDE = 35 24 38.95481	LONGITUDE = 79 59 44.87789
SPC 27 =>	NORTH(Y) = 605916.219 Feet	EAST(X) = 1703289.813 Feet
GRID SHIFT (NAD27 - NAD83)	NORTH = -67.198 feet	EAST = -75.835 feet
NAD83 CONVERGENCE (Θ) = -0 34 28.61		NAD83 SCALE FACTOR = 0.9998764
ELEVATION (NGVD 29) 164.1 meters (±0.3 m)	PID = EZ3788	GEOID90 GEOID HEIGHT IS -30.32 meters

SUB IS LOCATED APPROXIMATELY 6.8 MILES WNW OF TROY, AND 0.5 MILE ESE OF UWHARRIE COMMUNITY. TO REACH STATION FROM INTERSECTION OF SR 1150 WITH NC 109 AT UWHARRIE, PROCEED EASTERLY ALONG NC 109 FOR 0.55 MILE TO STATION ON THE LEFT, NEAR THE SOUTH CORNER OF A METAL FENCE AROUND AN ELECTRIC SUB-STATION. 0.15 MILE NW OF INTERSECTION WITH BUCK MOUNTAIN ROAD.

STATION MARK IS A STANDARD N. C. BRASS TRAVERSE DISK, STAMPED SUB 1974, SET IN THE TOP OF A CONCRETE CYLINDER, THE TOP OF WHICH IS FLUSH WITH THE SURFACE OF THE GROUND.

MARK IS 51.5 FT NE OF C/L OF NC 109
26.6 FT WNW OF C/L OF WESTERNMOST DRIVEWAY TO A ONE STORY BRICK HOUSE

7.6 FT SE OF SOUTH CORNER OF SUB-STATION FENCE
6.2 FT N OF PP WITH ALUMINUM REF. TAG
96.1 FT ESE OF PP WITH ALUMINUM REF. TAG

NGVD 29

National Geodetic Vertical Datum of 1929

NAVD 88

North American Vertical Datum of 1988

At the present time, most surveys that dealt with vertical components were referenced to NGVD 29. Since the last adjustment in 1929, the national vertical network has been enlarged with additional leveling and much of the original level lines have been releveled. Many areas of the United States have experienced crustal movement in the vertical component due to earthquakes, past glacial uplift and subsidence from withdrawal of fluids. As additional leveling was performed since 1929, these level networks were made to fit to the NGVD 29 datum. As more and more networks were added to NGVD 29 it became obvious that a new general least square adjustment was needed.

In 1977 the National Geodetic Survey began the huge task of readjusting the vertical network and redefining the vertical datum. The target date for completion was set for 1991. Before the adjustment could be accomplished, many kilometers of leveling were required along with putting observations in a digital format and verifying this data. In addition, other agencies that would be impacted by NAVD 88 were contacted to determine what problems would be encountered by a readjustment of the vertical datum.

After much hard work, the National Geodetic Survey released the vertical values based on NAVD 88 in 1991. On the succeeding pages (42-46) are some important facts about NGVD 29/NAVD 88 and how NAVD 88 will affect the land surveyors in North Carolina. We have also included a sample data sheet from NGS which contains both NGVD 29 and NAVD 88 elevations.

NAVD 88

North American Vertical Datum of 1988

The goals of NAVD 88 were:

Readjust the vertical network for the first time in 60 years;

Redefine and create a single datum for North America that will meet modern needs;

Create a truly international vertical datum;

Perform releveling of 80,000 Km of first order level lines to strengthen the network and replace destroyed bench marks;

Convert bench mark data to a computer-readable format (descriptions and field observation);

Approximate Geographic positions for all bench marks;

Improve geoid modeling using Global Positioning System and NAVD 88; and

Develop software to support NAVD 88.

History of Vertical Datums and Adjustments

1856 First vertical survey began in New York Bay, Hudson River

1877 Transcontinental Leveling Started, Hagerstown, Maryland

Network Adjustments:

Year	Kilometers of level lines	Number of Tide Stations
1900	21,000 Kms	5
1903	32,000 Kms	8
1907	38,000 Kms	8
1912	46,000 Kms	9
1929	75,159 Kms U.S (NGVD 29)	21 U.S.
	31,565 Kms Canada	5 Canada
1988	1,300,000 Kms	1

The NGVD 29 adjustment used the heights of 26 tidal bench marks referenced to local mean sea level and they were constrained to define a reference surface (datum) based on a value of 0.0 M for each local mean sea level. The NAVD 88 adjustment will be a minimally constrained adjustment holding one point fixed at Father Point/Rimouski (Point-au-Perc). With this adjustment, NAVD 88 will be a vertical datum based on an equipotential surface.

Impact of NAVD 88

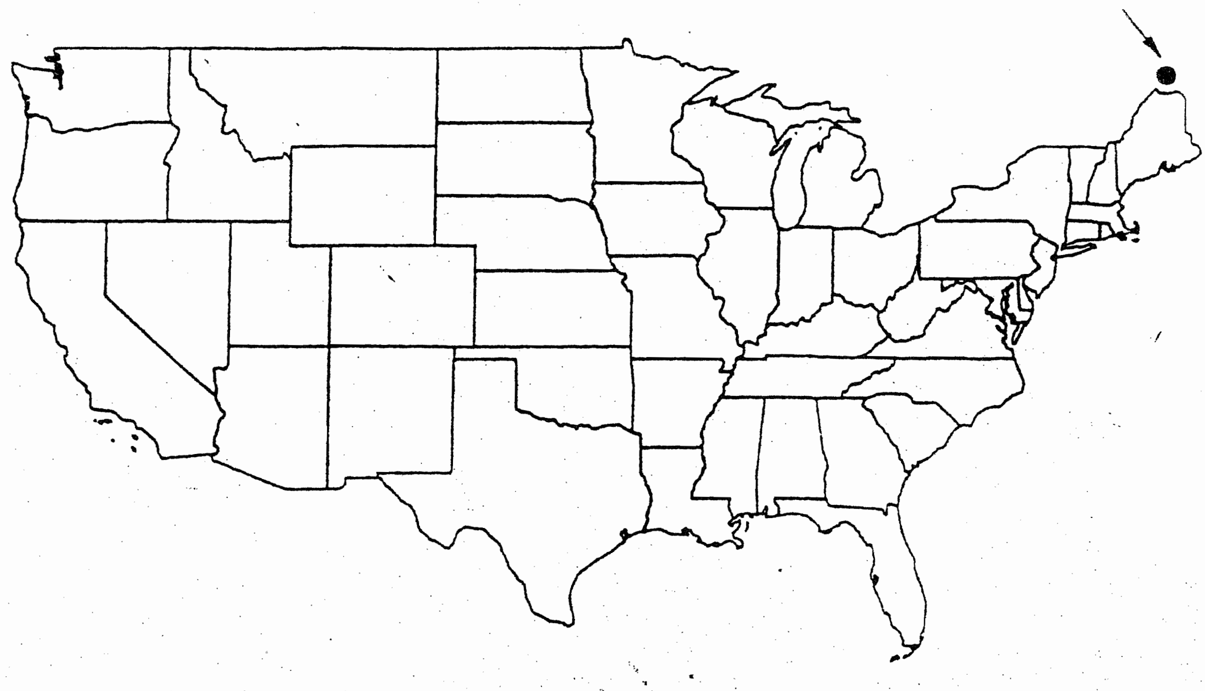
In stable areas, relative height changes between adjacent bench marks should only be a few millimeters. The absolute height value could change by as much as a few decimeters.

In many areas, there will be a single bias factor describing the difference between NGVD 29 and NAVD 88.

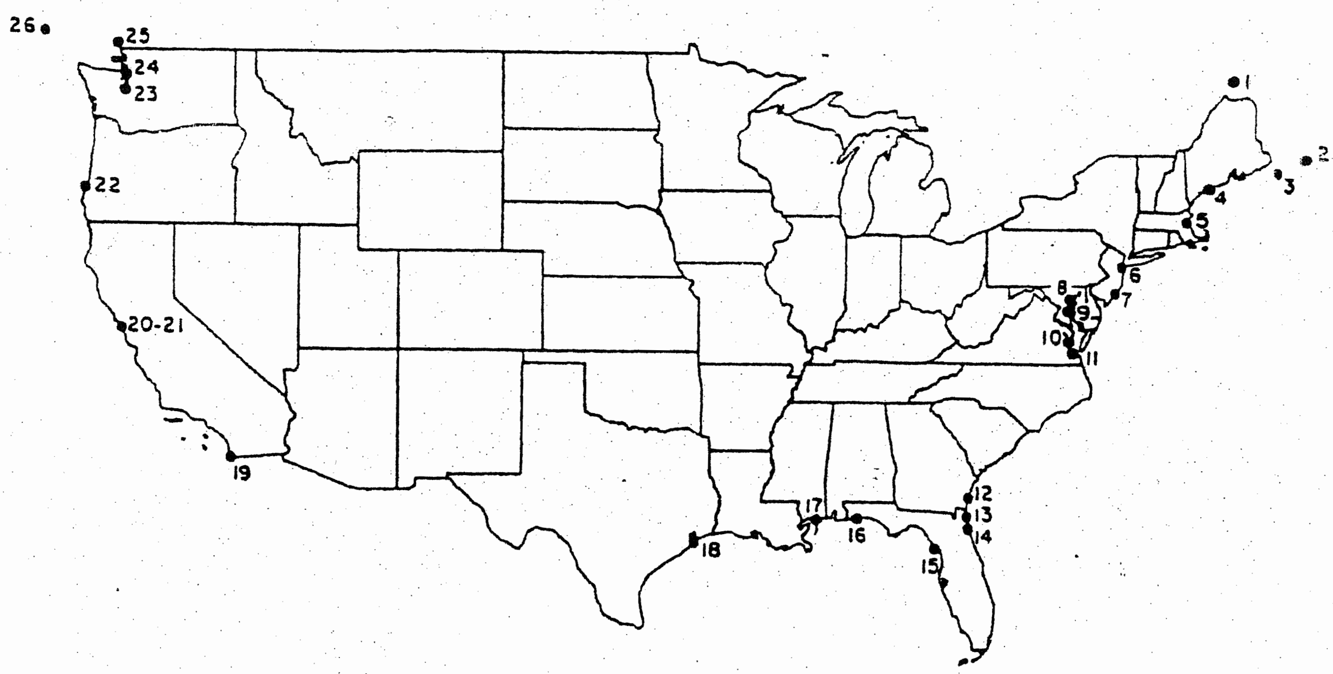
NAVD 88 will have a major impact on mapping agencies such as USGS and FEMA.

Impact of NAVD 88 in North Carolina

In North Carolina, the shift will vary from -0.3' in Western North Carolina to -1.0' in Eastern North Carolina. As of January, 1992, only NGS and NCGS vertical control will be included in the NAVD 88 adjustment. None of the third order bench marks other than those already in the NGRS database will have NAVD 88 values. NCGS is in the process of preparing the third order USGS and other agencies' data in a computer-readable format so that NGS can provide NAVD 88 values of these bench marks in North Carolina.

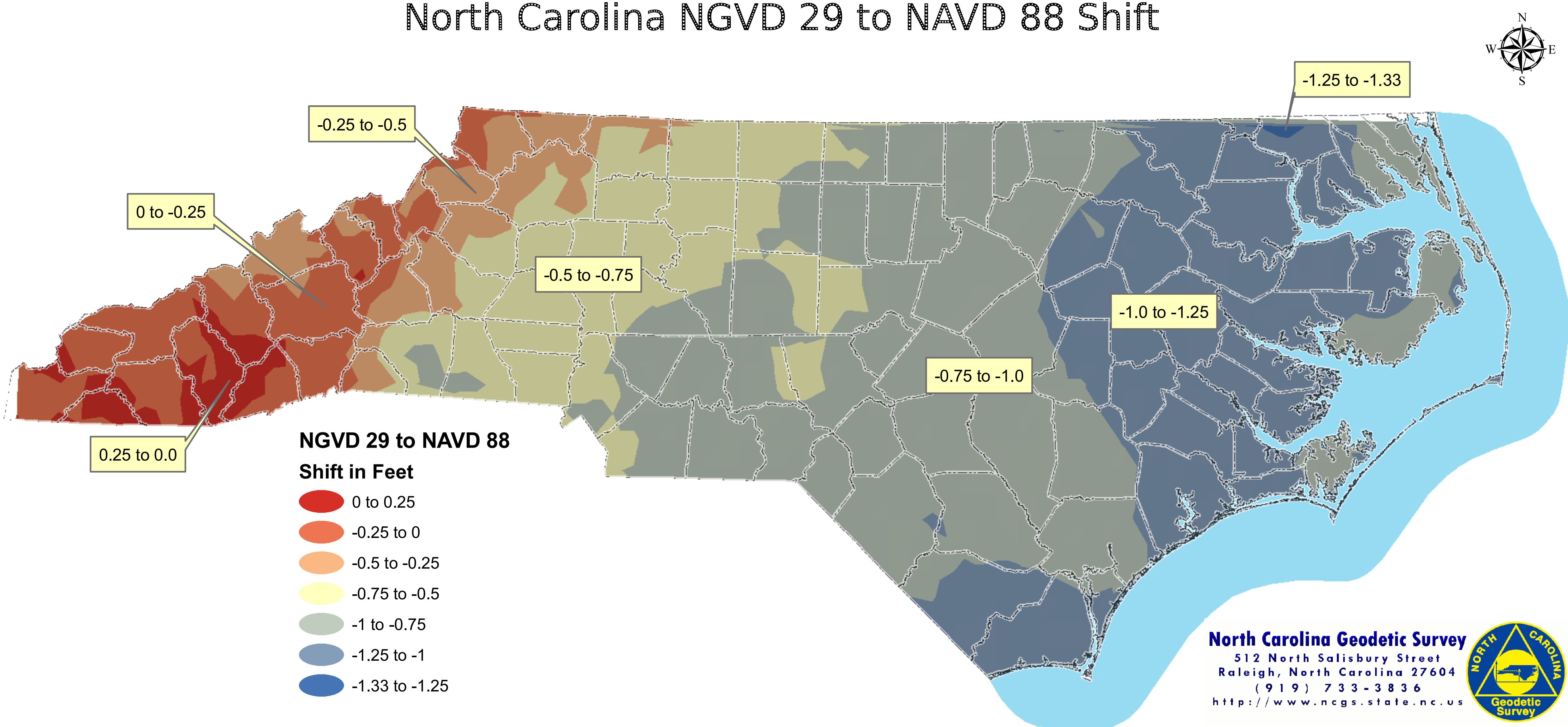


GAUGE SITES HELD FIXED IN 1929



1. FATHER POINT, QUE
2. HALIFAX, N.S.
3. YARMOUTH, N.S.
4. PORTLAND, ME.
5. BOSTON, MASS.
6. PERTH AMBOY, N.J.
7. ATLANTIC CITY, N.J.
8. BALTIMORE, MD.
9. ANNAPOLIS, MD.
10. OLD POINT COMFORT, VA.
11. NORFOLK, VA.
12. BRUNSWICK, GA.
13. FERNANDINA, FLA.
14. ST. AUGUSTINE, FLA.
15. CEDAR KEYS, FLA.
16. PENSACOLA, FLA.
17. BILOXI, MISS.
18. GALVESTON, TEX.
19. SAN DIEGO, CALIF.
20. SAN PEDRO, CALIF.
21. SAN FRANCISCO, CALIF.
22. FORT STEVENS, ORE.
23. SEATTLE, WASH.
24. ANACORTES, WASH.
25. VANCOUVER, B.C.
26. PRINCE RUPERT, B.C.

North Carolina NGVD 29 to NAVD 88 Shift



NORTH CAROLINA

Lambert conformal conic projection with two standard parallels

Plane coordinate projection tables

Zone Code: 3200

DATUM: NAD 83

Ellipsoidal constants

$a = 6378137$ m

--(See Figure 1)

$f = 1/298.25722210$

Defining constants

B_b = 33 45' (latitude of grid origin)

L_o = 79 00' (longitude of origin and Central Meridian, CM)

B_s = 34 20' (southern standard parallel)

--(See Figure 2)

B_n = 36 10' (northern standard parallel)

E_o = 609601.2199 m (easting coordinate of origin)

N_b = 0.0000 m (northing coordinate of origin)

Derived constants

ℓ = 0.577170255241 = ratio of the mapping angle to the longitude difference from the Central Meridian

K = 13178320.6222 m (mapping radius at the equator)

--(See Figure 3)

R_b = 9199785.5932 m (mapping radius at grid origin)

R = radius of the cone for the latitude of the station

(Longitude is greater than 79 degrees when Easting is less than 609601.2199 and less than 79 degrees when Easting is greater than 609601.2199)

(B_s, B_n, B_b, and L_o in degrees: minutes. Linear units in meters.)

(For a more detailed explanation of the North Carolina constants, the NOAA manual NOS NGS 5--State Plane Coordinate Syst 1983 by James E. Stem is an excellent source. See page 79 for information on how to obtain this manual.)

LAMBERT COORDINATES (Northing/Easting) FROM GEODETIC POSITIONS (Latitude/Longitude)

Θ (theta) = $(L_o - L)\,\ell$

$E = R\,(\sin\Theta) + E_o$

$N = R_b - R\,(\cos\Theta) + N_b$

Example: NCGS "SUB"

Latitude = 35° 24′ 39.45944″ Longitude = 79° 59′ 44.05158″

(theta) $\Theta = (L_o - L)\,\ell$

Θ = (79° 00′ 00″ - 79° 59′ 44.05158) .577170255241

Θ = $^{-}$0° 34′ 28.60796

$E = R\,(\sin\Theta) + E_o$ (Note: R is interpolated from tables)

E = 9015534.859 (sin $^{-}$0° 34′ 28.60796″) + 609601.2199

E = 519186.888 meters

$N = R_b - R\,(\cos\Theta) + N_b$

N = 9199785.5932 - 9015534.859 (cos $^{-}$0° 34′ 28.60796″) + 0.000

N = 184704.115 meters

Lo = Longitude of Central Meridian (79° 00′)

Eo = False Easting of Central Meridian (609601.2199 meters)

E = Easting of Point (meters)

Rb = Mapping radius of Central Meridian (9199785.5932 meters)

N = Northing of Point (meters)

Nb = Northing value of grid origin (0.000)

Θ = theta (mapping angle)

ℓ = 0.577170255241

R = radius of the cone for the longitude of the station

WARNING: Use sufficient significant digits for trig. functions.

GEODETIC POSITIONS (Latitude/Longitude) FROM LAMBERT COORDINATES (Northing/Easting)

$\tan(\Theta) = (E - E_o)/((R_b - (N - N_b))$

$R = (R_b - (N - N_b))/\cos(\Theta)$

Longitude = L_o - theta/ℓ

ϕ from table using R

EXAMPLE: NCGS "JIM"

N = 184,809.724 meters E = 518,664.028 meters

$$\tan \Theta\,(\text{theta}) = \frac{E - Eo}{Rb - (N - Nb)}$$

$$\tan \Theta = \frac{518664.028 - 609601.2199}{9199785.5932 - (184809.724 - 0.000)}$$

$$= -0^\circ\ 34'\ 40.59415''$$

$$R = \frac{(Rb - (N - Nb))}{\cos \Theta}$$

$$R = \frac{9199785.5932 - (184809.724 - 0)}{\cos - 0^\circ\ 34'\ 40.59415''} = 9015434.515$$

From tables, interpolate radius to obtain Latitude.

Radius at "JIM" = 9015434.515 meters

From tables: 35° 24' R = 9016750.806
35° 25' R = 9014901.900

From tables, the radius decreases 30.81510 meters per second of latitude.

We can see that the radius at "JIM" is between 35° 24' and 35° 25'. By interpolation, we determine the latitude.

9016750.806 - 9015434.515 = 1316.291

$$\frac{1316.291}{30.81510} = 42.7158'' \text{ of latitude}$$

Latitude of "JIM" = 35° 24' 42.7158"

(Longitude) $\lambda = L_o - \frac{\Theta \text{ (theta)}}{\ell}$

$\lambda = 79^\circ\ 00'\ 00'' - \frac{^{-}2080.59415'}{.577170255241}$ (Note: convert theta to seconds)

$\lambda = 79^\circ\ 00'\ 00'' - {}^{-}1^\circ\ 00'\ 04.818736$

(Longitude) $\lambda = 80^\circ\ 00'\ 04.818736''$

Lo = Longitude of Central Meridian (79° 00′)

Eo = False Easting of Central Meridian (609601.2199 meters)

E = Easting of Point (meters)

Rb = Mapping radius of Central Meridian (9199785.5932 meters)

N = Northing of Point (meters)

Nb = Northing value of grid origin (0.000)

Θ = theta (mapping angle)

ℓ = 0.577170255241

R = radius of the cone for the longitude of the station

WARNING: Use sufficient significant digits for trig. functions.

NORTH CAROLINA
Lambert conformal conic projection tables

Lat	R (meters)	tab diff.	k=scale factor
33 45'	9199785.593	30.81699	1.00021249
33 46	9197936.574	30.81685	1.00020500
33 47	9196087.563	30.81671	1.00019761
33 48	9194238.560	30.81656	1.00019029
33 49	9192389.566	30.81643	1.00018306
33 50	9190540.581	30.81629	1.00017591
33 51	9188691.603	30.81616	1.00016884
33 52	9186842.634	30.81603	1.00016185
33 53	9184993.672	30.81590	1.00015495
33 54	9183144.718	30.81577	1.00014813
33 55	9181295.772	30.81565	1.00014140
33 56	9179446.833	30.81553	1.00013474
33 57	9177597.901	30.81541	1.00012817
33 58	9175748.976	30.81530	1.00012169
33 59	9173900.058	30.81519	1.00011528
34 0	9172051.147	30.81508	1.00010896
34 1	9170202.242	30.81497	1.00010272
34 2	9168353.344	30.81486	1.00009657
34 3	9166504.452	30.81476	1.00009050
34 4	9164655.566	30.81466	1.00008451
34 5	9162806.687	30.81457	1.00007860
34 6	9160957.813	30.81447	1.00007278
34 7	9159108.944	30.81438	1.00006704
34 8	9157260.081	30.81429	1.00006139
34 9	9155411.224	30.81420	1.00005581
34 10	9153562.372	30.81412	1.00005032
34 11	9151713.525	30.81404	1.00004492
34 12	9149864.682	30.81396	1.00003959
34 13	9148015.845	30.81388	1.00003435
34 14	9146167.012	30.81381	1.00002919
34 15	9144318.183	30.81374	1.00002412
34 16	9142469.359	30.81367	1.00001913
34 17	9140620.539	30.81360	1.00001422
34 18	9138771.722	30.81354	1.00000940
34 19	9136922.910	30.81348	1.00000466

NORTH CAROLINA
Lambert conformal conic projection tables

Lat	R (meters)	tab diff.	k=scale factor
34 20'	9135074.101	30.81342	1.00000000
34 21	9133225.296	30.81337	0.99999543
34 22	9131376.494	30.81331	0.99999093
34 23	9129527.695	30.81326	0.99998653
34 24	9127678.899	30.81321	0.99998220
34 25	9125830.106	30.81317	0.99997796
34 26	9123981.316	30.81313	0.99997381
34 27	9122132.529	30.81309	0.99996973
34 28	9120283.743	30.81305	0.99996574
34 29	9118434.961	30.81301	0.99996183
34 30	9116586.180	30.81298	0.99995801
34 31	9114737.401	30.81295	0.99995427
34 32	9112888.624	30.81292	0.99995061
34 33	9111039.848	30.81290	0.99994704
34 34	9109191.074	30.81288	0.99994355
34 35	9107342.301	30.81286	0.99994014
34 36	9105493.530	30.81284	0.99993682
34 37	9103644.759	30.81283	0.99993358
34 38	9101795.990	30.81282	0.99993043
34 39	9099947.221	30.81281	0.99992736
34 40	9098098.452	30.81280	0.99992437
34 41	9096249.684	30.81280	0.99992146
34 42	9094400.916	30.81280	0.99991864
34 43	9092552.149	30.81280	0.99991591
34 44	9090703.381	30.81280	0.99991325
34 45	9088854.613	30.81281	0.99991068
34 46	9087005.844	30.81282	0.99990820
34 47	9085157.075	30.81283	0.99990579
34 48	9083308.305	30.81284	0.99990348
34 49	9081459.535	30.81286	0.99990124
34 50	9079610.763	30.81288	0.99989909
34 51	9077761.990	30.81290	0.99989702
34 52	9075913.216	30.81293	0.99989504
34 53	9074064.441	30.81295	0.99989314
34 54	9072215.663	30.81298	0.99989132
34 55	9070366.884	30.81302	0.99988959
34 56	9068518.103	30.81305	0.99988794
34 57	9066669.320	30.81309	0.99988638
34 58	9064820.535	30.81313	0.99988490
34 59	9062971.747	30.81317	0.99988350

NORTH CAROLINA
Lambert conformal conic projection tables

Lat	R (meters)	tab diff.	k=scale factor
35 0'	9061122.956	30.81322	0.99988219
35 1	9059274.163	30.81327	0.99988096
35 2	9057425.367	30.81332	0.99987982
35 3	9055576.568	30.81337	0.99987876
35 4	9053727.766	30.81343	0.99987778
35 5	9051878.960	30.81349	0.99987689
35 6	9050030.151	30.81355	0.99987608
35 7	9048181.338	30.81361	0.99987536
35 8	9046332.522	30.81368	0.99987472
35 9	9044483.701	30.81375	0.99987416
35 10	9042634.876	30.81382	0.99987369
35 11	9040786.047	30.81389	0.99987330
35 12	9038937.213	30.81397	0.99987300
35 13	9037088.375	30.81405	0.99987278
35 14	9035239.532	30.81413	0.99987264
35 15	9033390.684	30.81422	0.99987259
35 16	9031541.831	30.81430	0.99987263
35 17	9029692.973	30.81439	0.99987274
35 18	9027844.110	30.81449	0.99987294
35 19	9025995.240	30.81458	0.99987323
35 20	9024146.365	30.81468	0.99987360
35 21	9022297.485	30.81478	0.99987406
35 22	9020448.598	30.81488	0.99987459
35 23	9018599.705	30.81499	0.99987522
35 24	9016750.806	30.81510	0.99987593
35 25	9014901.900	30.81521	0.99987672
35 26	9013052.987	30.81532	0.99987759
35 27	9011204.068	30.81544	0.99987856
35 28	9009355.142	30.81556	0.99987960
35 29	9007506.209	30.81568	0.99988073
35 30	9005657.268	30.81580	0.99988194
35 31	9003808.320	30.81593	0.99988324
35 32	9001959.364	30.81606	0.99988463
35 33	9000110.401	30.81619	0.99988609
35 34	8998261.429	30.81632	0.99988765
35 35	8996412.450	30.81646	0.99988928
35 36	8994563.462	30.81660	0.99989100
35 37	8992714.466	30.81674	0.99989281
35 38	8990865.461	30.81689	0.99989470
35 39	8989016.448	30.81704	0.99989668

NORTH CAROLINA
Lambert conformal conic projection tables

Lat	R (meters)	tab diff.	k=scale factor
35 40'	8987167.426	30.81719	0.99989874
35 41	8985318.395	30.81734	0.99990088
35 42	8983469.355	30.81749	0.99990311
35 43	8981620.305	30.81765	0.99990543
35 44	8979771.246	30.81781	0.99990782
35 45	8977922.177	30.81798	0.99991031
35 46	8976073.098	30.81814	0.99991288
35 47	8974224.010	30.81831	0.99991553
35 48	8972374.911	30.81848	0.99991827
35 49	8970525.802	30.81866	0.99992109
35 50	8968676.683	30.81883	0.99992400
35 51	8966827.553	30.81901	0.99992699
35 52	8964978.412	30.81919	0.99993007
35 53	8963129.260	30.81938	0.99993323
35 54	8961280.097	30.81957	0.99993648
35 55	8959430.923	30.81976	0.99993981
35 56	8957581.738	30.81995	0.99994323
35 57	8955732.541	30.82014	0.99994673
35 58	8953883.333	30.82034	0.99995032
35 59	8952034.112	30.82054	0.99995399
36 0	8950184.880	30.82074	0.99995775
36 1	8948335.635	30.82095	0.99996159
36 2	8946486.378	30.82116	0.99996552
36 3	8944637.109	30.82137	0.99996953
36 4	8942787.826	30.82158	0.99997363
36 5	8940938.531	30.82180	0.99997781
36 6	8939089.224	30.82202	0.99998208
36 7	8937239.903	30.82224	0.99998643
36 8	8935390.568	30.82246	0.99999087
36 9	8933541.220	30.82269	0.99999539
36 10	8931691.859	30.82292	1.00000000
36 11	8929842.484	30.82315	1.00000469
36 12	8927993.095	30.82339	1.00000947
36 13	8926143.692	30.82362	1.00001434
36 14	8924294.274	30.82386	1.00001929
36 15	8922444.843	30.82411	1.00002432
36 16	8920595.396	30.82435	1.00002944
36 17	8918745.935	30.82460	1.00003465
36 18	8916896.459	30.82485	1.00003994
36 19	8915046.968	30.82510	1.00004532

NORTH CAROLINA
Lambert conformal conic projection tables

Lat	R (meters)	tab diff.	k=scale factor
36 20'	8913197.462	30.82536	1.00005078
36 21	8911347.941	30.82562	1.00005633
36 22	8909498.404	30.82588	1.00006196
36 23	8907648.851	30.82614	1.00006768
36 24	8905799.283	30.82641	1.00007349
36 25	8903949.698	30.82668	1.00007938
36 26	8902100.098	30.82695	1.00008535
36 27	8900250.481	30.82722	1.00009141
36 28	8898400.847	30.82750	1.00009756
36 29	8896551.197	30.82778	1.00010379
36 30	8894701.531	30.82806	1.00011011
36 31	8892851.847	30.82835	1.00011651
36 32	8891002.146	30.82864	1.00012300
36 33	8889152.428	30.82893	1.00012958
36 34	8887302.692	30.82922	1.00013624
36 35	8885452.939	30.82951	1.00014298
36 36	8883603.168	30.82981	1.00014982
36 37	8881753.380	30.83011	1.00015674
36 38	8879903.573	30.83042	1.00016374
36 39	8878053.748	30.83072	1.00017083
36 40	8876203.904	30.83103	1.00017800

North Carolina Geodetic Survey
EDM Baselines

N.C. Geodetic Survey maintains 14 EDM baselines in North Carolina. We have received requests for baseline information and instructions on how to properly use the baselines. Looking at the published baseline information sheet, you see that two distances (slope mk/mk and horizontal) are given for each section of the baseline. To isolate the error in your EDM and prism, the slope mk/mk distance should be used. This can be accomplished by setting your EDM and prism at the same height above the baseline marks. Be sure you have the proper atmospheric and prism constant set into your EDM, the displayed distance should match the published slope mk/mk distance. By using this method, you isolate the EDM and prism from any other factors that might create error. If the slope mk/mk distance matches within tolerance, you can then reduce the slope distance to horizontal and make that comparison.

Some guidelines we use at NCGS when testing our EDM equipment:

1. Use the same prism at the baseline as you do in the field with your EDM.

2. Set the EDM and prism on tripods to insure stable conditions during the measurements. Don't use a range pole to mount a prism until you have confirmed that your EDM is working properly.

3. Document all results of your EDM test for future reference.

4. Don't panic if your EDM doesn't operate within tolerance. Check your prism constant and atmospheric correction to make sure they have been entered properly. Check with NCGS to insure that the monuments haven't been disturbed.

The baseline at Raeford was monumented by NCGS, calibrated by NGS and paid for by local firms and individuals from the Fayetteville/Raeford area.

There is another baseline in Hamlet that was established by Rice International in 1974 and remeasured by NGS in 1980. Information and data for this line is on file at the NCSS (N.C. Society of Surveyors) and NCGS offices.

Please maintain strict safety precautions at all times when driving or walking along taxiways and runways. Most authorities would prefer that, after determining there are no take-off or landing approaches in progress, you drive along the edge of runway pavement rather than the grassy areas, especially when ground is soft. Park vehicles completely out of flight paths when measuring distances. If any incident occurs which you feel airport authorities should be aware of, please do not hesitate to notify local authorities and our NCGS office.

The National Geodetic Survey no longer has the funds nor field personnel to reimburse and calibrate baselines every five years as required. We would very much appreciate your sending a copy of any measurements you make to NCGS so that a permanent file on each baseline may be maintained for determining stability of marks and rate of usage of each line.

Additional site information:

Asheville	- Along state right-of-way near Dreamland Drive-In
Hendersonville	- Destroyed by Construction.
Hamlet	- must check in with airport manager's office before measuring.
Maple	- same as above.
Statesville	- same as above.
Franklin	- same as above.
Raeford	- there is no gate; usually there is someone there.
Wallace	- seldom anyone on premises, but gate is open during the day.
Everetts	- gate is locked when no one there, but usually there is an attendant in the hangar; also, only a short walk to runway.
Marion	- check with airport manager or personnel in hangar before measuring.
Shelby	- check with airport manager before measuring; gate locked after 5 pm.
Whiteville	- check with airport manager before measuring; gate locked after 5 pm.
Jefferson	- check with airport manager before measuring.
Manteo	- check with airport manager before measuring.
Maple (Currituck Co.)	- check with airport manager before measuring.

The data results are given in meters for slope distance mark to mark <u>and</u> horizontal distance between each mark. Distances in feet may be obtained by multiplying by 3.2808333333...

North Carolina Department of Environment and Natural Resources

GEODETIC SURVEY

Home About NCGS Contact

Statewide Electronic Distance Measuring Instrument (EDMI) Calibration Baselines have been established across the state of North Carolina. GPS. To obtain the data files for the Baseline, click on the symbol of the Baseline you are interested in. If you have any questions or comments, please contact Gary Thompson gary.thompson@ncdenr.gov by e-mail or by phone at (919)733-3836.

NC EDM CALIBRATION BASELINES

NC Geodetic Survey . DENR-Division of Land Resources. 512 N. Salisbury Street Raleigh, NC 27604 . (919) 733-3836

Raleigh EDM Calibration Baseline

FROM STATION	TO STATION	HOR DIST (M)	MARK TO MARK (M)	STD ERROR (MM)
RALEIGH 000	RALEIGH 150	149.9473	149.9710	0.1
RALEIGH 000	RALEIGH 400	399.8802	399.9615	0.2
RALEIGH 000	RALEIGH 1400	1399.9235	1399.9615	0.3
RALEIGH 150	RALEIGH 400	249.9329	249.9913	0.1
RALEIGH 150	RALEIGH 1400	1249.9760	1249.9994	0.2
RALEIGH 400	RALEIGH 1400	1000.0427	1000.0452	0.2

STATION	NGVD 29 ELEVATION IN METERS
RALEIGH 000	95.440
RALEIGH 150	92.778
RALEIGH 400	87.377
RALEIGH 1400	85.134

The base line is located about 13.4 KM (8.3 MI) southwest of Wake Forest, 11.3 KM (7.0 MI) northeast of Raleigh and 3.7 KM (2.3 MI) northeast of the junction of U.S. highways 1 and 401. The base line runs along and is approximately parallel with a metal right-of-way fence that borders the western edge of U.S. 1 and the eastern edge of U.S. highway 1 service road.

The base line is a northeast-southwest line with the 0 meter point on the southwest end. It consists of the 0, 150, 400 and 1400 meter points. The base line disks are North Carolina Geodetic Survey triangulation disks.

To reach the 0 meter point from U.S. highway 1 bridge over U.S. highway 401, located on the north side of Raleigh, go north on U.S. highway 1 (Capital Boulevard) for 3.4 KM (21. MI) to the intersection of Old Wake Forest Road on the left. Turn left and go westerly on Old Wake Forest Road for 0.10 KM (0.06 MI) to the intersection of U.S. highway 1 service road on the right. Turn right then bear right and go east following a metal right-of-way fence for 0.10 KM (0.06 MI) to the 0 meter point near the right-of-way fence corner.

The 0 meter point is a North Carolina Geodetic Survey disk stamped "RALEIGH 000" set in the top of a 28 cm (11 in) diameter concrete post recessed 2.5 cm (1 in) below the surface of the ground. It is 43.2 meters (141.7 feet) southwest of a wooden utility pole with an aluminum reference tag, 35.0 meters (114.8 feet) southeast of the centerline of the frontage road, 21.5 meters (70.5 feet) north of a wooden utility pole with an aluminum reference tag and 8.2 meters (26.9 feet) west of a metal witness post at the right-of-way fence corner.

The 150 meter point is a North Carolina Geodetic Survey disk stamped "RALEIGH 150" set in the top of a 25 cm (10 in) diameter concrete post recessed 2.5 cm (1 in) below the surface of the ground. It is 51.5 meters (169.0 feet) northeast of a wooden utility pole with an aluminum reference tag, 17.3 meters (56.8 feet) southeast of the centerline of the frontage road, 10.0 meters (32.8 feet) southwest of a wooden utility pole with an aluminum reference tag and 8.2 meters (26.9 feet) northwest of a fiberglass witness post in the metal right-of-way fence.

The 400 meter point is a North Carolina Goedetic Survey disk stamped "RALEIGH 400" set in the top of a 33 cm (13 in) diameter concrete post flush with the surface of the ground. It is 9.4 meters (30.8 feet) west of a wooden utility pole with an aluminum reference tag, 7.8 meters (25.6 feet) northwest of a fiberglass witness post in the metal right-of-way fence and 6.7 meters (22.0 feet) southeast of the centerline of the frontage road.

The 1400 meter point is a North Carolina Geodetic Survey disk stamped "RALEIGH 1400" set in the top of a 33 cm (13 in) diameter concrete post flush with the surface of the ground. It is 59.0 meters (193.6 feet) southwest of the extended southern entrance drive centerline for the Mill Outlet Village, 9.7 meters (31.8 feet) southeast of the centerline of the frontage road and 4.7 meters (15.4 feet) northwest of a fiberglass witness post in the metal right-of-way fence.

CBL users should take care in plumbing over all points. Elevations are for CBL use only. Traffic on both highways is heavy; saftey precautions are recommended.

United States Department of the Interior

GEOLOGICAL SURVEY
BOX 25046 M.S. 968
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY REFER TO:

Branch of Global Seismology and Geomagnetism

Values of Magnetic Declination

These tables give the estimated values of magnetic declination at each degree of latitude and longitude covering the area of interest of your inquiry. Where available the values are given from 1750 to 1900 at ten-year intervals, and from 1900 to 1995 at five-year intervals, in degrees and minutes of arc. Values for intervening years may be found by interpolation; similarly, values for a few years beyond 1995 may be derived by extrapolation.

Values of declination prior to 1955 were derived using the source data of Table 4 of Coast and Geodetic Survey Publication 40-2, "United States Magnetic Tables for 1960." Values from 1955 through 1967.5 were derived from the 3077 Magnetic Chart Series of the Coast and Geodetic Survey for 1955, 1960, and 1965. Values of declination from 1967.5 through 1972.5 were obtained using the model for USGS Map I-911, Magnetic Declination in the United States - Epoch 1975.0. Values from 1972.5 to 1984.5 were derived using the model for USGS Map I-1283, Magnetic Declination in the United States - Epoch 1980.0 Declination values subsequent to 1984.5 were obtained using the U.S. Spherical Harmonic Models for 1985 and 1990 (USCON85 and USCON90) of the U.S. Geological Survey Branch of Global Seismology and Geomagnetism.

The accuracy of the 1995 values is generally within one-half degree, but natural or artificial disturbances could cause differences of several degrees. The values of declination have been given to the nearest minute so that secular change may be properly illustrated.

The accuracy of the secular change for the more recent decades is probably within a few minutes for a ten-year period. For the earlier part of the table the secular change is less reliable.

U.S. Geological Survey (GS&G)
Mail Stop 968
Box 25046, Denver Federal Center
Denver, CO 80225-0046

V A L U E S   O F   M A G N E T I C   D E C L I N A T I O N

LAT	33	33	33	33	33	33	33	33	33	LAT
LONG	75	74	73	72	71	70	69	68	67	LONG
1750	na	na	na	na	na	na	na	na	na	1750
1760	na	na	na	na	na	na	na	na	na	1760
1770	na	na	na	na	na	na	na	na	na	1770
1780	na	na	na	na	na	na	na	na	na	1780
1790	na	na	na	na	na	na	na	na	na	1790
1800	na	na	na	na	na	na	na	na	na	1800
1810	na	na	na	na	na	na	na	na	na	1810
1820	na	na	na	na	na	na	na	na	na	1820
1830	na	na	na	na	na	na	na	na	na	1830
1840	na	na	na	na	na	na	na	na	na	1840
1850	na	na	na	na	na	na	na	na	na	1850
1860	na	na	na	na	na	na	na	na	na	1860
1870	na	na	na	na	na	na	na	na	na	1870
1880	na	na	na	na	na	na	na	na	na	1880
1890	na	na	na	na	na	na	na	na	na	1890
1900	na	na	na	na	na	na	na	na	na	1900
1905	na	na	na	na	na	na	na	na	na	1905
1910	na	na	na	na	na	na	na	na	na	1910
1915	na	na	na	na	na	na	na	na	na	1915
1920	na	na	na	na	na	na	na	na	na	1920
1925	na	na	na	na	na	na	na	na	na	1925
1930	na	na	na	na	na	na	na	na	na	1930
1935	na	na	na	na	na	na	na	na	na	1935
1940	na	na	na	na	na	na	na	na	na	1940
1945	na	na	na	na	na	na	na	na	na	1945
1950	na	na	na	na	na	na	na	na	na	1950
1955	na	na	na	na	na	na	na	na	na	1955
1960	na	na	na	na	na	na	na	na	na	1960
1965	na	na	na	na	na	na	na	na	na	1965
1970	na	na	na	na	na	na	na	na	na	1970
1975	na	na	na	na	na	na	na	na	na	1975
1980	na	na	na	na	na	na	na	na	na	1980
1985	8 46W	9 31W	10 14W	10 57W	11 38W	12 18W	12 56W	13 33W	14 9W	1985
1990	9 17W	10 0W	10 42W	11 23W	12 3W	12 41W	13 17W	13 52W	14 25W	1990
1995	9 47W	10 29W	11 9W	11 49W	12 26W	13 3W	13 37W	14 10W	14 41W	1995

TABLE PREPARED BY NATIONAL GEOPHYSICAL DATA CENTER,
N E S D I S, N O A A.   12/18/1991

VALUES OF MAGNETIC DECLINATION

LAT	33	33	33	33	33	33	33	33	33	LAT
LONG	84	83	82	81	80	79	78	77	76	LONG
1750	2 57E	2 38E	2 20E	2 2E	1 43E	1 19E	na	na	na	1750
1760	3 34	3 14	2 56	2 38	2 18	1 53	na	na	na	1760
1770	4 9	3 49	3 30	3 11	2 51	2 25	na	na	na	1770
1780	4 42	4 21	4 1	3 40	3 18	2 51	na	na	na	1780
1790	5 8	4 45	4 23	4 1	3 38	3 9	na	na	na	1790
1800	5 26	5 2	4 39	4 15	3 49	3 18	na	na	na	1800
1810	5 36	5 10	4 46	4 20	3 52	3 19	na	na	na	1810
1820	5 37	5 10	4 44	4 16	3 47	3 13	na	na	na	1820
1830	5 31	5 1	4 34	4 4	3 33	2 57	na	na	na	1830
1840	5 15	4 44	4 14	3 44	3 11	2 33	na	na	na	1840
1850	4 53	4 20	3 49	3 17	2 42	2 3	na	na	na	1850
1860	4 23	3 49	3 18	2 45	2 9	1 30	na	na	na	1860
1870	3 49	3 14	2 41	2 7	1 31	0 51	na	na	na	1870
1880	3 10	2 35	2 2	1 29	0 53	0 14E	na	na	na	1880
1890	2 30	1 57	1 25	0 52	0 17E	0 22W	na	na	na	1890
1900	2 0	1 26	0 53	0 20	0 15W	0 55	na	na	na	1900
1905	1 53	1 17	0 42	0 8E	0 29	1 10	na	na	na	1905
1910	1 43	1 5	0 29	0 8W	0 46	1 28	na	na	na	1910
1915	1 40	1 1	0 23	0 15	0 56	1 40	na	na	na	1915
1920	1 40	0 59	0 20	0 20	1 2	1 47	na	na	na	1920
1925	1 32	0 51	0 11	0 31	1 14	2 1	na	na	na	1925
1930	1 26	0 44	0 2E	0 40	1 25	2 13	na	na	na	1930
1935	1 24	0 40	0 2W	0 46	1 32	2 22	na	na	na	1935
1940	1 33	0 48	0 4E	0 41	1 28	2 18	na	na	na	1940
1945	1 35	0 50	0 6	0 40	1 28	2 19	na	na	na	1945
1950	1 36	0 50	0 6E	0 41	1 29	2 21	na	na	na	1950
1955	1 26	0 39	0 6W	0 53	1 41	2 33	na	na	na	1955
1960	1 8	0 22E	0 24	1 11	1 59	2 51	na	na	na	1960
1965	0 42	0 5W	0 50	1 37	2 25	3 17	na	na	na	1965
1970	0 9E	0 38	1 24	2 10	2 58	3 49	na	na	na	1970
1975	0 34W	1 20	2 6	2 52	3 39	4 29	na	na	na	1975
1980	1 21W	2 7W	2 52W	3 38W	4 25W	5 14W	na	na	na	1980
1985	1 49W	2 35W	3 21W	4 8W	4 55W	5 42W	6 28W	7 15W	8 1W	1985
1990	2 24W	3 11W	3 57W	4 43W	5 30W	6 16W	7 2W	7 48W	8 33W	1990
1995	3 0W	3 46W	4 32W	5 18W	6 5W	6 50W	7 35W	8 20W	9 4W	1995

TABLE PREPARED BY NATIONAL GEOPHYSICAL DATA CENTER,
N E S D I S, N O A A. 12/18/1991

V A L U E S   O F   M A G N E T I C   D E C L I N A T I O N

LAT	34	34	34	34	34	34	34	34	34	LAT
LONG	79	78	77	76	75	74	73	72	71	LONG
1750	0 58E	0 35E	0 15E	0 5W	na	na	na	na	na	1750
1760	1 33	1 9	0 49	0 28E	na	na	na	na	na	1760
1770	2 5	1 40	1 18	0 56	na	na	na	na	na	1770
1780	2 32	2 5	1 41	1 17	na	na	na	na	na	1780
1790	2 50	2 22	1 56	1 30	na	na	na	na	na	1790
1800	3 0	2 30	2 1	1 32	na	na	na	na	na	1800
1810	3 2	2 30	1 59	1 28	na	na	na	na	na	1810
1820	2 55	2 22	1 49	1 16	na	na	na	na	na	1820
1830	2 39	2 4	1 30	0 55	na	na	na	na	na	1830
1840	2 16	1 39	1 4	0 28E	na	na	na	na	na	1840
1850	1 45	1 7	0 31E	0 6W	na	na	na	na	na	1850
1860	1 12	0 33E	0 4W	0 42	na	na	na	na	na	1860
1870	0 33E	0 7W	0 44	1 22	na	na	na	na	na	1870
1880	0 5W	0 43	1 20	1 57	na	na	na	na	na	1880
1890	0 41	1 19	1 54	2 30	na	na	na	na	na	1890
1900	1 14	1 53	2 28	3 4	na	na	na	na	na	1900
1905	1 30	2 9	2 47	3 24	na	na	na	na	na	1905
1910	1 49	2 30	3 9	3 48	na	na	na	na	na	1910
1915	2 1	2 44	3 25	4 6	na	na	na	na	na	1915
1920	2 9	2 53	3 36	4 19	na	na	na	na	na	1920
1925	2 23	3 9	3 54	4 38	na	na	na	na	na	1925
1930	2 36	3 23	4 9	4 55	na	na	na	na	na	1930
1935	2 45	3 34	4 21	5 8	na	na	na	na	na	1935
1940	2 42	3 31	4 20	5 8	na	na	na	na	na	1940
1945	2 42	3 33	4 23	5 12	na	na	na	na	na	1945
1950	2 43	3 34	4 25	5 15	na	na	na	na	na	1950
1955	2 54	3 45	4 36	5 26	na	na	na	na	na	1955
1960	3 10	4 1	4 51	5 41	na	na	na	na	na	1960
1965	3 35	4 26	5 15	6 4	na	na	na	na	na	1965
1970	4 6	4 56	5 45	6 33	na	na	na	na	na	1970
1975	4 46	5 35	6 22	7 9	na	na	na	na	na	1975
1980	5 30W	6 18W	7 4W	7 49W	na	na	na	na	na	1980
1985	6 0W	6 48W	7 35W	8 21W	9 7W	9 52W	10 36W	11 18W	12 0W	1985
1990	6 34W	7 20W	8 6W	8 52W	9 36W	10 20W	11 2W	11 43W	12 23W	1990
1995	7 7W	7 53W	8 38W	9 22W	10 5W	10 47W	11 28W	12 7W	12 45W	1995

TABLE PREPARED BY NATIONAL GEOPHYSICAL DATA CENTER,
N E S D I S, N O A A.   12/18/1991

V A L U E S   O F   M A G N E T I C   D E C L I N A T I O N

LAT	34	34	34	34	34	34	34	34	34	LAT
LONG	88	87	86	85	84	83	82	81	80	LONG
1750	4 11E	3 48E	3 25E	3 2E	2 43E	2 22E	2 4E	1 43E	1 20E	1750
1760	4 49	4 26	4 3	3 40	3 20	2 59	2 41	2 19	1 56	1760
1770	5 28	5 4	4 41	4 17	3 56	3 35	3 16	2 54	2 30	1770
1780	6 3	5 39	5 15	4 51	4 30	4 7	3 47	3 23	2 58	1780
1790	6 33	6 8	5 43	5 18	4 56	4 32	4 10	3 45	3 18	1790
1800	6 57	6 31	6 5	5 38	5 15	4 49	4 26	3 59	3 30	1800
1810	7 14	6 46	6 18	5 50	5 25	4 58	4 33	4 4	3 33	1810
1820	7 22	6 52	6 23	5 53	5 26	4 57	4 31	4 0	3 28	1820
1830	7 22	6 51	6 20	5 48	5 19	4 49	4 21	3 48	3 14	1830
1840	7 14	6 41	6 8	5 34	5 3	4 31	4 1	3 27	2 52	1840
1850	6 58	6 23	5 48	5 12	4 40	4 6	3 35	3 0	2 23	1850
1860	6 35	5 58	5 21	4 44	4 10	3 36	3 4	2 28	1 50	1860
1870	6 6	5 28	4 50	4 11	3 36	3 0	2 27	1 50	1 12	1870
1880	5 28	4 49	4 10	3 31	2 56	2 20	1 47	1 11	0 33E	1880
1890	4 47	4 8	3 29	2 51	2 16	1 41	1 9	0 34	0 4W	1890
1900	4 19	3 39	2 59	2 20	1 45	1 9	0 36	0 1E	0 37	1900
1905	4 17	3 35	2 54	2 14	1 37	1 0	0 25	0 12W	0 51	1905
1910	4 13	3 29	2 46	2 5	1 27	0 48	0 10	0 28	1 8	1910
1915	4 15	3 30	2 46	2 3	1 23	0 42	0 3E	0 37	1 19	1915
1920	4 16	3 31	2 46	2 2	1 22	0 40	0 1W	0 42	1 25	1920
1925	4 10	3 25	2 39	1 55	1 13	0 31	0 11	0 53	1 38	1925
1930	4 8	3 21	2 35	1 49	1 7	0 23	0 20	1 3	1 49	1930
1935	4 10	3 22	2 34	1 48	1 4	0 19	0 24	1 10	1 57	1935
1940	4 20	3 32	2 44	1 57	1 13	0 27	0 18	1 4	1 52	1940
1945	4 24	3 36	2 48	2 0	1 15	0 29	0 16	1 3	1 52	1945
1950	4 28	3 39	2 50	2 2	1 17	0 30	0 16	1 3	1 52	1950
1955	4 20	3 31	2 42	1 54	1 8	0 20	0 26	1 14	2 3	1955
1960	4 4	3 15	2 26	1 38	0 52	0 4E	0 43	1 30	2 19	1960
1965	3 39	2 50	2 1	1 12	0 26E	0 22W	1 9	1 56	2 45	1965
1970	3 9	2 19	1 30	0 41E	0 6W	0 54	1 40	2 28	3 16	1970
1975	2 28	1 38	0 49	0 1W	0 48	1 35	2 22	3 8	3 57	1975
1980	1 41E	0 51E	0 1E	0 48W	1 35W	2 22W	3 8W	3 54W	4 42W	1980
1985	0 58E	0 14E	0 31W	1 16W	2 3W	2 50W	3 37W	4 25W	5 13W	1985
1990	0 25E	0 20W	1 5W	1 51W	2 38W	3 25W	4 12W	5 0W	5 47W	1990
1995	0 8W	0 54W	1 40W	2 26W	3 13W	4 0W	4 47W	5 34W	6 21W	1995

TABLE PREPARED BY NATIONAL GEOPHYSICAL DATA CENTER,
N E S D I S, N O A A. 12/18/1991

V A L U E S O F M A G N E T I C D E C L I N A T I O N

LAT	35	35	35	35	35	35	35	35	35	LAT
LONG	83	82	81	80	79	78	77	76	75	LONG
1750	2 4E	1 44E	1 21E	0 57E	0 34E	0 10E	0 12W	0 33W	na	1750
1760	2 42	2 22	1 59	1 34	1 10	0 45	0 23E	0 1E	na	1760
1770	3 19	2 58	2 34	2 9	1 43	1 17	0 53	0 30	na	1770
1780	3 51	3 29	3 4	2 38	2 10	1 43	1 17	0 51	na	1780
1790	4 17	3 53	3 27	2 59	2 30	2 1	1 32	1 5	na	1790
1800	4 35	4 10	3 42	3 12	2 41	2 10	1 38	1 8	na	1800
1810	4 43	4 17	3 47	3 15	2 43	2 10	1 37	1 4	na	1810
1820	4 43	4 15	3 43	3 10	2 36	2 2	1 27	0 52	na	1820
1830	4 34	4 5	3 31	2 56	2 20	1 44	1 7	0 31	na	1830
1840	4 16	3 45	3 10	2 34	1 56	1 19	0 41	0 4E	na	1840
1850	3 51	3 19	2 43	2 5	1 26	0 47	0 8E	0 31W	na	1850
1860	3 21	2 47	2 10	1 31	0 52	0 12E	0 28W	1 7	na	1860
1870	2 45	2 10	1 32	0 53	0 13E	0 28W	1 8	1 47	na	1870
1880	2 5	1 30	0 53	0 13E	0 26W	1 5	1 44	2 22	na	1880
1890	1 25	0 51	0 15E	0 23W	1 2	1 41	2 18	2 55	na	1890
1900	0 53	0 18	0 18W	0 57	1 36	2 16	2 53	3 30	na	1900
1905	0 43	0 7E	0 31	1 11	1 51	2 32	3 12	3 51	na	1905
1910	0 31	0 7W	0 47	1 29	2 11	2 53	3 34	4 15	na	1910
1915	0 24	0 16	0 57	1 40	2 24	3 8	3 51	4 33	na	1915
1920	0 20	0 21	1 4	1 48	2 33	3 18	4 3	4 47	na	1920
1925	0 10	0 32	1 16	2 2	2 48	3 35	4 21	5 7	na	1925
1930	0 1E	0 42	1 27	2 14	3 1	3 50	4 37	5 24	na	1930
1935	0 3W	0 47	1 34	2 21	3 10	4 0	4 49	5 37	na	1935
1940	0 5E	0 41	1 28	2 17	3 7	3 58	4 48	5 37	na	1940
1945	0 7	0 39	1 27	2 16	3 7	3 59	4 50	5 40	na	1945
1950	0 9	0 38	1 26	2 16	3 8	4 0	4 52	5 43	na	1950
1955	~~na~~ 0 6E	0 47	1 36	2 26	3 17	4 10	5 2	5 53	na	1955
1960	0 15W	1 3	1 51	2 41	3 33	4 25	5 17	6 7	na	1960
1965	0 40	1 28	2 16	3 6	3 57	4 48	5 39	6 29	na	1965
1970	1 11	1 58	2 46	3 35	4 26	5 17	6 7	6 56	na	1970
1975	1 51	2 38	3 25	4 14	5 3	5 54	6 42	7 30	na	1975
1980	2 38W	3 24W	4 11W	4 59W	5 47W	6 36W	7 23W	8 9W	na	1980
1985	3 6W	3 54W	4 43W	5 31W	6 20W	7 8W	7 55W	8 42W	9 28W	1985
1990	3 41W	4 29W	5 17W	6 5W	6 52W	7 39W	8 26W	9 12W	9 56W	1990
1995	4 15W	5 2W	5 50W	6 37W	7 24W	8 10W	8 56W	9 40W	10 24W	1995

TABLE PREPARED BY NATIONAL GEOPHYSICAL DATA CENTER,
N E S D I S, N O A A. 12/18/1991

V A L U E S O F M A G N E T I C D E C L I N A T I O N

LAT	35	35	35	35	35	35	35	35	35	LAT
LONG	92	91	90	89	88	87	86	85	84	LONG
1750	na	na	na	na	na	3 38E	3 13E	2 49E	2 28E	1750
1760	na	na	na	na	na	4 16	3 51	3 28	3 6	1760
1770	na	na	na	na	na	4 56	4 30	4 6	3 43	1770
1780	na	na	na	na	na	5 31	5 5	4 40	4 17	1780
1790	na	na	na	na	na	6 1	5 34	5 8	4 44	1790
1800	8 7E	7 53E	7 40E	7 19E	6 54E	6 24	5 56	5 29	5 3	1800
1810	8 29	8 15	8 1	7 38	7 11	6 39	6 9	5 40	5 13	1810
1820	8 45	8 28	8 12	7 48	7 19	6 46	6 14	5 43	5 14	1820
1830	8 54	8 35	8 17	7 50	7 19	6 44	6 11	5 38	5 7	1830
1840	8 53	8 32	8 11	7 43	7 11	6 34	5 59	5 24	4 51	1840
1850	8 43	8 21	7 58	7 28	6 54	6 16	5 39	5 2	4 27	1850
1860	8 27	8 2	7 37	7 6	6 30	5 50	5 11	4 33	3 57	1860
1870	8 5	7 38	7 11	6 38	6 1	5 20	4 40	4 1	3 23	1870
1880	7 31	7 3	6 34	6 0	5 22	4 41	4 0	3 21	2 43	1880
1890	6 52	6 23	5 54	5 19	4 41	3 59	3 19	2 40	2 2	1890
1900	6 27	5 57	5 27	4 51	4 12	3 29	2 48	2 9	1 31	1900
1905	6 30	5 58	5 26	4 50	4 9	3 25	2 43	2 2	1 23	1905
1910	6 32	5 59	5 25	4 47	4 4	3 19	2 35	1 53	1 12	1910
1915	6 36	6 2	5 27	4 48	4 5	3 18	2 32	1 49	1 7	1915
1920	6 38	6 3	5 28	4 49	4 5	3 18	2 31	1 47	1 4	1920
1925	6 32	5 57	5 22	4 42	3 58	3 10	2 23	1 38	0 54	1925
1930	6 31	5 56	5 20	4 39	3 54	3 6	2 18	1 32	0 47	1930
1935	6 35	5 59	5 23	4 41	3 56	3 6	2 17	1 30	0 44	1935
1940	6 43	6 8	5 32	4 51	4 5	3 16	2 27	1 39	0 52	1940
1945	6 47	6 12	5 37	4 56	4 10	3 20	2 31	1 43	0 55	1945
1950	6 50	6 16	5 41	5 0	4 14	3 24	2 34	1 45	0 58	1950
1955	6 44	6 9	5 34	4 53	4 7	3 17	2 27	1 37	0 49	1955
1960	6 30	5 55	5 20	4 38	3 52	3 2	2 12	1 22	0 34	1960
1965	6 8	5 32	4 56	4 15	3 28	2 38	1 47	0 57	0 9E	1965
1970	5 41	5 5	4 29	3 46	2 59	2 8	1 18	0 28E	0 21W	1970
1975	5 3	4 26	3 49	3 6	2 19	1 28	0 37E	0 13W	1 3	1975
1980	4 17E	3 40E	3 2E	2 19E	1 31E	0 40E	0 11W	1 1W	1 50W	1980
1985	3 41E	2 59E	2 16E	1 33E	0 48E	0 2E	0 43W	1 30W	2 18W	1985
1990	3 11E	2 28E	1 45E	1 0E	0 15E	0 31W	1 18W	2 5W	2 53W	1990
1995	2 40E	1 56E	1 12E	0 27E	0 18W	1 5W	1 52W	2 39W	3 27W	1995

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VALUES OF MAGNETIC DECLINATION

LAT	36	36	36	36	36	36	36	36	36	LAT
LONG	78	77	76	75	74	73	72	71	70	LONG
1750	0 17W	0 41W	1 4W	na	na	na	na	na	na	1750
1760	0 19E	0 5W	0 29W	na	na	na	na	na	na	1760
1770	0 52	0 26E	0 1E	na	na	na	na	na	na	1770
1780	1 18	0 50	0 23	na	na	na	na	na	na	1780
1790	1 37	1 7	0 37	na	na	na	na	na	na	1790
1800	1 47	1 14	0 41	na	na	na	na	na	na	1800
1810	1 48	1 13	0 38	na	na	na	na	na	na	1810
1820	1 40	1 3	0 26	na	na	na	na	na	na	1820
1830	1 22	0 43	0 5E	na	na	na	na	na	na	1830
1840	0 56	0 16E	0 23W	na	na	na	na	na	na	1840
1850	0 24E	0 17W	0 58	na	na	na	na	na	na	1850
1860	0 11W	0 53	1 34	na	na	na	na	na	na	1860
1870	0 51	1 33	2 14	na	na	na	na	na	na	1870
1880	1 29	2 10	2 50	na	na	na	na	na	na	1880
1890	2 5	2 44	3 23	na	na	na	na	na	na	1890
1900	2 40	3 20	3 59	na	na	na	na	na	na	1900
1905	2 57	3 39	4 19	na	na	na	na	na	na	1905
1910	3 18	4 1	4 43	na	na	na	na	na	na	1910
1915	3 34	4 19	5 3	na	na	na	na	na	na	1915
1920	3 45	4 31	5 17	na	na	na	na	na	na	1920
1925	4 2	4 50	5 37	na	na	na	na	na	na	1925
1930	4 17	5 6	5 54	na	na	na	na	na	na	1930
1935	4 28	5 18	6 7	na	na	na	na	na	na	1935
1940	4 25	5 17	6 7	na	na	na	na	na	na	1940
1945	4 27	5 19	6 10	na	na	na	na	na	na	1945
1950	4 27	5 20	6 11	na	na	na	na	na	na	1950
1955	4 36	5 29	6 20	na	na	na	na	na	na	1955
1960	4 50	5 43	6 34	na	na	na	na	na	na	1960
1965	5 12	6 4	6 54	na	na	na	na	na	na	1965
1970	5 38	6 29	7 19	na	na	na	na	na	na	1970
1975	6 14	7 3	7 52	na	na	na	na	na	na	1975
1980	6 55W	7 43W	8 30W	na	na	na	na	na	na	1980
1985	7 29W	8 17W	9 4W	9 51W	10 37W	11 21W	12 4W	12 46W	13 26W	1985
1990	7 59W	8 46W	9 32W	10 18W	11 2W	11 44W	12 26W	13 5W	13 43W	1990
1995	8 29W	9 15W	10 0W	10 43W	11 26W	12 7W	12 46W	13 24W	14 0W	1995

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V A L U E S   O F   M A G N E T I C   D E C L I N A T I O N

LAT	36	36	36	36	36	36	36	36	36	LAT
LONG	87	86	85	84	83	82	81	80	79	LONG
1750	na	3 1E	2 36E	2 13E	1 48E	1 22E	0 59E	0 34E	0 9E	1750
1760	na	3 40	3 15	2 52	2 27	2 1	1 38	1 12	0 46	1760
1770	na	4 20	3 54	3 30	3 4	2 38	2 14	1 47	1 20	1770
1780	na	4 55	4 28	4 4	3 37	3 10	2 45	2 17	1 48	1780
1790	na	5 25	4 57	4 31	4 3	3 35	3 8	2 39	2 9	1790
1800	6 18E	5 48	5 18	4 51	4 22	3 53	3 24	2 53	2 21	1800
1810	6 33	6 1	5 30	5 1	4 31	4 0	3 30	2 57	2 23	1810
1820	6 40	6 6	5 33	5 2	4 30	3 58	3 26	2 52	2 17	1820
1830	6 38	6 2	5 27	4 55	4 21	3 47	3 14	2 38	2 1	1830
1840	6 28	5 50	5 13	4 38	4 3	3 27	2 52	2 15	1 36	1840
1850	6 9	5 30	4 51	4 14	3 38	3 1	2 25	1 46	1 6	1850
1860	5 43	5 2	4 22	3 44	3 7	2 29	1 52	1 12	0 31E	1860
1870	5 13	4 31	3 49	3 9	2 31	1 52	1 14	0 33E	0 8W	1870
1880	4 33	3 51	3 9	2 29	1 51	1 12	0 34E	0 7W	0 47	1880
1890	3 51	3 9	2 27	1 48	1 10	0 32E	0 5W	0 44	1 24	1890
1900	3 20	2 38	1 56	1 16	0 38	0 1W	0 38	1 18	1 58	1900
1905	3 16	2 32	1 48	1 7	0 28	0 12	0 51	1 32	2 14	1905
1910	3 9	2 23	1 38	0 56	0 14	0 27	1 8	1 50	2 33	1910
1915	3 6	2 19	1 33	0 49	0 6	0 37	1 19	2 3	2 48	1915
1920	3 4	2 16	1 30	0 45	0 1E	0 43	1 26	2 11	2 57	1920
1925	2 56	2 7	1 20	0 34	0 11W	0 56	1 40	2 26	3 13	1925
1930	2 50	2 0	1 12	0 26	0 20	1 6	1 52	2 39	3 27	1930
1935	2 50	2 0	1 10	0 23	0 24	1 12	1 58	2 46	3 37	1935
1940	3 0	2 9	1 19	0 31	0 17	1 5	1 53	2 42	3 33	1940
1945	3 4	2 14	1 23	0 34	0 15	1 3	1 51	2 41	3 33	1945
1950	3 9	2 18	1 26	0 37	0 12	1 1	1 50	2 40	3 33	1950
1955	3 2	2 11	1 19	0 29	0 20	1 9	1 58	2 48	3 41	1955
1960	2 48	1 56	1 4	0 15E	0 35	1 24	2 13	3 3	3 56	1960
1965	2 24	1 33	0 40	0 10W	0 59	1 48	2 36	3 26	4 19	1965
1970	1 57	1 5	0 12E	0 38	1 28	2 16	3 4	3 54	4 46	1970
1975	1 16	0 24E	0 28W	1 19	2 7	2 55	3 43	4 32	5 22	1975
1980	0 28E	0 24W	1 16W	2 6W	2 54W	3 41W	4 28W	5 16W	6 5W	1980
1985	0 9W	0 56W	1 45W	2 33W	3 23W	4 12W	5 1W	5 51W	6 40W	1985
1990	0 43W	1 31W	2 19W	3 8W	3 56W	4 45W	5 34W	6 23W	7 11W	1990
1995	1 16W	2 4W	2 53W	3 41W	4 30W	5 19W	6 7W	6 55W	7 42W	1995

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V A L U E S O F M A G N E T I C D E C L I N A T I O N

LAT	37	37	37	37	37	37	37	37	37	LAT
LONG	82	81	80	79	78	77	76	75	74	LONG
1750	0 59E	0 33E	0 7E	0 20W	0 46W	1 13W	1 39W	na	na	1750
1760	1 38	1 12	0 46	0 19E	0 8W	0 37	1 3	na	na	1760
1770	2 16	1 49	1 22	0 54	0 26E	0 4W	0 32	na	na	1770
1780	2 49	2 20	1 52	1 22	0 53	0 21E	0 9W	na	na	1780
1790	3 15	2 45	2 15	1 44	1 12	0 38	0 6E	na	na	1790
1800	3 33	3 1	2 30	1 56	1 23	0 46	0 11	na	na	1800
1810	3 41	3 7	2 34	1 59	1 24	0 45	0 8E	na	na	1810
1820	3 39	3 4	2 29	1 53	1 16	0 35	0 4W	na	na	1820
1830	3 28	2 51	2 15	1 37	0 58	0 16E	0 25	na	na	1830
1840	3 8	2 30	1 52	1 12	0 32E	0 12W	0 53	na	na	1840
1850	2 41	2 2	1 23	0 41	0 1W	0 46	1 29	na	na	1850
1860	2 9	1 29	0 49	0 7E	0 36	1 22	2 5	na	na	1860
1870	1 32	0 52	0 11E	0 33W	1 16	2 2	2 45	na	na	1870
1880	0 52	0 12E	0 30W	1 12	1 55	2 40	3 22	na	na	1880
1890	0 12E	0 27W	1 7	1 49	2 31	3 14	3 55	na	na	1890
1900	0 21W	1 2	1 42	2 24	3 7	3 50	4 32	na	na	1900
1905	0 33	1 15	1 56	2 40	3 24	4 9	4 52	na	na	1905
1910	0 48	1 31	2 14	3 0	3 45	4 31	5 16	na	na	1910
1915	1 0	1 44	2 29	3 16	4 2	4 51	5 37	na	na	1915
1920	1 7	1 52	2 38	3 26	4 14	5 4	5 51	na	na	1920
1925	1 21	2 7	2 54	3 43	4 32	5 23	6 12	na	na	1925
1930	1 32	2 20	3 7	3 58	4 48	5 40	6 30	na	na	1930
1935	1 38	2 27	3 15	4 7	4 59	5 52	6 43	na	na	1935
1940	1 31	2 21	3 11	4 4	4 56	5 50	6 42	na	na	1940
1945	1 29	2 20	3 10	4 4	4 57	5 52	6 45	na	na	1945
1950	1 26	2 17	3 8	4 2	4 56	5 52	6 45	na	na	1950
1955	1 33	2 24	3 15	4 9	5 4	6 0	6 53	na	na	1955
1960	1 47	2 37	3 28	4 23	5 17	6 12	7 5	na	na	1960
1965	2 9	3 0	3 50	4 44	5 37	6 31	7 24	na	na	1965
1970	2 36	3 26	4 15	5 8	6 1	6 55	7 46	na	na	1970
1975	3 14	4 3	4 52	5 43	6 35	7 27	8 16	na	na	1975
1980	3 59W	4 47W	5 35W	6 25W	7 15W	8 5W	8 53W	na	na	1980
1985	4 30W	5 21W	6 11W	7 1W	7 51W	8 40W	9 28W	10 15W	11 1W	1985
1990	5 3W	5 53W	6 42W	7 31W	8 20W	9 7W	9 54W	10 40W	11 24W	1990
1995	5 35W	6 24W	7 13W	8 1W	8 48W	9 35W	10 20W	11 4W	11 47W	1995

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V A L U E S   O F   M A G N E T I C   D E C L I N A T I O N

LAT	37	37	37	37	37	37	37	37	37	LAT
LONG	91	90	89	88	87	86	85	84	83	LONG
1750	na	na	na	na	na	na	na	na	1 24E	1750
1760	na	na	na	na	na	na	na	na	2 4	1760
1770	na	na	na	na	na	na	na	na	2 42	1770
1780	na	na	na	na	na	na	na	na	3 16	1780
1790	na	na	na	na	na	na	na	na	3 43	1790
1800	7 55E	7 35E	7 11E	6 44E	6 10E	5 37E	5 4E	4 34E	4 2	1800
1810	8 18	7 57	7 31	7 2	6 25	5 50	5 16	4 44	4 11	1810
1820	8 32	8 9	7 42	7 11	6 32	5 55	5 19	4 46	4 11	1820
1830	8 39	8 13	7 44	7 11	6 30	5 51	5 13	4 39	4 2	1830
1840	8 35	8 7	7 36	7 2	6 19	5 39	4 59	4 22	3 44	1840
1850	8 23	7 54	7 20	6 44	6 0	5 18	4 36	3 58	3 18	1850
1860	8 4	7 33	6 58	6 19	5 34	4 50	4 7	3 28	2 47	1860
1870	7 39	7 6	6 30	5 50	5 4	4 19	3 34	2 53	2 11	1870
1880	7 3	6 28	5 51	5 10	4 24	3 39	2 54	2 13	1 31	1880
1890	6 22	5 47	5 9	4 27	3 41	2 56	2 12	1 31	0 51	1890
1900	5 54	5 18	4 39	3 56	3 10	2 25	1 40	0 59	0 18	1900
1905	5 53	5 16	4 36	3 52	3 5	2 18	1 33	0 50	0 7E	1905
1910	5 52	5 13	4 32	3 46	2 57	2 9	1 22	0 38	0 6W	1910
1915	5 52	5 12	4 29	3 43	2 53	2 3	1 15	0 29	0 17	1915
1920	5 51	5 10	4 27	3 40	2 50	2 0	1 10	0 24	0 22	1920
1925	5 42	5 1	4 18	3 31	2 40	1 49	0 59	0 12	0 35	1925
1930	5 38	4 57	4 13	3 25	2 33	1 41	0 51	0 3E	0 46	1930
1935	5 40	4 59	4 14	3 25	2 32	1 40	0 48	0 1W	0 51	1935
1940	5 49	5 8	4 23	3 34	2 41	1 49	0 57	0 7E	0 43	1940
1945	5 53	5 13	4 28	3 39	2 46	1 54	1 1	0 11	0 41	1945
1950	5 58	5 17	4 33	3 44	2 51	1 58	1 5	0 15	0 37	1950
1955	5 52	5 12	4 28	3 39	2 46	1 53	0 59	0 9E	0 44	1955
1960	5 40	4 59	4 15	3 26	2 32	1 39	0 46	0 5W	0 58	1960
1965	5 18	4 37	3 52	3 3	2 9	1 16	0 23E	0 29	1 21	1965
1970	4 53	4 12	3 27	2 37	1 43	0 50	0 4W	0 55	1 47	1970
1975	4 14	3 32	2 47	1 57	1 3	0 10E	0 43	1 35	2 26	1975
1980	3 26E	2 44E	1 59E	1 9E	0 15E	0 38W	1 31W	2 22W	3 12W	1980
1985	2 45E	2 0E	1 13E	0 26E	0 21W	1 10W	2 0W	2 50W	3 40W	1985
1990	2 14E	1 28E	0 41E	0 7W	0 55W	1 44W	2 33W	3 23W	4 13W	1990
1995	1 42E	0 55E	0 8E	0 40W	1 28W	2 17W	3 7W	3 56W	4 46W	1995

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N.C. GRID CHECKLIST

-To properly tie a survey to the North Carolina Coordinate System, you need:

1. A grid distance from the control monument to a corner of the property that is being surveyed.

    a. Ellipsoid Correction Factor (Page 19 - 20)

    b. Scale Correction Factor (Page 23 - 24)

    c. Combined Factor (Page 23 - 24)

2. Azimuth (Grid) orientation - Remember Grid=True - Theta (Page 13)

-The above criteria are required when a parcel of land you are surveying is within 2000' of a horizontal control monument.

-The precision of the grid connection should equal or exceed the precision of the boundary survey being tied to grid.

-Remember to label the coordinates NAD 27 or NAD 83.

-Any coordinates issued by NCGS as preliminary should be labeled as such.

-If only one control monument is accessible or available, occupy the control station and observe a solar or polaris observation to orient your tie to grid.

-Magnetic Bearings should not be used when grid control is available.

-When grid monuments are used which, at the time of the survey, have no coordinates, then the angle and distance observed from the grid monuments should be shown on the plat.

TRANSFORMATION OF

NAD 27 to NAD 83
NAD 83 to NAD 27

Before you attempt to perform a datum transformation, you should answer the following questions. The answers to these questions will help you determine which method of transformation will meet your needs.

1. What datum are the existing coordinates on?
2. What datum do I want the new coordinates on?
3. How large a geographical area do I want to convert at one time?
4. How many points are common to both datums?
5. How are the common points distributed?
6. How accurate are the existing coordinates and how accurate do I want the new coordinates?

The National Geodetic Survey (NGS) recommends the following methods of datum transformation:

Method 1 - Recomputation and Adjustment of Original Adjustment

This method is by far the superior method to be used by land surveyors. It requires using the original field observations to recompute the survey using NAD 83 coordinates at the tie points. NGS will perform the datum transformation if the following criteria are met:

-Submit original field observations and station descriptions to NGS.

-Original field observation <u>must</u> be tied to the National Geodetic Horizontal Network.

-Field procedures must be performed to at least Third Order, Class I accuracy.

-Survey points must be monumented and described.

-Field observations must be submitted in a format that is compatible with NGS format (Blue Book). For information on the Blue Book format, see the Federal Geodetic Control Committee publication "Input Formats and Specifications of the National Geodetic Survey Data Base."

Method 2 - Rigorous Transformation

This method can be performed by the land surveyor and both NCGS and NGS. It uses one of the software packages that performs a least square transformation. NADCON and CORPSCON are two of the software packages that can perform this function; there are other packages available that will provide this service, also.

NADCON and CORPSCON are basically the same program; they differ in choices of data input and output. NADCON only allows entries by geographic position (latitude and longitude) and output is the same. CORPSCON allows input and output by geographic positions and state plane coordinates. For example, when using CORPSCON, you can input NAD 27 geographic positions and output NAD 83 state plane coordinates. Because of these options, CORPSCON is a more flexible program. Both NADCON and CORPSCON work very well but they have limitations that must be taken into consideration when performing a transformation.

Remember, the most accurate method of performing a datum transformation is Method 1.

Method 3: Simplified Transformation

In the area in which you need to perform the transformation, locate horizontal control monuments that are common to both datums (NAD 27 and NAD 83). Compute the shift between the two datums at each monument.

Compute an average shift by combining and meaning the shifts in the Northings and Eastings. Transform your NAD 27 coordinates to NAD 83 by applying the average shift to the NAD 27 coordinates or vice versa. Again, if you are working in a small area (5 miles or less), this method will provide satisfactory results. The quality of the NAD 83 coordinates will depend on the distribution of the common points that were used to compute the area's average shift. Points that are used to compute the average shift should be evenly distributed around the area that is to be transformed. You cannot improve the quality of the survey data by performing a transformation, but your quality can be diminished if the proper methods and techniques are not used.

NAD CONVERSION SOFTWARE (CORPSCON)

Engineer Topographic Laboratories
Star Chamber Expedition

All input values are NAD 27, state plane zone 3200 (FEET).
All output values are NAD 83, state plane zone 3200 (Meters).

STATION			INPUT (transformed to)	OUTPUT
TROY			586173.024 N	178686.333 N
			1730972.714 E	527624.645 E
Convergence			0-31 14.80	-0 31 14.32
Scale Factor			0.99987428	0.99987429
Grid Shift (US Ft),	Delta North =	67.054		
	Delta East =	75.810		
Datum Shift(sec),	Delta Lat. =	0.508		
	Delta Lon. =	-0.834		

All input values are NAD 27, state plane zone 3200 (FEET).
All output values are NAD 83, state plane zone 3200 (US Feet).

STATION			INPUT (transformed to)	OUTPUT
DANESE			619630.214 N	619680.755 N
			731768.078 E	731837.766 E
Convergence			-2 27 22.90	-2 27 22.62
Scale Factor			0.99987500	0.99987501
Grid Shift(US Ft),	Delta North =	50.541		
	Delta East =	69.688		
Datum Shift(sec),	Delta Lat. =	0.359		
	Delta Lon. =	-0.466		

Corpscon costs $30.00 per copy.
To order write or call:

National Geodetic Information Center
N/CG174, Rockwall Building, Room 24
National Geodetic Survey, NOAA
Rockville, Maryland 20852
Telephone 1-301-443-8631

OR

North Carolina Geodetic Survey
512 North Salisbury St.
Raleigh, N.C. 27611
Telephone 919-733-3836 (Fax 919-733-4407)

BIBLIOGRAPHY

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Meade, Buford K., The Practical Use of the Oregon State Plane Coordinate System, Proceedings of the 1964 Surveying and Mapping Conference, Oregon State University, Corvallis, Oregon, also available from National Geodetic Survey

Simmons, Lansing G., Geodetic and Grid Angles - State Coordinate Systems, ESSA Technical Report C & GS 36, available through the Superintendent of Documents, Government Printing Office, Washington, D. C. 20402

Stem, James E., State Plane Coordinate System of 1983, NOAA Manual NOS NGS 5, available through National Geodetic Information Center, NOAA, Rockville, Maryland 20852

For a listing of various National Geodetic Survey literature and workshop materials, contact the National Geodetic Information Center:

N/CG174, Rockwall Building - Room 24
National Geodetic Survey, NOAA
Rockville, Maryland 20852
Telephone 1-301-443-8631