City of Knoxville Survey Control Network
June 2014

The following is a brief overview of the development of the City of Knoxville's survey control network, and an explanation of how to use the control data provided.

In September, 2011, NGS published results of the National Adjustment of 2011 Project to replace and improve upon NSRS (2007). The new adjustment is called NAD 83(2011/PA11/MA11) epoch 2010.00. The realization name has two parts: the datum tag in parentheses after NAD 83, and the epoch date in decimal years. (PA11) and (MA11) refer to the Pacific and Mariana tectonic plates respectively, while (2011) refers to the North America plate. Since the new realization is dynamic, taking into account crustal motion, the epoch 2010.00 tag means the published positions are as they were on January 1, 2010. In the U.S., excluding Hawaii which is on the Pacific plate, the realization is called simply NAD 83(2011).

For anyone interested the following link leads to a detailed explanation of the new system:

http://www.ngs.noaa.gov/web/surveys/NA2011/

Update: (current June 2014) From August 2013 through May 2014 fifty-seven points in the City Survey Control Network were reobserved with a Leica GS14 GNSS receiver with the intention of bringing the network into closer agreement with Real Time Kinematic (RTK) positions derived from the TDOT GNSS Reference Network. This included twenty-nine usable remaining points from the original fifty point network, plus twenty-eight additional points selected for suitable locations to use as supplemental control. The observations were submitted to the NGS Online Positioning User Service (OPUS), and the resulting positions were held fixed as control for a readjustment of the City Survey Control Network.

History:

In 1988, the City of Knoxville contracted Aero Services to observe 50 first-order (10 PPM) GPS points and submit the data in "Blue Book" format for inclusion into the NGS database.

To ensure an agreement between state and local coordinates, the Tennessee Geodetic Reference Network (TGRN) was used as control for the project. The TGRN was an order B (1 PPM) Global Positioning System (GPS) referenced to the North American Datum of 1983 (NAD83) developed as a joint effort between Tennessee Department of Transportation (TDOT) and the National Geodetic Survey (NGS).

Densification of the original 50-point network was at first accomplished with conventional traverse methods, first with Kern E1/DM503 total stations, and later a Topcon GTS 500. Multiple angle sets were observed and distances were corrected for temperature and barometric pressure. Over 166 miles of traverse were completed in 93 separate lines with an average closure of approximately 10 PPM (1:100,000). Leveling was done with a Pentax AL-M3 level and SM3 micrometer, and a precision 3-meter invar staff. Since early 1999 virtually all fieldwork has been done with GPS receivers.

In September 1991 the City of Knoxville published coordinates referenced to the 1991 NGS readjustment officially named NAD 83(1991).

In 1995, the NGS published a new nationwide adjustment officially named NAD 83(1995), which was adopted by TDOT. After observing numerous new GPS ties directly to the TGRN the City of Knoxville's network was readjusted. In April 1999 the City of Knoxville published coordinates referenced to NAD 83(1995).

The early GPS observations used NGS gravity model GEOID96 to compute elevations from GPS observations. GEOID99 was used when it became available in late 1999, and GEOID03 has been used since its release in late 2003.

In March 2007 the National Geodetic Survey (NGS) released the results of the latest North American Datum of 1983 (NAD83) readjustment, known as the National Spatial Reference System of 2007 (NSRS2007). The official name is NAD 83(NSRS 2007), sometimes written in short form as NAD

83(2007).

This readjustment was done to address deficiencies in the National network. As individual state High Accuracy Reference Networks (HARN) were developed, most were independently adjusted, thus never integrated into a contiguous nationwide network. This resulted in discrepancies between state HARNs. The NAD83 (NSRS2007) adjustment solved these problems with a simultaneous adjustment of state HARN positions using Continuously Operating Reference Stations (CORS) stations as fixed references. This brought HARN and CORS coordinates into close agreement, and corrected inconsistencies between state HARNs. Since the CORS network is a dynamic system which reflects positional shifts due to crustal motion, and HARNs are passive systems, there can never be an exact equivalency between the two systems.

In addition to the original 60-point Tennessee HARN, known as the Tennessee Geodetic Reference Network (TGRN), the Tennessee Department of Transportation (TDOT) now has in place a 22-station real-time CORS network (TDOT GNSS Reference Network).

In October 2009 the City of Knoxville published survey control data readjusted to NAD83 (NSRS2007). This was accomplished using NGS adjusted coordinates of the City of Knoxville's original 50-point network plus TDOT GPS 20 and GPS 21.

In June 2013 City of Knoxville survey data was readjusted to NAD83 (2011). This was accomplished using NGS adjusted coordinates of the City of Knoxville's original 50-point network

Use of geodetic and grid data supplied in this publication:

The City of Knoxville control data provided for each point includes state plane coordinates, latitude and longitude, elevations (NGVD29 and NAVD88), scale factor, convergence value and intervisible points. Other information includes point descriptions and "to reach" instructions. All linear units are expressed in U.S. Survey Feet.

The projection employed to calculate the state plane coordinates **(SPC)** used in the State of Tennessee is the **Lambert Conformal Conic Projection**, which projects ground positions onto an imaginary cone, the axis of which coincides with the earth's polar axis.

When using the City of Knoxville control system, it should be kept in mind that there are two factors that affect the relationship between distances inversed from **SPC** and distances measured in the field. One is the **sea level factor (SLF)**, and the other is the **scale factor (SF)**.

The **SLF** is used to reduce surface measurements to a common datum. It may be easily calculated by using the mean elevation of the survey line and the mean radius of the earth.

SLF = R ÷ (R + h)
where **R** = 20,906,000 ft (mean radius of the earth)
h = elevation above sea level in feet

For small surveys, the average elevation of the area surveyed is completely adequate for reducing the entire survey to sea level. If a high degree of precision is needed, however, large surveys over uneven terrain should have each line reduced individually by using the mean elevation of its end points.

The **SF** is used to correct distortion of the sea level distances that occurs because measurements made on the curved surface of the earth are being projected onto a flat plane. As with the **SLF**, small surveys may be corrected with an average factor for the area. Corrections for individual lines are unnecessary, except in high-precision surveys. For the surveyor who needs the information, exact scale factors are being published for each point in the control network.

The **SLF** and **SF** are normally multiplied to derive the **combined grid factor (GF)**, which may then be used to reduce distances to the grid with one operation.

GF = **SLF** × **SF**
Grid distance = **GF** × **horizontal** distance at the surface

Anywhere in the Knoxville area, a **local grid factor** of **.9999** may be used with acceptable precision for most surveys. This is based on a scale factor for the approximate middle latitude of the City, and a mean elevation for the local area.

For example, the **grid distance** inversed between GPS 0018 and GPS 0019 is **1979.539** feet. An Engineering Department survey crew checked this line, measuring a horizontal distance of **1979.714** feet at the instrument elevation. Below is a comparison of the results obtained by reducing the field measurement using both the local grid factor, and an approximate, but more precise method using the average scale factors of the two end points of the line. An **exact reduction** exists, but it is beyond the scope of this manual. It is more trouble to apply, and will not give significantly different results from the approximate method until the line is several miles in length.

Approximate reduction:

GPS 0018: elevation = 972.34
scale factor = .99995117

GPS 0019: elevation = 958.24
scale factor = .99995139

Mean elevation = (972.34 + 958.24) ÷ 2 = 965.29
SLF = 20,906,000 ÷ (20,906,000 + 965.29) = .99995383
Mean SF = (.99995117 + .99995139) ÷ 2 = .99995128
GF = .99995383 × .99995128 = .99990511
Grid Distance = 1979.714 × .99990511 = 1979.526 **(reduced measurement)**

1979.526 - 1979.539 **(inversed grid distance)** = -0.013 (precision ratio =1:152,000)

Local reduction:

Grid Distance = 1979.714 × .9999 = 1979.516 **(reduced measurement)**

1979.516 - 1979.539 **(inversed grid distance)** = -0.023 (precision ratio =1:86,000)

As can be seen here, the local factor gives satisfactory results for anything other than large control surveys. Depending on the location and elevation of a given survey, the agreement between the approximate and local reduction may be better or worse than in the above examples.

Convergence angle:

The **convergence angle**, also known as **mapping angle** or **theta** (θ), is the difference between the grid and geodetic azimuth at a given point. Geodetic azimuths may be determined by using latitudes and longitudes to inverse between two points or by corrected astronomic observations, and differ from grid azimuths because lines of longitude converge toward the poles.

Grid azimuth = geodetic azimuth - θ + (T-t)

The second term (T-t), which is a small curvature correction applied to horizontal angles, may be ignored for all lines of less than 5 miles - it is shown here for completeness only.

Elevations:

Since November 2001, elevations have been published both on the National Geodetic Vertical Datum of 1929 **(**NGVD29) **and** the North American Vertical Datum of 1988 (NAVD 88). This is to help minimize confusion during the transition to NAVD88. In the Knoxville area, the NAVD88 elevation of a point is, on average, 0.43 foot less than its NGVD29 elevation, ranging from a minimum value of -0.37 foot to a maximum value of -0.47 foot.

Additionally, elevations are now categorized by the method used to determine them, i.e., direct leveling, trigonometric, or GPS. Leveled elevations are determined by differential leveling using second-order equipment.

Elevations determined by GPS and leveling are published to the nearest hundredth (0.01) of a foot, although GPS orthometric heights are generally considered to have a tolerance of +/-1cm (0.036 ft). Trigonometric elevations are determined by traditional means, and are published to the nearest tenth (0.1) of a foot.