Basis-of-Bearing

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Statement of need:

When submitted for recording or review by an approving body, the basis-of-bearing should be shown on each survey plat for the purpose of establishing a common reference and for the convenience of subsequent users. Eventually, this improved basis-of-bearing requirement should be included in the New Mexico minimum standards for surveying. In practice, the word "azimuth" can also be used to describe a bearing or direction. For routine applications, no distinction is made between "true" north, "astronomic" north, and "geodetic" north. On higher-order surveys, there is a difference that should be accommodated.

Statement of Proposed Standard:

In order to accommodate both routine and higher-order surveys, the basis-of-bearing notation on a plat should be one of the following statements:

- The basis-of-bearing on this plat is true north with respect to the longitudinal meridian through "a point identified and shown on the plat."

- The basis-of-bearing on this plat is true or astronomic (circle one) north with respect to "a point identified and shown on the plat" and is accurate within _____ arc seconds at the 95% (two sigma) level of confidence." For purposes of this survey, true north and geodetic north are synonymous.

Characteristic:

The basis-of-bearing is physically defined and easily implemented. The physical characteristic of a basis-of-bearing is that all meridians are north/south longitudinal lines as determined by the earth's rotation. Because the earth is not flat, meridians are not parallel but converge at the north and south poles. Computation and use of meridian convergence between points on a survey is an essential part of being able to relate one bearing with another.

Responsibility:

It is the responsibility of the surveyor signing the plat to ensure correct determination of the true bearing through the point of reference identified on each plat.

Primary Technical Issue:

Since meridians are not parallel and since bearings are often determined on the basis of measured angles between adjacent lines, it is prudent for all bearings on a plat to be referenced to the one named true bearing rather than giving the true bearing for each line. The 2009 BLM manual recognizes same in Section 2-11, but goes on to accommodate what is called "true mean bearing." Understandably, "true mean bearing" has its place but "true mean bearing" is an approximation. Given modern computational tools and better models, the practice of using true bearings or azimuths (both forward and reverse) is preferred over "true mean bearing" on higher-order surveys.

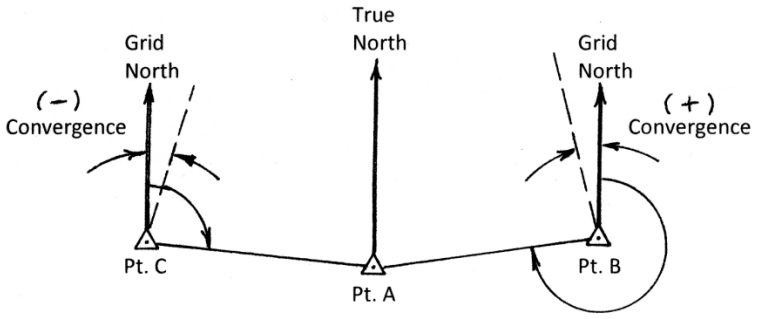
Other issues include:

1. The current practice of naming the direction between two adjacent points on a plat as the basis-of-bearing has merit but falls short of providing a permanent reference. If one or both points are disturbed or missing, the basis-of-bearing cannot be duplicated in a subsequent survey without resorting to other collaborating data. When bearings on a common line between a new survey and a survey (or description) of record are significantly different, the notation "surveyed direction" and "record direction" on the common line provides adequate notice to subsequent users.

2. It helps to understand that bearings are absolute with respect to the reference meridian and that measured angles are relative quantities. Typically, but not always, the angle between lines on a plat is more critical than is the absolute orientation of a line.

    a. The previous statement applies to angles measured with a transit or theodolite.
    b. It is also true that an angle is the difference between two directions (bearings/azimuths).
    c. Independent directions may be determined with a magnetic compass (magnetic declination is also needed), with a Burt's Solar Compass, with an astronomical observation (Sun or Polaris), or by GPS observations (determining a GPS derived direction requires data collected at two points).

3. Convergence between meridians is a physical fact that figures prominently into the proposed standard. Computation and use of convergence is a small price to pay for realizing the benefits provided by a common physical reference.



True Azimuth = Grid Azimuth + Convergence.

Notes:

a. The central (or reference) meridian has a value of longitude and goes through Pt. A. Any point on the survey plat can be chosen as Pt. A. Convergence at any other second point (Pt. B, Pt. C, etc.) is computed with respect to that central (reference) meridian.
b. When using a map projection, the longitude of the central (reference) meridian is a projection parameter and should be identified on the survey plat.
c. The convergence is positive (+) for points east of the central (reference) meridian and negative (-) for points west of the central (reference) meridian.
d. The equation (True Azimuth = Grid Azimuth + convergence) is applicable for points either east or west of the reference meridian.
e. For higher-order surveys or on lines more than approximately 4 miles in length a "second term correction" (also called t-T) as recommended by NGS in NOAA Manual NOS NGS 5 *State Plane Coordinate System of 1983* may be needed. Deflection-of-the-vertical considerations may also be needed to distinguish between "astronomic" and "geodetic" directions on such surveys.
f. The units of convergence (typically seconds of arc) are determined by units of longitude difference in equations (1) and (2) following.

g. Convergence is computed as:

$$Convergence_{at\ B} = (\lambda_B - \lambda_A) sin\varphi_B \quad \text{when using East longitude.} \qquad (1)$$

$$Convergence_{at\ B} = (\lambda_A - \lambda_B) sin\varphi_B \quad \text{when using West longitude.} \qquad (2)$$

4. Using convergence, existing state plane, UTM, and other projection grid bearings can be readily converted to true north at any specified point on the plat. Latitude and longitude are needed.

5. Choice of a datum remains the prerogative of the surveyor signing the plat. But, whatever datum is used, the procedure for converting a named datum-specific azimuth to true north is a small price to pay for standardization.

6. On those precise (engineering) surveys for which using a different ellipsoid or datum makes a significant difference (not very often), the basis-of-bearing may need to be subject to other geodetic considerations such as second-term-correction and/or deflection-of-the-vertical – see note "e" above. Standards for such surveys are not covered by the New Mexico minimum survey standards but should be included in the contractual details between the professional surveyor and the client or funding agency.

7. Most of these concepts are illustrated on page 9 of http://www.globalcogo.com/3DGPS.pdf.

8. An astronomic observation (Sun or Polaris) can be used effectively to obtain a true azimuth at a specified point. The stated reference point for true bearing on the plat need not be the point at which the astronomic observation was made but convergence between the meridian of observation and the stated reference point needs to be determined and used correctly.

9. GPS observations are an effective way to determine true north. The primary product of an observed GPS vector (baseline) is ΔX/ΔY/ΔZ geocentric earth-centered earth-fixed (ECEF) coordinates. The true azimuth of a GPS line from "here" to "there" is arctan (Δe/Δn) where:

   $\Delta e = -\Delta X \sin\lambda + \Delta Y \cos\lambda$

   $\Delta n = -\Delta X \sin\phi \cos\lambda - \Delta Y \sin\phi \sin\lambda + \Delta Z \sin\phi$

   where: ϕ = geodetic latitude north of equator and λ = east longitude of "here."

10. The angular misclosure on survey that starts on one astronomic azimuth and closes on another will be "polluted" by the convergence between points (unless computed and removed). Failure to recognize that systematic error has been included on many licensing exams and has been a source of grief for anyone attempting to close such a traverse without accommodating convergence.

11. An observed magnetic bearing can be converted to true bearing by use of magnetic declination. This procedure is legitimate, but rarely used in practice because better methods are available.

12. The Burt Solar Compass is another method that has been used in the past for determining true north for a survey.

Assumptions Underlying Article on Basis-of-Bearing

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The following items reflect feedback from two primary sources – those responding to the Basis-of-Bearing article published in the May 2013 issue of the NMPS Benchmarks and from persons responding to the SurveyorConnect (http://surveyorconnect.com/index.php?mode=thread&id=203562) bulletin board. Comments also appear in other threads on SurveyorConnect that can be found by searching "basis of bearing" on that site. The thoughtful suggestions of many are sincerely appreciated.

I. In developing the proposed basis-of-bearing article, our goal was to remain true to simple basics. "North" is a physical concept defined by the Earth's spin axis. Meridians converge at the poles and are not parallel. "True" north is often taken to be either geodetic or astronomic. The difference is generally small and seldom exceeds 10-15 seconds of arc. If and when that difference matters, it should be discussed between the professional surveyor and his/her client or recording office.
   A. Astronomic north is determined by astronomical observation and is affected by the deflection-of-vertical at the point of observation.
   B. Geodetic north is referenced to the mathematical Conventional Terrestrial Pole (CTP).

II. Licensed surveyors are expected to be responsible to the public, to the profession, and to themselves. That means professionals enjoy a great deal of latitude in deciding appropriate methods and procedures for determining and meeting the needs of their clients. In addition, professionals and technicians alike are expected to understand basic concepts and to be responsible for maintaining a level of competence commensurate with the services performed. We all participate in life-long learning but no one enjoys a monopoly on the "truth." Respectful discussion of ideas (even differing opinions) is essential for maintaining individual competence and for collective enhancement of our professional image/reputation.

III. Some respondents opined that angles are more important than directions. That point is valid and conceded within the context of "absolute" and "relative." Briefly, relative is viewed as being associated with measurements and absolute is viewed as associated with a reference. Many are comfortable with the practice of measuring angles and computing directions. In that case, directions are dependent on measured angles and both are essential. But, the process of identifying a common basis-of-bearing that is most appropriate for professional practice needs to recognize other methods as well. A compass determines an independent direction, an astronomical observation (solar or star-shot) determines a direction that is independent of other lines on the ground, and GPS provides independent directions. A basis-of-bearing needs to be an absolute reference.

IV. Some who responded were quick to offer, "This is how I do it." with the implication that the public and the profession are accordingly well served. For the most part, those points are valid and such practice exceeds the "minimum" level being identified. The question for those persons is, "Should everyone be expected to do it your way?" Typically, the answer is "no" because there are other legitimate methods that could be used. The proposed basis-of-bearing is simple, elegant, and offers many benefits. One particular response implied that "elegant" and "practical" are mutually exclusive. We disagree.

V. Under the "This is how I do it." scenario, those who provide more technical detail than the minimum required are to be commended for their diligence and for providing future users the information needed to duplicate or to follow their work. In some cases, the pendulum may swing too far. What is the benefit of requiring subsequent users to sort through details of datums, ellipsoids, projections, brands of equipment, or computational methodology in order to establish compatibility between one "flavor" of reference or another? Technicians have every right to be proud of doing a good job and being able to justify all the details. Those talents are viewed as prerequisites to becoming a professional. On the other hand, professionals have the prerogative and larger responsibility to make decisions in a broader context; that is, understanding implications of the difference between standards and specifications. The proposed basis-of-bearing is a simple standard while specifications are left to the surveyor's professional judgment.

VI. Various respondents expressed a preference for using a grid bearing as the basis-of-bearing. Given the current preponderance of use, that preference has merit. However, true north is "closer" to physical reality while a grid bearing depends upon knowing which map projection is being used (UTM, state plane, low distortion projection, etc) and parameters associated therewith. The public is well-served by using true north as the common basis-of-bearing and it is easier for users of other methods to compute and use true north than the converse.

VII. The proposed basis-of-bearing contains a subjective difference between "routine" and "higher-order" applications. Control surveys, some engineering surveys, and deformation monitoring surveys are examples in which the "higher-order" criteria should be applied. Of various factors that can be considered as discriminating between routine and higher-order, the most reliable discriminator is probably the proven standard deviation of the reference. All higher-order surveys should certainly have a (2 sigma) standard deviation less than 10 seconds of arc. Understandably, a standard deviation less than 10 seconds of arc does not, in itself, qualify a reference as "higher-order." For example, stating that GPS equipment was used, that a 1 second theodolite was used, that the distance to the backsight is more than 100 meters (~330 feet), or that the reference is based on a particular ellipsoid, datum or projection does not qualify a reference as being "higher-order." Numerous specifications need to be met for a reference to be "higher-order."