Basis of Bearings

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NYSAPLS 2018 Conference

INTRODUCTION:

- Over 25 years experience in the surveying profession
- Graduate of Penn State survey program
- Licensed in Pennsylvania, New York, West Virginia and Colorado
- Been a member of home state's professional society for many years; presenter at several of Pennsylvania's annual conferences
- Just another surveyor trying to share information with others and gain knowledge from fellow professionals.

WARNING:

This presentation is not intended to be a class lecture. The intent is to present the attendees with information I have gathered thru various sources and stimulate discussion on these topics. Participation from the attendees is essential to the success of the session. Everyone in attendance is asked to provide input and ask questions. By gathering input from those present, we may all learn something by the end of the day.

THE ATTENDEES

• How many are licensed surveyors in New York or another state?

•Anyone a licensed professional, not a surveyor?

•Those that are not licensed as a surveyor, are you in pursuit of a license?

THE ATTENDEES

•How long have you been involved in the surveying profession?

•How many have a college degree in surveying?

Objectives of this Webinar:

- Define "Basis of Bearing"
- Clarify the difference between "Grid North" and "True North"
- Review the commonly used basis of bearings

Objectives of this Webinar:

- Discuss how each method is derived
- Identify common problems or mistakes found with each method
- Encourage discussion within the group to share knowledge and experience

WHAT IS BASIS OF BEARING?

Per Writing Legal Descriptions by Gurdon Wattles:

" A 'basis of bearings' is a determination for the orientation of angular relationships of lines in a description or on a map."

WHY DO WE CARE?

- Surveyors use Bearings and Distances every day
- It is a Geo-referenced world
- Allows us to retrace the 'footsteps' of others
- Could we do without?
- We are the professionals that should care

HOW DOES THE BASIS OF BEARING AFFECT THE WORK OF A SURVEYOR?

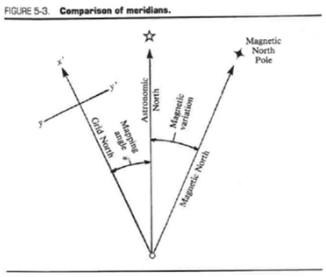
Commonly Used Terms:

- Bearing
- Greenwich Hour Angle
- Declination
- Ephemeris
- Isogonic Map or Chart

Commonly Used Terms:

- Latitude
- Longitude
- True North
- Magnetic North
- Grid North

Methods for Basis of Bearing :



Commonly used Basis of Bearing:

- Assumed
- Record Document
- Magnetic / Compass
- Stellar Observation
- GPS / GNSS Derived

Methods for Basis of Bearing:

Assumed:

- Random “North”
- Commonly used on ‘small’ projects
- Quick and easy
- Can be changed later during the project
- Problem: no way to retrace the bearings as it was 100% random

Methods for Basis of Bearing :

Assumed:

- Concerns:
  - Non-repeatable process
  - Cannot overlay survey on other data without rotation
- Benefits
  - Easy method
  - No calculations to determine north

Methods for Basis of Bearing :

Reference to other Documents:

- Tie into parts of another document
- Actually is using another basis for bearing
- Sometimes, the basis for the record being relied upon is not clear or known
- Referral document may be unrecorded

Methods for Basis of Bearing :

Reference to other Documents:

- Documents may include:
  - Previous deed of record
  - Adjoining parcel's deed of record
  - Subdivision Plans
  - Roadway Plans
  - Previous Survey (subject or adjoining)
  - Documents do not need to be recorded or public knowledge

Methods for Basis of Bearing :

Reference to other Documents:

- Concerns:
  - Basis of referenced document?
  - Non-repeatable process without the previous document
- Benefits
  - Easy method
  - No calculations

Methods for Basis of Bearing :

Magnetic / Compass:

- Relies upon a magnetic observation
- Magnetic North versus True North is a factor
- Requires compensation for Magnetic Declination
- Errors in the method can vary greatly dependent on the process used.

Methods for Basis of Bearing :

Magnetic / Compass:

- Magnetic North is ??
- True North is ??
- What is the difference?
- How do we compensate for Magnetic Declination from one survey to the next?

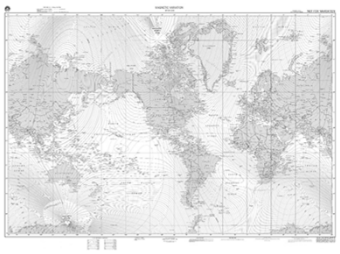
Methods for Basis of Bearing :

Magnetic / Compass:

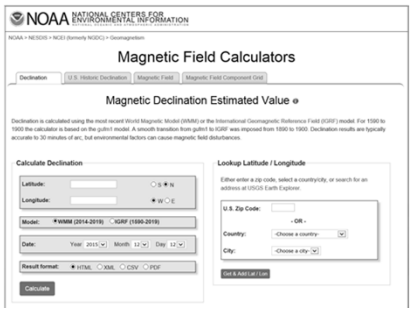
- Magnetic Declination can be:
  - Secular
  - Daily
  - Annual
  - Irregular

Magnetic Declination in 1890:

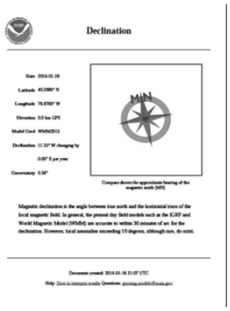
Magnetic Declination in 2010:



Magnetic Declination Online Tool:



Magnetic Declination in 2016:



Methods for Basis of Bearing :

Magnetic / Compass:

- Procedure requires observation between two (2) fixed points
- From the first point, the next point is sighted
- The direction is read from the compass face, this is bearing of the line

Methods for Basis of Bearing :

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Methods for Basis of Bearing :

Magnetic / Compass:

- Conversion from True North to Magnetic North is simple math
- You need to know the declination at the time of the observation
- Declination to WEST = add declination value if bearing is NE or SW; subtract is NW or SE
- Declination to EAST; reverse the above

Methods for Basis of Bearing :

THE BEARING OF A PROPERTY LINE IS OBSERVED WITH A QUALITY SURVEYOR'S COMPASS TO BE SOUTH 43° 30' EAST. THE OBSERVATION IS REPORTED TO HAVE BEEN MADE IN 1962. ACCORDING TO HISTORICAL RECORDS, THE MAGNETIC DECLINATION AT THAT TIME WAS 3 ° 15' WEST.

WHAT IS THE GEODETIC BEARING OF THE LINE TODAY?

GEODETIC BEARING = MAGNETIC BEARING + MAGNETIC DECLINATION
= SOUTH 43° 30' EAST + 3° 15'
= SOUTH 46° 45' EAST

Methods for Basis of Bearing :

IN 1878 THE BEARING OF THE CENTERLINE OF A ROADWAY WAS REPORTED TO BE NORTH 26° 15' EAST. A NOTE ON THE HIGHWAY PLAN INDICATES THE BASIS OF BEARINGS WAS DETERMINED THRU COMPASS OBSERVATION DURING THE ROADWAY LAYOUT SURVEY IN 1878. ACCORDING TO HISTORIC RECORDS, THE MAGNETIC DECLINATION IN 1878 FOR THIS LOCATION WAS 07° 15' WEST. YOU ARE DOING A LOCAL SURVEY AND HAVE FOUND MONUMENTATION OF THE ROAD'S CENTERLINE WHICH YOU BELIVE TO BE ORIGINAL TO THE 1878 SURVEY. THE CURRENT MAGNETIC DECLINATION IN THIS AREA IS 04° 30' EAST. WHAT IS THE CURRENT BEARING OF THE LINE USING MAGNETIC NORTH AS YOUR BASIS OF BEARING?

WHAT IS THE GEODETIC BEARING OF THE LINE TODAY?

GEODETIC BEARING = MAGNETIC BEARING - MAGNETIC DECLINATION
= NORTH 26° 15' EAST - 07° 15'
= NORTH 19° 00' EAST

MAGNETIC BEARING = GEODETIC BEARING - MAGNETIC DECLINATION
= NORTH 19° 00' EAST - 04° 30'
= NORTH 14° 30' EAST

Methods for Basis of Bearing :

Magnetic / Compass Method - Benefits:

- Straight forward procedure
- Equipment simple to use
- Minimal calculations

Methods for Basis of Bearing :

Magnetic / Compass Method - Concerns:

- Observations are subject to declination
- Quality of Compass
- Errors in compass operation / function / reading
  - Magnetic interference
  - Needle stick / bent needle
  - Angle reading
  - Parallax in glass
  - Instrument leveling

Methods for Basis of Bearing :

Stellar Observation:

- Uses a survey instrument to observe the position of heavenly body at a given time as they relate to fixed points in the earth
- Typically uses the Sun or Polaris
- Requires detailed calculations
- Tried and tested method for determining where you are and which way is True North

Methods for Basis of Bearing :

Stellar Observation:

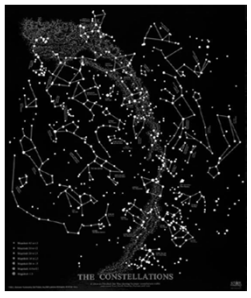
- Why the Sun or Polaris?
  - Easy to see
  - Known positions / track in sky
- Which is more accurate?

Methods for Basis of Bearing :

Stellar Observation:

- Polaris' position in the sky – almost true north
- Best time to view Polaris is between lower culminations
- In the Northern Hemisphere, Polaris appears to move very slowly
- Locations close to Equator use caution using Polaris
- Use Hour Angle method for calculations

Methods for Basis of Bearing :



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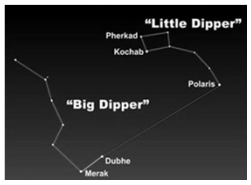

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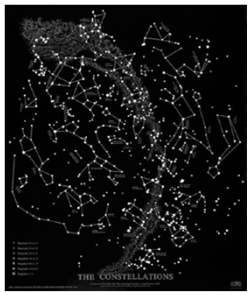

Methods for Basis of Bearing :

Stellar Observation Field Procedure:

- Place survey instrument on first known point
- Sight the second known point, set zero on horizontal scale
- Sight the star with the instrument placing the crosshairs just ahead of the star in its projected path

Methods for Basis of Bearing :

Stellar Observation Field Procedure:

- Note the time at which the star crosses the vertical crosshair, as well as the horizontal angle
- Repeat this process in both direct and reverse
- Observation of the Sun requires special precautions
- Expected locations of the star to be sighted are typically computed ahead

Methods for Basis of Bearing :

Stellar Observation Computations:

- The time of each observation must be reduced to Local Civic Time
- A value for GHA must be interpolated from ephemeris data
- Mathematical calculations are now performed to determine the bearing

Methods for Basis of Bearing :

GIVEN THE FOLLOWING INFORMATION, WHAT IS THE ASTRONOMIC AZIMUTH OF A LEG OF THE SURVEY TRAVERSE?

- THE LOCAL OBSERVATION DATE IS APRIL 8, 1986 (THE GREENWHICH DATE IS APRIL 9, 1986).
- $GHA_{\gamma 0} = 162^{\circ}\ 05'\ 46.1"$
- $DECL_{0} = 89^{\circ}\ 12'\ 14.98"$
- $GHA_{\gamma 24} = 164^{\circ}\ 04'\ 58.6"$
- $DECL_{24} = 89^{\circ}\ 12'\ 14.63"$
- TIME OF FIRST SIGHTING OF POLARIS IS $2^{H}\ 16^{M}\ 21.5^{SEC}$ (IN UT TIME)
- PROJECT LOCATION: LATITUDE 34° 57' 23"E
  LONGITUDE 91° 46' 35" W
- IN THE FIELD, THREE (3) SETS OF OBSERVATIONS WERE PERFORMED IN BOTH DIRECT AND REVERSE SCOPE POSITIONS FROM POINT MONO:

SET	POINT	SCOPE	TIME	ANGLE
1	BM1	DIRECT	---	00° 00' 00.0"
	POLARIS	DIRECT	02:16:21.5	94° 35' 02.3"
	POLARIS	REVERSE	02:19:36.1	274° 35' 10.5"
	BM1	REVERSE	---	180° 00' 08.4"
2	BM1	DIRECT	---	60° 03' 20.7"
	POLARIS	DIRECT	02:20:10.0	154° 39' 11.9"
	POLARIS	REVERSE	02:30:14.4	334° 39' 24.7"
	BM1	REVERSE	---	240° 03' 16.8"
3	BM1	DIRECT	---	120° 06' 44.5"
	POLARIS	DIRECT	02:41:57.6	214° 43' 52.2"
	POLARIS	REVERSE	02:44:10.9	294° 44' 06.1"
	BM1	REVERSE	---	300° 06' 39.6"

Methods for Basis of Bearing :

STEP #1 – DETERMINE GHA

GHA = GHA0 + (GHA24 – GHA0 + 360°) X (UT / 24H)

= 162° 05' 46.1" + (164° 04' 58.6" – 162° 05' 46.1") X ($2^{H}16^{M}21.5^{SEC}$/24)

= 197.279917°

STEP #2 – DETERMINE LHA

LHA = GHA – WEST LONGITUDE

= 197.27917° - 91° 46' 35"

= 105.50279°

STEP #3 – DETERMINE DECLINATION

DECL = $DECL_{0}$ + ($DECL_{24}$ – $DECL_{0}$) X (UT / 24H)

= 89° 12' 14.98" + (89° 12' 14.90" – 89° 12' 14.98") ($2^{H}16^{M}21.5^{SEC}$/24)

= 89.204152°

STEP #4 – DETERMINE AZIMUTH OF POLARIS

AZIMUTH = TAN^{-1} [-SIN LHA) / (COS (LATUTUDE) X TAN(DECL) – SIN(LATITUDE)X COS(LHA))]

= TAN^{-1} [-SIN 105.50279°) / ((COS 37° 57' 23") X (TAN 89.204152°) – (SIN 37° 57' 23") X (COS 105.50279°)

= TAN^{-1} [-0.963617 / 56.926017]

= -0.96970° OR MORE CORRECTLY 359.03022°

Methods for Basis of Bearing :

STEP #5 – DETERMINE AZIMUTH TO BM1

AZIMUTH = $AZIMUTH_{POLARIS}$ – ANGLE TO BM1

= 359.03022° - (94° 35' 02.3" – 00° 00' 08.2")

= 264° 26' 54.7"

**** *NOTE: THIS IS BASED ON THE DIRECT READING FROM ANGLE OBSERVATION SET #1. YOU MUST REPEAT THIS PROCESS FOR EACH OF THE THREE (3) OBSERVATION SETS.* ****

SET	AZIMUTH DIRECT	AZIMUTH REVERSE
1	264° 26' 54.7"	264° 26' 48.5"
2	264° 26' 54.1"	264° 26' 47.9"
3	264° 26' 55.0"	264° 26' 48.7"

THEREFORE, AFTER CALCULATING EACH AZIMUTH, AN AVERAGE OF THE RESULTS IS CALCULATED AND THE RESULTING ANSWER IS THE FINAL ZIMUTH TO BE USED.

$AZIMUTH_{FINAL}$ = AVERAGE AZIMUTH FROM EACH SET, DIRECT & DEVERSE

= 264° 26' 51.4"

WHICH RESULTS IN A BEARING OF THE LINE MONO TO BM1 OF:

SOUTH 84° 26' 51.4" WEST

Methods for Basis of Bearing :

Stellar Observation - Concerns:

- Unfamiliar process
- Precise timekeeping is needed
- Clear sky is needed
- Possible need for specialized equipment
- Accuracy of instrument
- Mathematical calculations

Methods for Basis of Bearing :

Stellar Observation - Benefits:

- Tried and tested process
- No electronics are needed
- Reliable method

Methods for Basis of Bearing :

Stellar Observation – Reinforcement of the Principles:

- US Naval Academy suspended teaching Celestial Navigation in the 90's
- In November of 2015, the Naval Academy announced they were bringing the training back
- Why the change of attitude?

Methods for Basis of Bearing :

Stellar Observation – Reinforcement of the Principles:

"Knowledge of celestial navigation in the GPS era provides a solid back-up from navigation in the event GPS becomes unreliable for whatever reason." Captain Timothy Tisch, instructor US Merchant Marine Academy. "It is also good professional practice to use one navigational system to verify the accuracy of another."

Methods for Basis of Bearing :

GPS / GNSS Derived:

- The equipment tells us which was is Grid North
- Based on a pre-programmed coordinate system / datum
- In reality it is a advanced stellar observation
  - The receiver uses signals from the satellites to determine a position on the earth
  - The satellite's position is known and part of the internal calculations

Methods for Basis of Bearing :

Methods for Basis of Bearing :

GPS / GNSS Derived - Concerns:

- Concerns
  - Relies on the use of GPS/GNSS equipment
  - Relies on proper entry of coordinate system
  - Surveyor must assume calculations are correct
- Benefits
  - Quick and easy process
  - Bearing base determination is seamless with other work (RTK or Static) no extra steps

Practical Application:

Practical Applications / Discussions:

If no basis of bearing is noted in a survey (plan or legal description) what do you assume?

- Prior to 1850, assumption is magnetic bearing base
- From 1850 to 1950 official surveys required reference to true meridian
- This requirement was removed in 1950, assumption is back to magnetic

Practical Applications / Discussions:

If no basis of bearing is noted in a survey (plan or legal description) what do you assume?

Practical Applications / Discussions:

Curtis Brown's 24th Principle

"The basis of bearings should be indicated and should not be left to speculation or assumption on the part of the surveyor or the courts."

More specifically: "(c) Where no basis of bearing is given or implied by a call for a map, true or magnetic bearings are to be used, depending on the presumption in the particular state."

Practical Applications / Discussions:

How should we document Basis of Bearing?

- Survey plans
  - Sipe's method
  - Audience ideas
- Legal Descriptions
- Report of Survey

Recap:

- Understanding the Basis of Bearing is important when conducting a retracement survey.
- Providing some reference to the basis of bearing used in the survey in our record documents is key for those that follow us.
- Surveyors are the professionals that should be experts in Basis of Bearing and therefore have a duty to help others understand what it really means.

References & Credits:

I cannot take credit for the technical information in this presentation, it is a collection or research I have collected from a host of sources that include:

- *The Advantages of Polaris Observations in Land Surveying* – Robert Fink & Jerry Wahl
- Boundary Retracement Principles and Procedures for Pennsylvania, 4th Edition – Knud Everett Hermansen
- Brown's Boundary Control and Legal Principles, 6th Edition – Walter Robilard, Donald Wilson & Curtis Brown
- Compass Land Surveying – Henry Seip
- Definitions of Surveying and Associated Terms, ACSM

References & Credits:

Contd…

- Elementary Surveying – Breed & Housner
- Elementary Surveying, 8th Edition – Wolf & Ghilani
- Land Survey Descriptions – Gurdon Wattles
- Manual of Surveying Instruction – Bureau of Land Management
- The Surveying Handbook – Russell Brinker & Roy Minnick
- www.Cadastral.com - website

References & Credits:

Contd…

- Teaching and interactions from various surveyors I have worked with including:
  - Gregory Kohl, P.L.S.
  - Gary Cuppels, P.L.S.
  - Robert Miller, P.L.S.
  - Mathew Boozer, S.I.T.
  - And others ….