Determination of Elevations

North Carolina Geodetic Survey

Elevation Determination Methods

- Global Navigation Satellite System (GNSS)
  - Static
    - OPUS-S
    - OPUS-RS
  - Kinematic
  - Real Time Kinematic (RTK)
  - Real Time Network (RTN)
  - Leveling

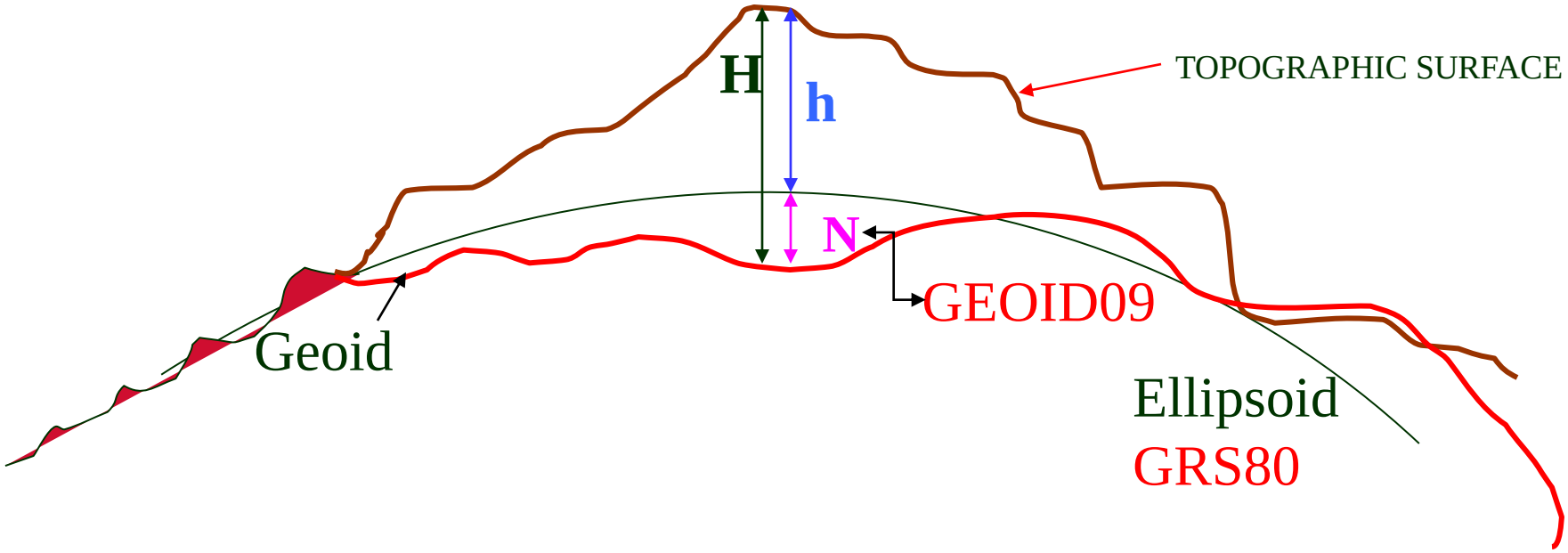
ELLIPSOID - GEOID RELATIONSHIP

H = Orthometric Height (NAVD 88)

h = Ellipsoidal Height (NAD 83)

N = Geoid Height (GEOID09)

$$H = h - N$$

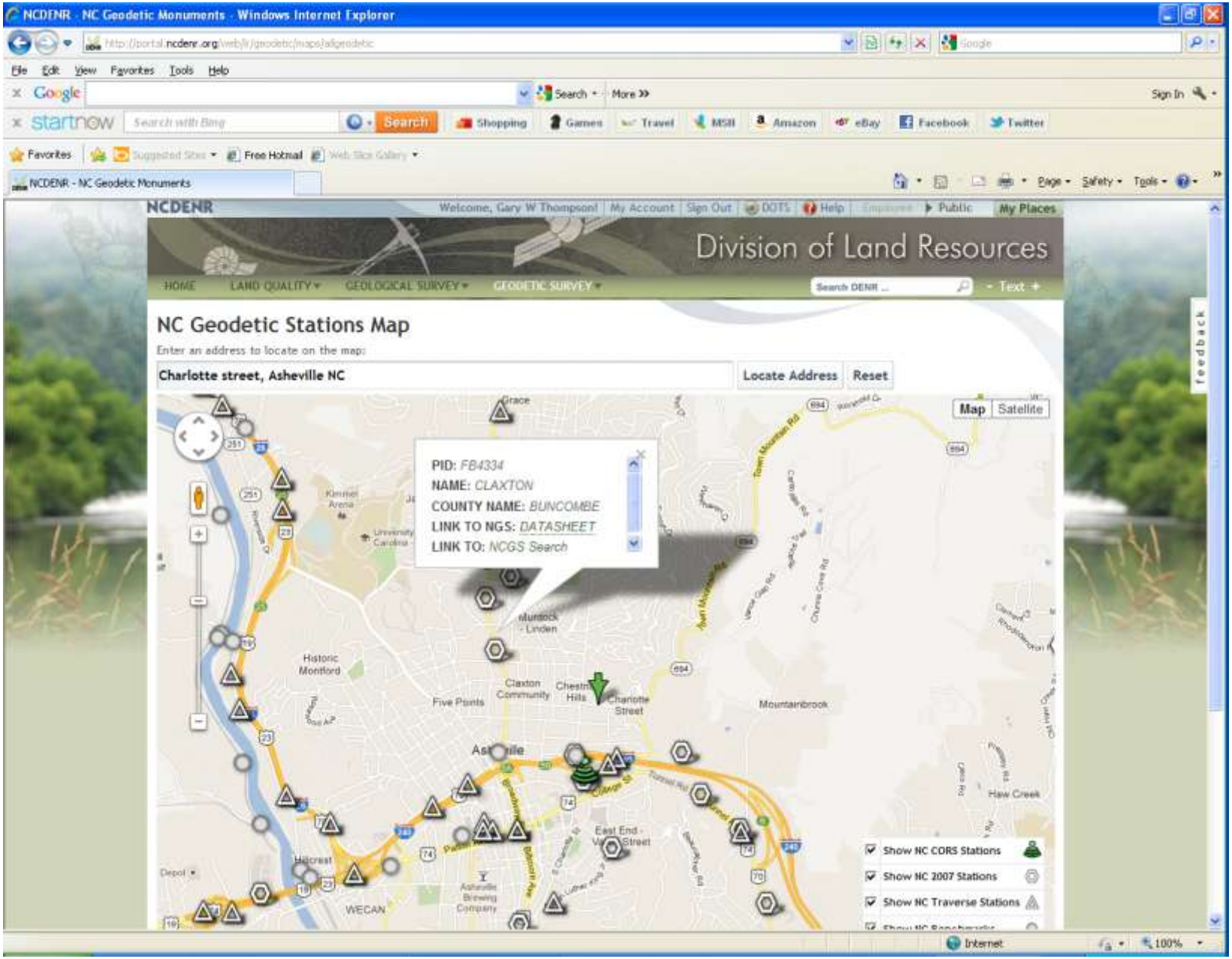


GNSS Surveying

- Static
  - First method of GPS surveying
  - Highest accuracy and precision
  - Primary technique used for control networks

GNSS Surveying

- Reconnaissance
  - Mark recovery
    - Horizontal and vertical control
    - CORS
  - Visibility charts
  - Photographs
  - Clear view of the sky


NCDENR - NC Geodetic Monuments - Windows Internet Explorer
NCDENR - NC Geodetic Monuments
NCDENR
Welcome, Gary W Thompson!
My Account
Sign Out
Help
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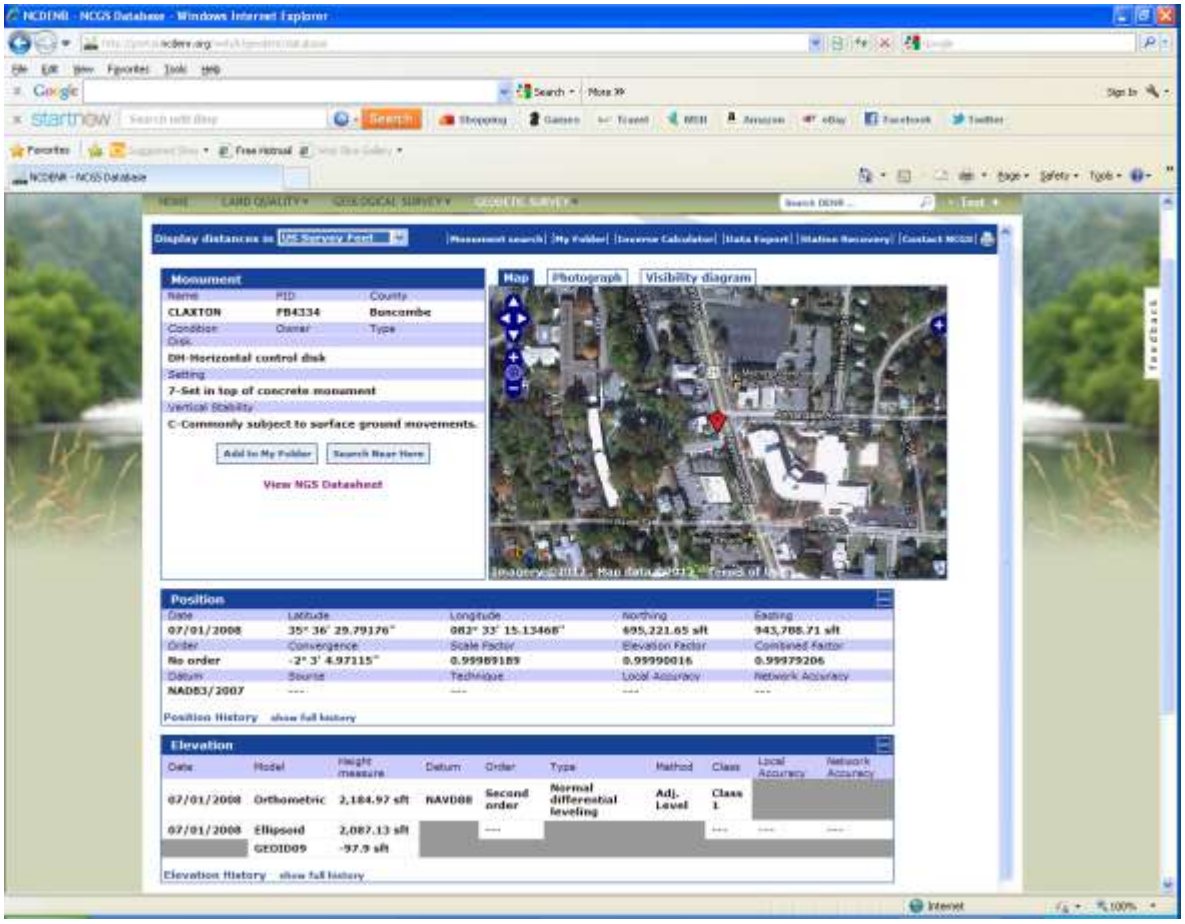
Division of Land Resources
HOME
LAND QUALITY
GEOLOGICAL SURVEY
GEODETIC SURVEY
Search DENR ...
Text
NC Geodetic Stations Map
Enter an address to locate on the map:
Charlotte street, Asheville NC
Locate Address
Reset
Map
Satellite
PID: FB4334
NAME: CLAXTON
COUNTY NAME: BUNCOMBE
LINK TO NGS: DATASHEET
LINK TO: NCGS Search
Show NC CORS Stations
Show NC 2007 Stations
Show NC Traverse Stations
feedback
Internet
100%

Geodetic Control Information



DATASHEETS - Windows Internet Explorer

http://www.ngs.noaa.gov/cgi-bin/ds_mark.prl?PidBox=FB4334

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DATASHEETS

Page Safety Tools

See file dsdata.txt for more information about the datasheet.

```
DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 7.88.3
1        National Geodetic Survey,   Retrieval Date = JUNE 12, 2012
 FB4334 ***********************************************************************
 FB4334  DESIGNATION -  CLAXTON
 FB4334  PID         -  FB4334
 FB4334  STATE/COUNTY-  NC/BUNCOMBE
 FB4334  COUNTRY     -  US
 FB4334  USGS QUAD   -  ASHEVILLE (1991)
 FB4334
 FB4334                        *CURRENT SURVEY CONTROL
 FB4334  ______________________________________________________________________
 FB4334* NAD 83(2007) POSITION- 35 36 29.79176(N) 082 33 15.13468(W)   ADJUSTED
 FB4334* NAD 83(2007) ELLIP HT-   636.158 (meters)         (02/10/07)   ADJUSTED
 FB4334* NAD 83(2007) EPOCH    -  2002.00
 FB4334* NAVD 88 ORTHO HEIGHT -   665.980  (meters)    2184.97  (feet) ADJUSTED
 FB4334  ______________________________________________________________________
 FB4334  NAD 83(2007) X  -    672,814.491 (meters)                     COMP
 FB4334  NAD 83(2007) Y  - -5,148,164.068 (meters)                     COMP
 FB4334  NAD 83(2007) Z  -  3,693,311.949 (meters)                     COMP
 FB4334  LAPLACE CORR    -         -1.21  (seconds)                    DEFLEC09
 FB4334  GEOID HEIGHT    -        -29.83  (meters)                     GEOID09
 FB4334  DYNAMIC HEIGHT  -        665.302 (meters)     2182.75  (feet) COMP
 FB4334  MODELED GRAVITY -    979,593.1   (mgal)                       NAVD 88
 FB4334
 FB4334  VERT ORDER      -  SECOND    CLASS I
 FB4334
 FB4334  FGDC Geospatial Positioning Accuracy Standards (95% confidence, cm)
 FB4334  Type                                        Horiz  Ellip  Dist(km)
 FB4334  ----------------------------------------------------------------------
 FB4334  NETWORK                                      0.52   0.71
 FB4334  ----------------------------------------------------------------------
 FB4334  MEDIAN LOCAL ACCURACY AND DIST (007 points)   0.53   0.73      1.44
 FB4334  ----------------------------------------------------------------------
 FB4334  NOTE: Click here for information on individual local accuracy
 FB4334  values and other accuracy information.
 FB4334
 FB4334
 FB4334.The horizontal coordinates were established by GPS observations
 FB4334.and adjusted by the National Geodetic Survey in February 2007.
 FB4334
 FB4334.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 FB4334.See www.ngs.noaa.gov/web/surveys/NSRS2007 for more information.
 FB4334
 FB4334 The horizontal coordinates are valid at the epoch date displayed above
```

Done Internet 100%

NCDENR - NCGS Database - Windows Internet Explorer

http://portal.ncdenr.org/web/lr/geodetic/database

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NCDENR - NCGS Database

Page Safety Tools

HOME LAND QUALITY GEOLOGICAL SURVEY GEODETIC SURVEY Search DENR ... - Text +

Display distances in US Survey Feet | Monument search | My Folder | Inverse Calculator | Data Export | Station Recovery | Contact NCGS |

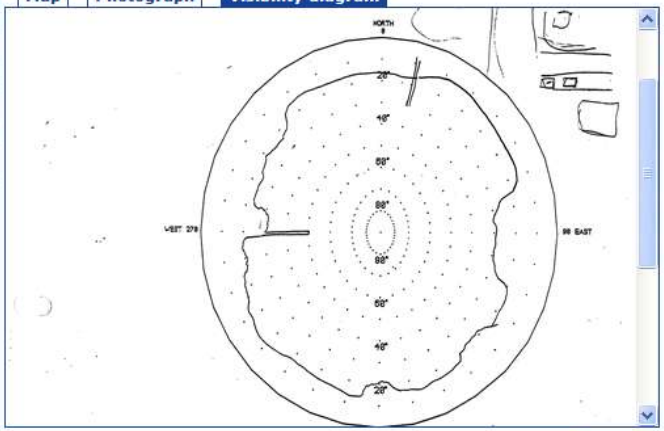
Monument

Name	PID	County
CLAXTON	**FB4334**	**Buncombe**
Condition	Owner	Type
Disk		
DH-Horizontal control disk		
Setting		
7-Set in top of concrete monument		
Vertical Stability		
C-Commonly subject to surface ground movements.		

Add to My Folder | Search Near Here

View NGS Datasheet

Map | Photograph | Visibility diagram



Position

Date	Latitude	Longitude	Northing	Easting
07/01/2008	**35° 36' 29.79176"**	**082° 33' 15.13468"**	**695,221.65 sft**	**943,788.71 sft**
Order	Convergence	Scale Factor	Elevation Factor	Combined Factor
No order	**-2° 3' 4.97115"**	**0.99989189**	**0.99990016**	**0.99979206**
Datum	Source	Technique	Local Accuracy	Network Accuracy
NAD83/2007	---	---	---	---

Position History show full history

Elevation

Date	Model	Height measure	Datum	Order	Type	Method	Class	Local Accuracy	Network Accuracy
07/01/2008	**Orthometric**	**2,184.97 sft**	**NAVD88**	**Second order**	**Normal differential leveling**	**Adj. Level**	**Class 1**		
07/01/2008	**Ellipsoid**	**2,087.13 sft**		---			---	---	---
	GEOID09	**-97.9 sft**							

Elevation History show full history

feedback

Internet 100%

Photo Types

Close-up

BWI D, AB6219, 1, 20071030

Eye-level

BWI D, AB6219, 2, 20071030

Photo Types

Horizontal

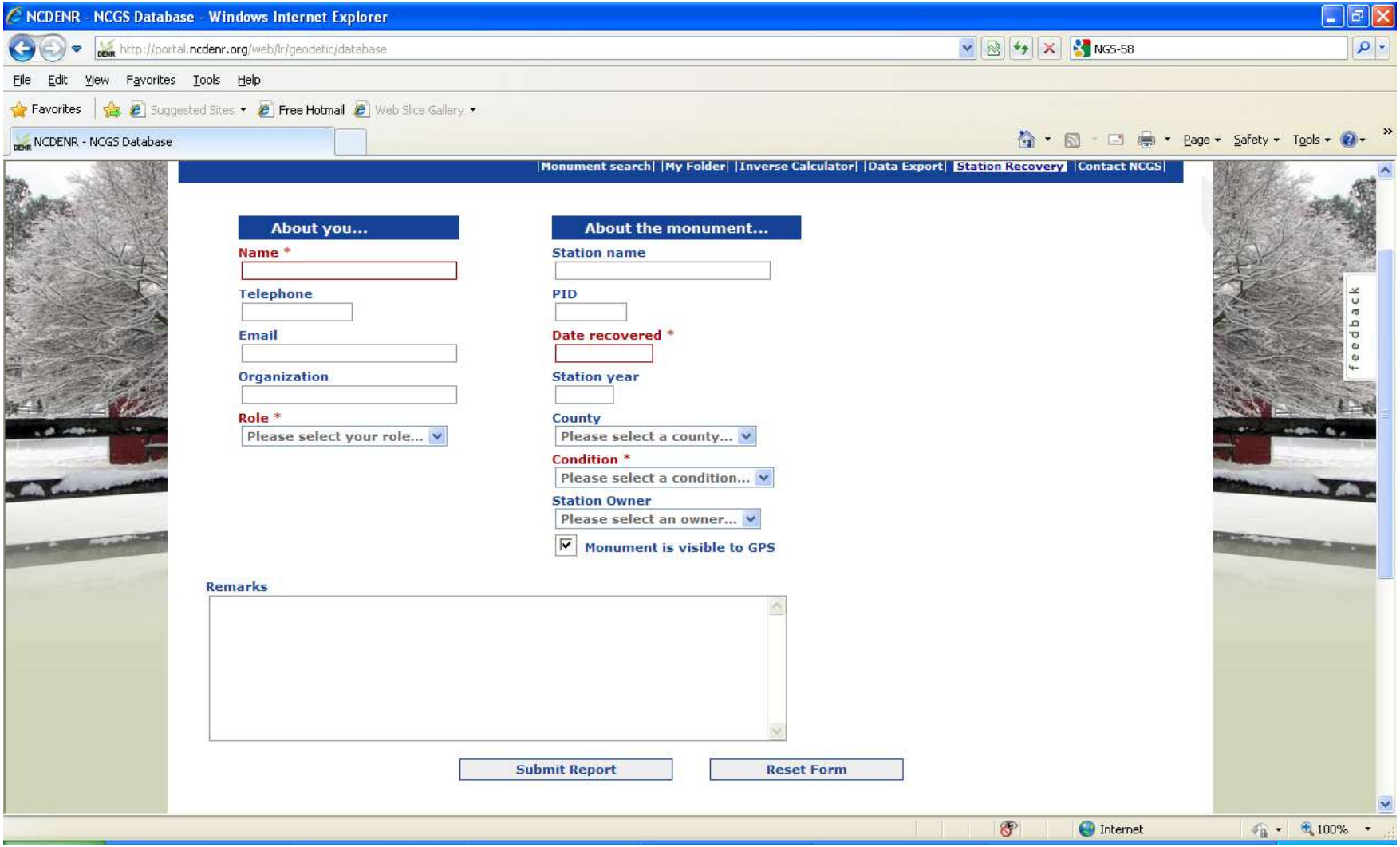
BWI D, AB6219, 3NE, 20071030

Stainless steel rod driven to refusal

Poured in place concrete post

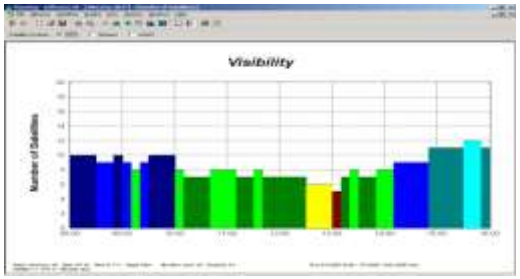

RESET
1970

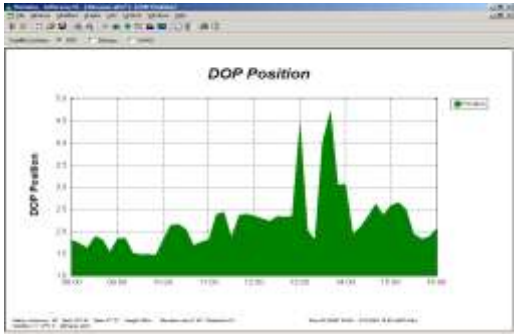
Recovery Form



Survey Grade (Static)

- Planning
  - Existing control (horizontal and vertical)
    - Use 1st order or better control (horizontal)
    - Don't mix horizontal control (1st, 2nd , and 3rd)
    - Use marks with Height Modernization or leveled derived NAVD88 heights
  - Mark access
  - Use your planning software
  - Good satellite geometry
    - PDOP < 6
  - Collect enough data
  - Space weather

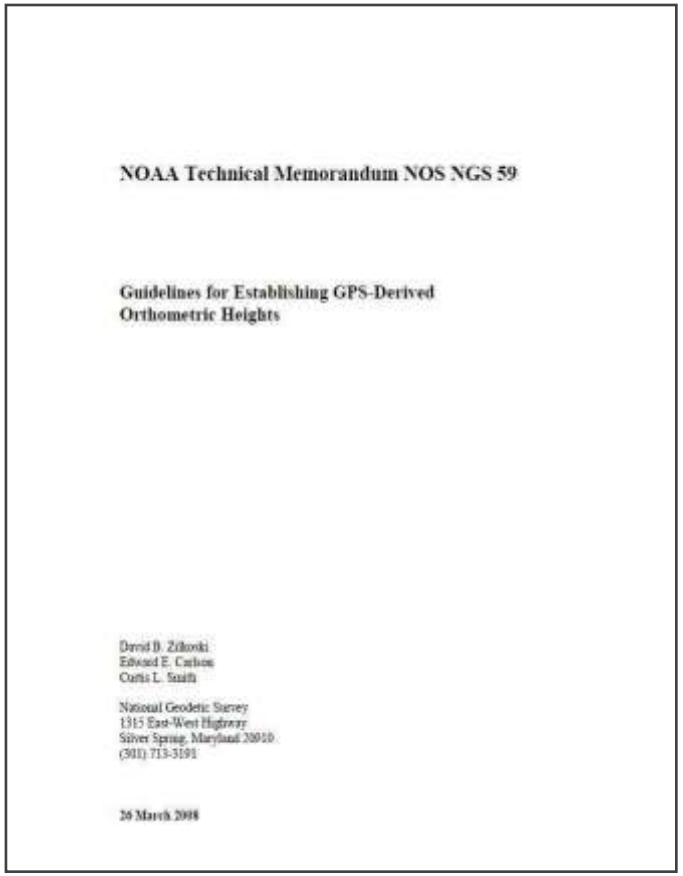




Survey Grade (Static)

- Field Observations
  - Schedule observations
  - Single or dual frequency receivers
  - Length of sessions

Guidelines for Establishing GPS-Derived Heights



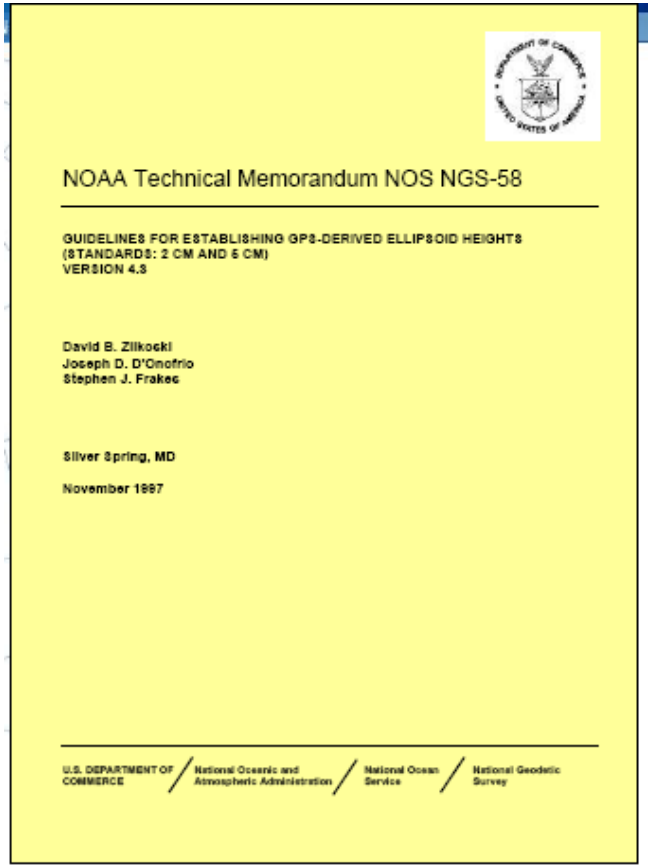
NOAA Technical Memorandum NOS NGS 59

Guidelines for Establishing GPS-Derived Orthometric Heights

David B. Zilkoski
Edward E. Carlson
Curtis L. Smith

National Geodetic Survey
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3191

16 March 2008



NOAA Technical Memorandum NOS NGS-58

GUIDELINES FOR ESTABLISHING GPS-DERIVED ELLIPSOID HEIGHTS
(STANDARDS: 2 CM AND 5 CM)
VERSION 4.3

David B. Zilkoski
Joseph D. D'Onofrio
Stephen J. Frakes

Silver Spring, MD

November 1997

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service / National Geodetic Survey

NGS – 59 Guidelines

- Must repeat base lines on different days and at different times of the day
- Must reobserve repeat base lines that disagree by more than 2 cm
- Stations must be connected to at least its two nearest neighbors

Three Basic Rules Of Height Determination

- **RULE 1: Follow NGS' Guidelines for Establishing GPS-Derived Orthometric Heights (Standards: 2cm and 5cm)**
- **RULE 2: Use the Latest National Geoid Model, i.e., Geoid 09 (Geoid12 when available)**
- **RULE 3: Use the Latest National Vertical Datum, i.e., NAVD 88**

OBSERVATIONS

NOS NGS-58/59

- **The Observing Scheme for all Stations Requires that Adjacent Stations (Base Lines) be Observed at Least Twice on Two Different Days And at Two Different Times of the Day**

EXAMPLES

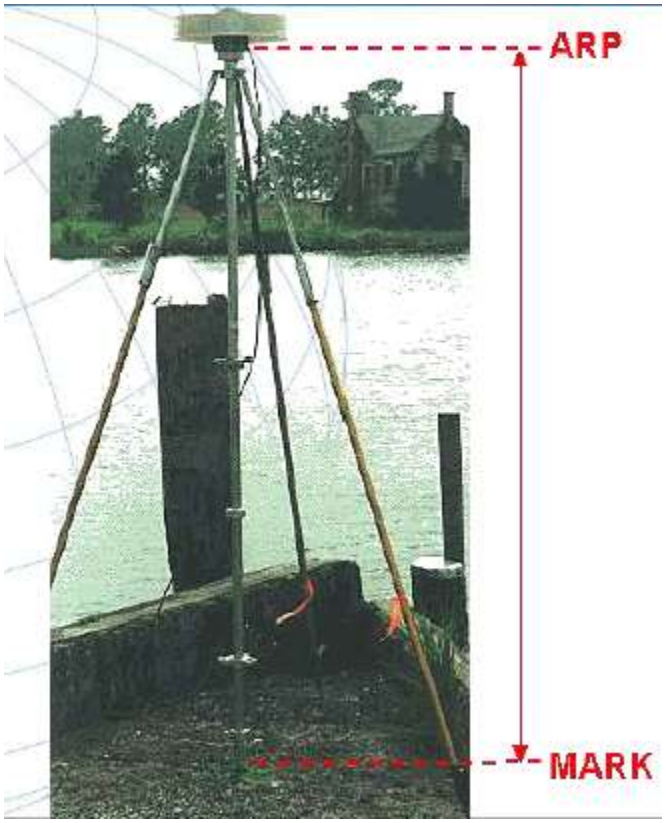
First-day Observations	Second-day Observations
Began During:	**Completed Anytime Between:**
8:00 a.m. to 8:30 a.m.	11:30 a.m. and 5:30 p.m.
10:30 am to 11:00 a.m.	2:00 p.m. and 8:00 p.m.
1:00 p.m. to 1:30 p.m.	4:30 a.m. and 10:00 a.m.

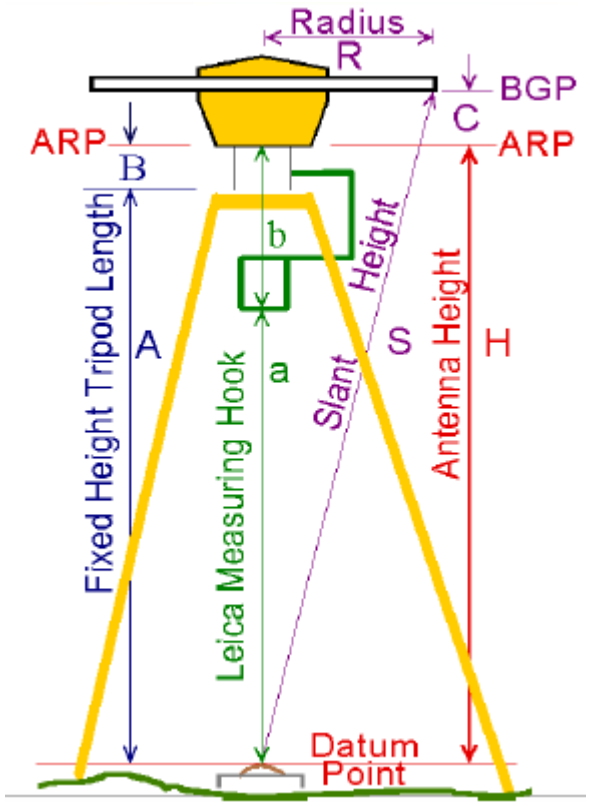
OBSERVATIONS

NOS NGS-58/59

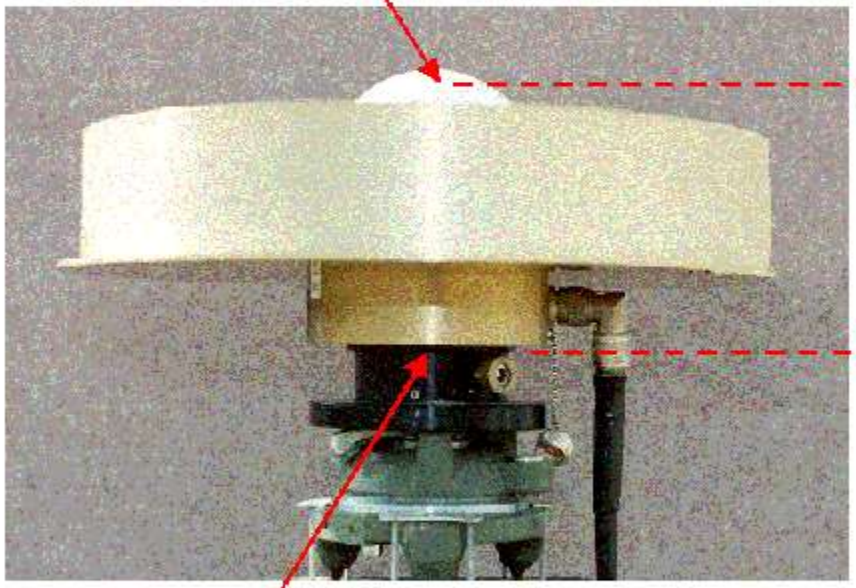
- **Data Shall Be Collected During Periods when the Vertical Dilution of Precision (VDOP) is less than 6 for at Least 90 % of Each 30-minute, or Longer, Observing Period.**
- **For Shorter Observing Periods a VDOP Greater than 6 Shall be Avoided.**
- **Travel Between Stations Should be Scheduled During Large VDOP Periods**

Height of Antenna Reference Point (ARP)





The antenna phase centers are located somewhere around here



The user does not need to know these offsets. They are passed to the processing software through the antenna type

The antenna offsets are the distance between the phase centers and the ARP

If the user selects NONE as the antenna type, the offsets are set to 0.000 and the antenna phase center becomes the reference point

The Antenna Reference Point (ARP) is almost always located in the center of the bottom surface of the antenna.

GNSS Surveying

- Pick a good open site for control points
- Redundancy
- Good satellite geometry
- Avoid areas that have sources for multipath
- Redundancy
- Avoid antenna height blunders
- Keep equipment adjusted for the highest accuracy
- Check known points before, during and after survey session
- Backup power supply
- The more redundancy the better

Adjustment

- Validity Check Data Files
  - Loop closures
  - Vector comparison

- Run Free Adjustment
  - Fix one (1) horizontal position, one (1) ellipsoid height
  - Check for blunders within project (Reject Obs?)

Adjustment

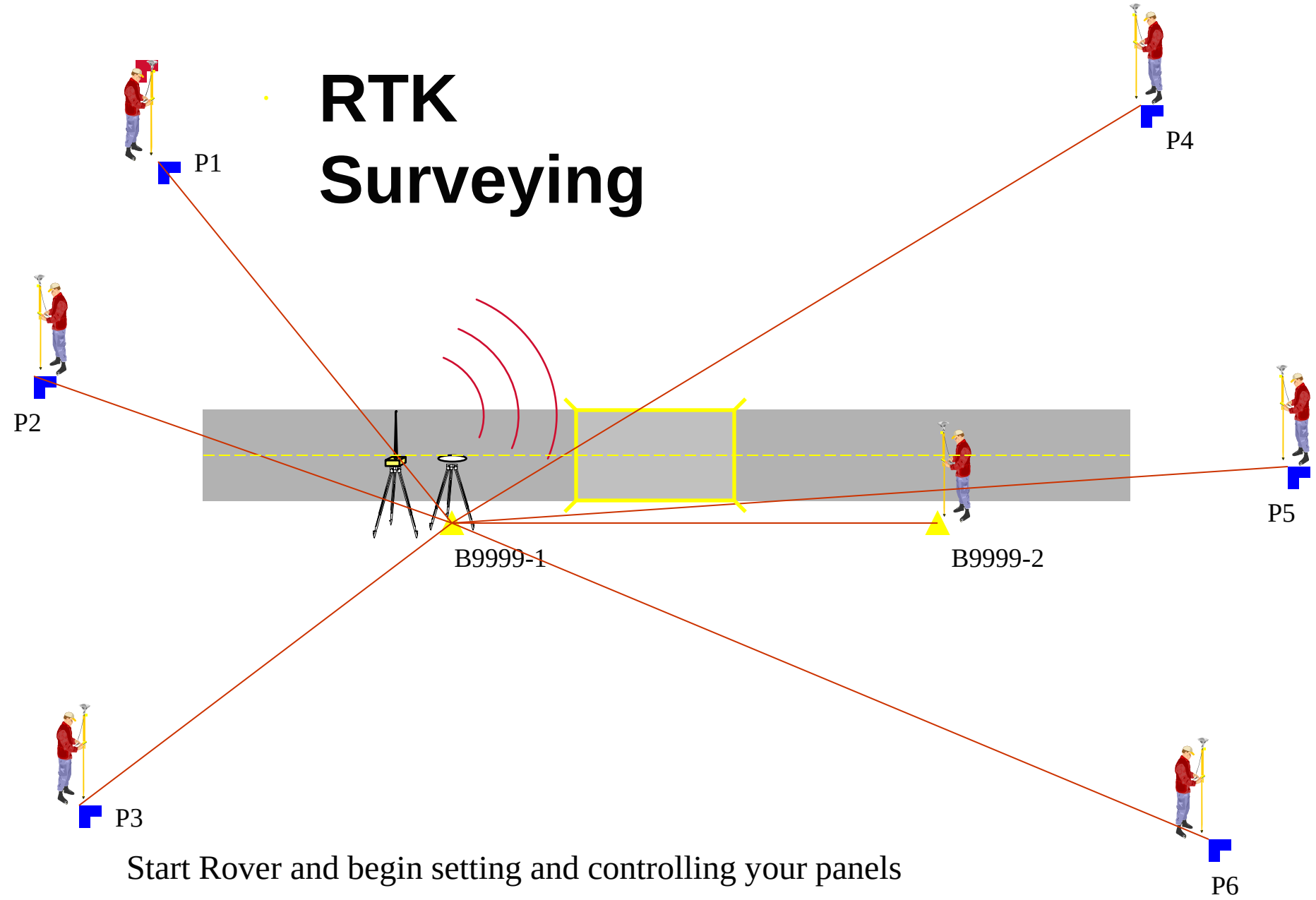
- Run Horizontal Constrained Adjustment
  - Fix all published positions and ellipsoid heights
  - Evaluate residuals for consistency with control
  - (Readjust positions, ellipsoid heights?)

- Run Vertical Free Adjustment
  - Add Geoid heights
  - Fix one (1) horizontal position and one published NAVD88 height

Adjustment

- Run Vertical Constrained Adjustment
  - Fix one (1) horizontal position, all published NAVD88 heights
  - Evaluate residuals for consistency with control (Readjust NAVD88 heights?)

RTK Surveying



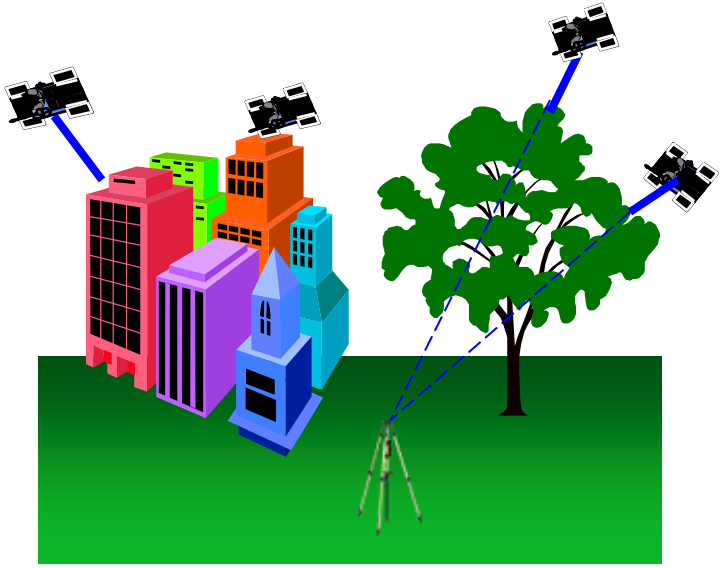
Start Rover and begin setting and controlling your panels

Classical RTK Surveying

- Limited range from single reference station
- Potential gross error in establishing reference station
- Dependency on single reference station

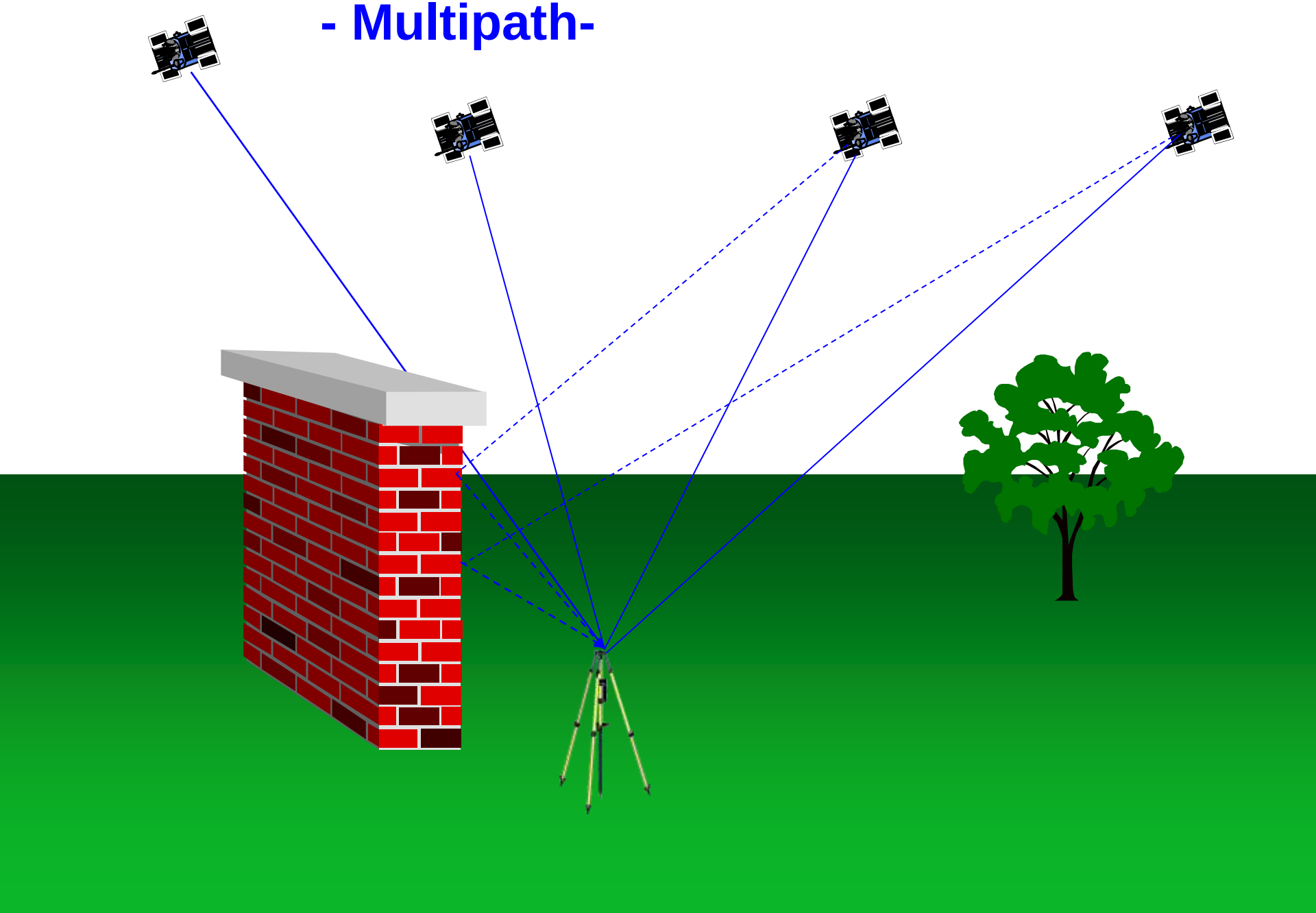
RTK Surveying

- Pick a good open site for base
- Redundancy
- Good satellite geometry
- Avoid areas that have sources for multipath
- Redundancy



GNSS Site Selection

GPS Signal Error Sources
- Multipath-



Collection Method Comparison
Traverse vs. RTK (in unfriendly GPS environment)

DELTA NORTH (m)	DELTA EAST (m)	ELEV DIFF (m)
0.158	0.395	4.613
-0.022	0.015	-0.122
-0.406	-1.865	1.423
-0.003	0.041	-0.084
-0.017	0.001	-0.072
-0.017	-0.010	0.032
0.983	0.664	2.101
0.015	0.442	0.124
0.035	0.057	-0.156
0.026	0.031	0.015
-0.600	2.067	1.333
-0.057	-0.016	0.010
0.412	-1.254	7.693
2.109	-1.637	-0.449
-0.200	-1.165	2.496

RTN Surveying

- Uses observations from multiple reference stations
- Continuously monitors integrity of reference station data
- Models systematic errors including:
  - ionosphere
  - troposphere
  - satellite orbit errors
  - multipath
- Creates a unique virtual reference station for each user's location
- Delivers the data in RTCM or CMR+ format to the rover

RTN Surveying

- Extended operating range with improved initialization and accuracy (50 km)
- Increased productivity
- Eliminates need to establish reference station
  - Set-up
  - Power supply
  - Physical security of RTK base

RTN Surveying

- All users in common, established coordinate frame
  - Old NC RTN(NAD83(NSRS2007)
  - New NC RTN (NAD83(2011)
- Provides integrity monitoring
- Uses established communications

RTN Surveying

- Utilize RTN at sites that has minimum sky blockage
  - Real time applications don’t like tree canopy or tall buildings
- Good network communications (no latency)
- Redundancy
- Good satellite geometry
- Avoid areas that have multipath sources
- Redundancy
- Check at know points of equal or higher accuracy

Three Basic Rules Of Height Determination

- **RULE 1: Follow NGS' Guidelines for Establishing GPS-Derived Orthometric Heights (Standards: 2cm and 5cm)**
  - **Different Days Different Times**
- **RULE 2: Use the Latest National Geoid Model, i.e., Geoid 09 (Geoid12 when available)**
- **RULE 3: Use the Latest National Vertical Datum, i.e., NAVD 88**

GNSS DERIVED HEIGHTS
Summary of expected orthometric heights precisions/accuracies

OPUS-S = 0.03m to 0.05 m

OPUS-RS = 0 0.03m to 0.05 m

NGS 58/59 = 0.02 m local, 0.05 m to NSRS

Single base RTK = 0.03 m $\leq$ 10 K

RTN = 0.02 m - 0.05 m

Highlights of New Elevation Certificate

- Latest version of the Elevation Certificate (EC) effective March 16, 2009 – March 31, 2012.

- Available for download (in both PDF and MS Word format) from FEMA's website at: http://www.fema.gov/library/viewRecord.do?id=1383

- Elevations certified on or after April 1, 2010, must be submitted on the new form.

- The current form will remain effective until further notice.

Section C (If zone has BFE)

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☐ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.

C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.

Benchmark Utilized _____ Vertical Datum _____

Conversion/Comments _____

			Check the measurement used.	
a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	_____.____	☐ feet	☐ meters (Puerto Rico only)
b)	Top of the next higher floor	_____.____	☐ feet	☐ meters (Puerto Rico only)
c)	Bottom of the lowest horizontal structural member (V Zones only)	_____.____	☐ feet	☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	_____.____	☐ feet	☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	_____.____	☐ feet	☐ meters (Puerto Rico only)
f)	Lowest adjacent (finished) grade next to building (LAG)	_____.____	☐ feet	☐ meters (Puerto Rico only)
g)	Highest adjacent (finished) grade next to building (HAG)	_____.____	☐ feet	☐ meters (Puerto Rico only)
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	_____.____	☐ feet	☐ meters (Puerto Rico only)

Section C2

C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.

Benchmark Utilized _____ Vertical Datum _____

Conversion/Comments _____

- A field survey is required for Items C2.a-h.
- Enter the Benchmark Utilized. Provide the PID or other unique identifier assigned by the maintainer of the benchmark. For GPS survey, indicate the benchmark used for the base station, the Continuously Operating Reference Stations (CORS) sites used for an On-line Positioning User Service (OPUS) solution (attach the OPUS report), or the name of the Real Time Network used.
- Note the Vertical Datum. All elevations for the certificate, including the elevations for Items C2.a-h, must use the same datum on which the BFE is based.
- Conversion/Comments. Show the conversion from the field survey datum used if it differs from the datum used for the BFE entered in Item B9 and indicate the conversion formula or software used. Show the datum conversion, if applicable, in this section or in the Comments area of Section D.

METADATA

Data About Data

DATUMS

NAD 27, NAD 83(1986), NAD83 (1995), NAD83(2001), NAD83(NSRS2007), NAD83(2011)

NGVD29, NAVD88

UNITS

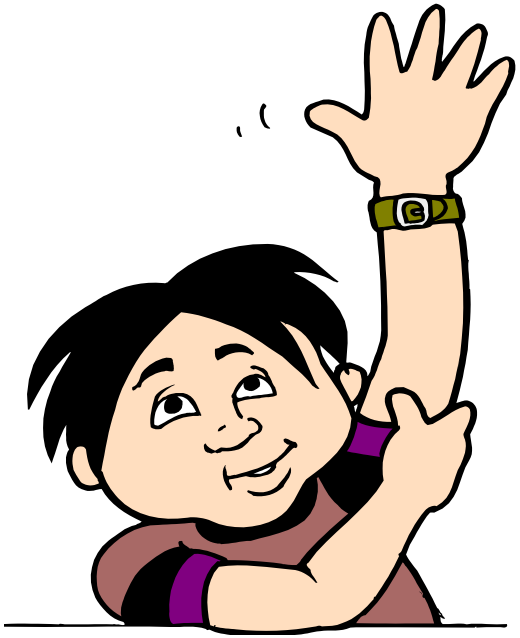
Meters, U.S. Survey Feet, International Feet, Chains, Rods, Pole

Fot?

Fuss?

Smoot?

Questions?



Gary Thompson, PLS
NC Geodetic Survey
512 North Salisbury Street
Raleigh, NC 27604
919-707-9230 phone

Gary.thompson@ncdenr.gov