Vertical Geodetic Control in Southern Louisiana: Providing the National Spatial Reference System in Dynamic Regions

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Overview

• NGS mission

• Approaches to provide up-to-date data: Louisiana model

• National Height Modernization Program

• Future
Mission of NGS

To define, maintain and provide access to the National Spatial Reference System to meet our nation’s economic, social, and environmental needs.

http://geodesy.noaa.gov/INFO/ngs_tenyearplan.pdf
From the NGS 10-Year Plan

- **Define the NSRS**
  - “The NSRS must be *more accurate* than all activities which build upon it, while still being practicably achievable.”

- **Maintain the NSRS**
  - “NGS must *track all of the temporal changes* to the defining points of the NSRS in such a way as to always maintain the accuracy in the NSRS definition.”

- **Provide Access to the NSRS**
  - “NGS must develop and maintain guidelines for users to access the NSRS at *a variety of accuracies.*”
  - “NGS will publish *all coordinates* of defining points of the NSRS *with an epoch tag and* will furthermore publish *velocities* relative to that epoch-tagged set of coordinates.”
Mission – The NSRS is…

• The official national coordinate system of the U.S. federal government which includes:
  – Geodetic latitude, longitude and height
  – Scale, gravity, and orientation
  – How these values change with time

• Components include:
  – National and Cooperative CORS
  – Network of passive monuments
  – Official national shoreline
  – Precise orbits of GNSS satellites used to define NSRS
  – Models and tools to describe how all of these quantities change over time.
Why worry about updating heights?
Height Modernization is ... 

...the establishment of accurate, reliable heights using GNSS technology in conjunction with traditional leveling, gravity, and modern remote sensing information....
To improve GPS-derived orthometric heights we need:

- Good ellipsoid heights
  - Better field procedures
  - Accurate ellipsoid heights at control stations

- An improved geoid model
  - Accurate ellipsoid heights
  - More bench marks observed by GPS

- Accurate orthometric heights at bench marks
Goals of NHMP

- Access to **accurate**, reliable heights nationally – NGS 58/59

- Standards that are **consistent** across the nation

- Data, technology, and tools that yield **consistent** results regardless of terrain and circumstances

- A system/process that will stand the test of time – “**Maintain-able**”
... new orthometric heights rely on new locations of the crust and the geoid

Effect of Subsidence on Orthometric Heights

NGS Benchmarks provide direct access to NAVD 88

In areas where there is uplift or subsidence, NGS Benchmarks experience a loss of relationship with NAVD 88.

New NAVD 88
Options for Updating Geodetic Control

1. Re-observe/Readjust – special case projects, gravity

2. Model motion, develop tools – monitor with CORS, satellite gravity

3. Metadata: Epochs, reliability scale, i.e. “Expiration date” on coordinates
NOAA Technical Report 50: Rates of Vertical Displacement

• 2004 Study by Kurt Shinkle, NGS and Dr. Roy Dokka, LSU

• Louisiana vertical control was out of date

• Study of historic leveling data provided a crude model for updating heights: Vertical Time Dependent Positioning (VTDP)
  - Historical 1st Order leveling from 1920-1995
  - Pensacola, FL – Texas border (short of Beaumont)
  - Include relative sea level change from tide gauges
  - Include CORS velocities

• Highest rates of subsidence, over 25mm/yr in Mississippi River Delta
Figure 5. Rates of vertical change derived from the latest rates computed for the benchmarks in this study.
2004 Survey to Update Vertical Control Network

- New leveling, GPS surveys to 99 bench marks
- Area of Survey – south of I-10
- Used VTDP to validate control and consistency of observations in adjustment
- New NAVD 88 heights used to refine geoid model (GEOID03)
- Control published for new heights only; other heights ‘suppressed’
2006 Southern Louisiana Project – Post-Katrina Recovery Project

- FEMA provided Funding through NGS
- Joint Survey Project between NGS and CO-OPS of NOAA, & the Louisiana Spatial Reference Center at LSU
- Included 27 Parishes across Southern Louisiana
Project Components

• Re-observe the 2004.65 Marks (99 marks)
• Observe & update an additional 240 marks
• Install a minimum of 16 additional Continuously Operating Reference Stations (CORS)
• Set up a pilot GPS Real Time Network (RTN) in SE LA
• Take gravity observations at 16 sites (relative & absolute)
• Install two new tide stations (Shell Beach & Amerada Pass)
South Louisiana Height Modernization Project 2006

VTDP Shift Values

- 2004.65 to 2006.81 Epochs

2.5-3 cm
3-4.8 cm
Results of 2006 Survey

- Updated Heights on 340 bench marks
- Observation data to contribute to subsidence rate research
- Additional gravity and height data to improve the geoid model used to convert GPS heights to NAVD88 heights
- Suppression of inconsistent out-dated heights
Estimate “subsidence” border
NGS Datasheet – Leveling

- National Geodetic Survey, Retrieval Date = JUNE 19, 2011
- DESIGNATION - 18 V 32
- PID - AA2906
- STATE/COUNTY - LA/EAST CARROLL
- USGS QUAD - MILLIKIN (1994)
- *CURRENT SURVEY CONTROL
- ____________________________________________________________
  - NAD 83(2007) - 32 54 27.65574 (N) 091 13 35.40957 (W) ADJUSTED
  - NAVD 88 - 32.001 (meters) 104.99 (feet) ADJUSTED
- ____________________________________________________________
  - EPOCH DATE - 2002.00
- LAPLACE CORR - -1.92 (seconds) DEFLEC09
- ELLIP HEIGHT - 5.765 (meters) (02/10/07) ADJUSTED
- GEOID HEIGHT - -26.241 (meters) GEOID09
- DYNAMIC HT - 31.966 (meters) 104.88 (feet) COMP
- ------- Accuracy Estimates (at 95% Confidence Level in cm) -------
  - Type PID Designation North East Ellip
- NETWORK AA2906 18 V 32
- VERT ORDER - SECOND CLASS I
- The orthometric height was determined by differential leveling and adjusted in May 1997.

NAVD88 – Ellipsoid Ht + Geoid Ht =
32.001 - 5.765 – 26.241 = -0.005 GEOID03
32.001 - 5.765 – 26.244 = -0.008 GEOID09
National Geodetic Survey, Retrieval Date = MARCH 18, 2009

BJ0196

HT_MOD - This is a Height Modernization Survey Station.

FBN - This is a Federal Base Network Control Station.

DESIGNATION - E 284 X

PID - BJ0196

STATE/COUNTY - LA/ST LANDRY

USGS QUAD - BAYOU CURRENT (1994)

*CURRENT SURVEY CONTROL

NAD 83(2007) - 30 46 55.32566(N) 091 46 23.63541(W) ADJUSTED

NAVD 88 - 11.54 (meters) 37.9 (feet) GPS OBS

EPOCH DATE - 2002.00

X - -169,707.673 (meters) COMP

Y - -5,481,757.847 (meters) COMP

Z - 3,245,148.124 (meters) COMP

LAPLACE CORR - 0.08 (seconds) DEFLEC99

ELLIP HEIGHT - -15.814 (meters) (02/10/07) ADJUSTED

GEOID HEIGHT - -27.25 (meters) GEOID03

---------- Accuracy Estimates (at 95% Confidence Level in cm) ----------

Type PID Designation North East Ellip

---------- NETWORK BJ0196 E 284 X ----------

0.25 0.25 0.76
### NGS Datasheet – GPS Height Mod

<table>
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<th>North</th>
<th>East</th>
<th>Units</th>
<th>Scale Factor</th>
<th>Converg.</th>
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</table>

- Elev Factor x Scale Factor = Combined Factor
- \[ \text{BJ0196! SPC LA S} = 1.00000248 \times 1.00001848 = 1.00002096 \]
- \[ \text{BJ0196! UTM 15} = 1.00000248 \times 0.99976997 = 0.99977245 \]

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**SUPERSEDED SURVEY CONTROL**

- **NJ0196**
  - NAD 83(1992) - 30 46 55.32569(N) 091 46 23.63496(W) AD( ) B
  - NAVD 88 (02/14/94) 11.408 (m) 37.43 (f) ADJUSTED 1 1
  - NAVD 88 (06/15/91) 11.444 (m) 37.55 (f) UNKNOWN 1 1
  - NGVD 29 (??/??/??) 11.404 (m) 37.41 (f) ADJUSTED 1 1

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- Superseded values are not recommended for survey control.
- NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
- See file `dsdata.txt` to determine how the superseded data were derived.
### NGS Datasheet – New Datasheets

1. National Geodetic Survey, Retrieval Date = MARCH 17, 2009

**AV0426** HT MOD - This is a Louisiana Height Modernization Survey Station.

**AV0426** DESIGNATION - D 215

**AV0426** PID - AV0426

**AV0426** STATE/COUNTY - LA/CAMERON

**AV0426** USGS QUAD - CREOLE (1982)

**AV0426**

*CURRENT SURVEY CONTROL*

**AV0426**

- **AV0426** NAD 83(2007) - 29 51 37.54827(N) 093 05 15.70510(W) ADJUSTED
- **AV0426** NAVD 88 - 0.65 (meters) 2.1 (feet) GPS OBS(2006.81)
- **AV0426** This station is located in a suspected subsidence area (see below).
- **AV0426** This station is included in the VTDP model (see below).

**AV0426**

- **AV0426** EPOCH DATE - 2002.00
- **AV0426** X - -298,190.692 (meters) COMP
- **AV0426** Y - -5,527,916.711 (meters) COMP
- **AV0426** Z - 3,156,952.642 (meters) COMP
- **AV0426** LAPLACE CORR - 0.40 (seconds) DEFLEC99
- **AV0426** ELLIP HEIGHT - -26.050 (meters) (03/12/08) ADJUSTED
- **AV0426** GEOID HEIGHT - -26.76 (meters) GEOID03

**AV0426**

- **AV0426** Accuracy Estimates (at 95% Confidence Level in cm) -------

<table>
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<tr>
<th>Type</th>
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<th>Designation</th>
<th>North</th>
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</table>
AV0426 Type PID Designation North East Ellip
AV0426 NETWORK AV0426 D 215 0.96 0.82 2.00

The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in February 2007.

The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).

AV0426  The horizontal coordinates are valid at the epoch date displayed above.
AV0426  The epoch date for horizontal control is a decimal equivalence of Year/Month/Day.
AV0426  The orthometric height was determined by GPS observations and a high-resolution geoid model.

** Due to the variability of land subsidence, the orthometric, ellipsoid, and geoid heights are valid at the date of observation. These heights must always be validated when used as control.
** The orthometric height was determined with a Vertical Time-dependent Positioning (VTDP) model and has been validated through GPS observations for the epoch indicated (see www.ngs.noaa.gov/heightmod/VTDP.shtml).
** The geoid height was determined by a new realization of GEOID93 for the Southern Louisiana Subsidence area (see www.ngs.noaa.gov/PC_PROD/GEOID03).
**NGS Datasheet – Mask Heights**

- **BK2416**
  - **DESIGNATION** - 28 A 032
  - **PID** - BK2416
  - **STATE/COUNTY** - LA/ST LANDRY
  - **USGS QUAD** - SUNSET (1983)

**CURRENT SURVEY CONTROL**

- **NAD 83(1992)** - 30 23 01.12137(N) 092 03 15.21777(W) ADJUSTED
- **NAVD 88** - **(meters)** **(feet)** NOT PUB

**This station is located in a suspected subsidence area (see below).**

- **LAPLACE CORR** - 0.40 (seconds) DEFLEC99
- **GEOID HEIGHT** - -27.45 (meters) GEOID03
- **DYNAMIC HT** - 14.510 (meters) 47.60 (feet) COMP
- **MODELED GRAV** - 979,322.9 (mgal) NAVD 88

- **HORZ ORDER** - SECOND
- **VERT ORDER** - FIRST CLASS II

The horizontal coordinates were established by classical geodetic methods and adjusted by the National Geodetic Survey in January 1993.

The orthometric height was determined by differential leveling and adjusted in February 1994.

**Due to the variability of land subsidence, the orthometric, ellipsoid, ...**
Underway: 2010 Survey

- GPS Observations on 120 Marks
- GPS Processing complete; Adjustment in progress
- Suppression of inconsistent out-dated heights – including those observed in 2006 not re-observed in 2010
What’s Next?
National Height Modernization Program

• Improve access to NAVD 88 today
  – Survey methods? Static vs. Real Time?
  – Ensure control is current?
  – Enable easy input of user data for NGS models
• Enhance infrastructure where there are gaps
• Support development of better geoid models
• Develop plan for maintaining datum
• Encourage partnerships, collaboration
• Support NGS ten-year plan
The National Geodetic Survey 10-year plan --
Mission, Vision and Strategy 2008-2018

- Official NGS policy as of Jan 9, 2008
  - Attention to accuracy
  - Attention to time-changes
  - Improved products and services
  - Integration with other fed missions
  - [www.ngs.noaa.gov/10yearplan](http://www.ngs.noaa.gov/10yearplan)

- 2022 Targets:
  - NAD 83 and NAVD 88 replaced
  - Cm-accuracy access to all coordinates
  - Customer-focused agency
  - Global scientific leadership

- New Datum Managers
  - Mark Eckl, Geometric (Horizontal)
  - Joe Evjen, Geopotential (Vertical)
Transition to the Future – GRAV-D

Gravity for the Redefinition of the American Vertical Datum

• Airborne Gravity Snapshot of all US and Territories
• Tracking of Absolute Gravity Changes at specific locations
• Re-define the Vertical Datum of the USA by 2022
• New subsidence monitoring paradigm
Height Modernization and the NGS Business Plan: Three Areas of Focus

Infrastructure

Models and Tools

Outside Capacity Building
Infrastructure

- CORS - Active control network helps us monitor movement 24/7
- Passive control network as needed
  - Use repeat surveys to monitor movement
  - Update coordinates: resurveys? Velocity models? Adjust accuracies or expire values?
Infrastructure

• Inclusion of data in NGS database improves models

• Metadata provided on datasheets: epoch dates, accuracy/reliability measures

• Multi-Year CORS Solution (MYCS) and NA2011

• Infrastructure gap analysis
Guidelines, Models, and Tools

- Guidelines: NGS58/59, RT, RTN
- Modeling
  - 1-cm geoid
  - HTDP, VTDP = TDP?
- Development of software, tools
  - Transformation models, VDatum
  - OPUS Variety Pack including -DB, -Projects
Outreach, Capacity Building

- Stage Geodetic Advisor Program
- Conferences, Workshops, Forums
- Corbin Training Center, Webinars
- Hands On Training: Leveling, OPUS-Projects
- Federal Geospatial Summits (2010, 2012)
- Regional partner meetings
National Height Modernization Building Partnerships

- **Funded Partners**
  - Academic Institutions
  - State and Local Governments
  - Spatial Reference Centers
- **Offices within NOAA**
  - National Weather Service
  - National Hurricane Center
  - Ocean and Atmosphere Research
  - National Ocean Service
- **Other federal agencies**
  - Department of Homeland Security/FEMA
  - US Army Corps of Engineers – e.g. levees, dams
  - US Geological Survey – e.g. stream gages
Station D 215; PID AV0426
NAVD 88 Heights:
1965 leveling field ht = 1.105 M
1986 leveling field ht = 0.930 M
NAVD 88 adj. = 0.9684 M
2004 GPS = 0.677 M
2006 GPS = 0.653 M
Fast is fine, but accuracy is everything. – Wyatt Earp

A witty saying proves nothing. - Voltaire

Questions

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http://www.ngs.noaa.gov/heightmod/EventsArchive.shtml