Wisconsin Height Modernization Program (WI-HMP) and Continuously Operating Reference Stations (CORS)

“Improving the Vertical Component of the Geodetic Network”

California Spatial Reference Center
San Jose, California
May 8, 2008
OUTLINE:

✓ Background for the WI-HMP
✓ Program Objectives
✓ Funding Strategies
✓ Procedures and Network Configurations
✓ Current Status
  • Passive GPS Networks and Leveling
  • CORS
  • Network Maintenance
  • Challenges Ahead
Wisconsin Height Modernization Program

- Began by WisDOT in 1998 to improve the vertical component of Geodetic Control in Wisconsin
  - Started with pilot project, now over 50% of state complete
- Partnering with National Geodetic Survey (NGS)
  - Developed WI-HMP standards to guide program so that data are included in the NSRS
  - Provide training and technical assistance to WisDOT staff
  - Support outreach activities to other states and regions
- As part of the growing development of WI-HMP, a Continuously Operating Reference Stations (CORS) network is being established
Height Modernization Objectives

- Eliminate inconsistencies between horizontal and vertical control data and supplement control where marks have been destroyed or are deemed unusable.
- Utilize GPS technology as a cost effective positioning tool (achieve 2-cm positional accuracy).
- Decrease the cost of surveying required for transportation related projects.
- Provide a substantial increase in accuracy of the vertical database to support a wide variety of data users throughout the state.
- Complete initial efforts by 2011.
Funding and Management

✓ Funding
  o State Transportation Funds
  o FHWA State Planning & Research (SPR) Funds
  o NOAA/NGS - Federal Earmark & Line Item Funds

✓ Staffing Support
  o DOT Program Manager
  o Two Geodetic Specialists
  o Two Limited Term Employees (varies)
  o Up to 28 consultant staff personnel (varies)
Height Modernization Layout

- **HARN station**
- **Primary Base Network**
- **Secondary Base Network**
- **Local Base Network**
- **Existing NGS Level line**
- **Decimated NGS Level line**
- **New WI-HMP Level line**

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Technical Consideration

...to get 2 cm elevations we need to ...

- Produce an accurate geoid model through accurate geoid heights every 25 km...
- Geoid heights can be determined through...
  - High accuracy GPS observations and geodetic leveling or
  - Performing gravity observations
- High accuracy GPS observations and geodetic leveling was chosen as preferred method
Procedures for WI–HMP

Four steps are necessary to complete each Phase for WI-HMP

✓ Planning and Reconnaissance (First Year)
✓ Monumentation (Second Year)
✓ Geodetic Surveying (Third Year)
✓ Reduction, Adjustment, and Publication of data (Fourth Year)
Planning and Reconnaissance

- State is divided into geographic regions (Phases)
- Search the NSRS for information on existing horizontal and vertical control
- Recover and evaluate all existing monumentation (published and non-published)
- Plan locations to supplement monumentation where deficiencies exist
- Hold outreach meetings with local officials to discuss plans and modify when necessary
Monumentation

- Performed in the Summer/Fall of year prior to the year of the survey
- New monuments are 16-inch diameter, 8-foot deep pour-in-place concrete posts or disks set in stable structures
- Private sector firms are contracted to construct monuments
- Monuments are described in accordance with the Federal Geodetic Control Subcommittee (FGCS) “Blue Book” standards
WI-HMP Monumentation
Geodetic Surveying for WI-HMP

- Geodetic (Conventional) Leveling
- Primary Global Positioning System (GPS) Survey Campaign (Static)
- Secondary and Local GPS Survey Campaign (Static)
WI-HMP Geodetic Leveling

- Utilize digital leveling equipment with data recording capabilities of 0.0001 m
- Follow FGCS 2nd Order – Class 1 specs
  - Instrument collimation performed each day of observations
  - 60 meters maximum sight lengths
  - Balance Backsight/Foresights
  - Double observe each section of leveling under different environmental conditions
  - Use turning pins and staff supports
- Utilize All Terrain Vehicles (ATVs)
Leveling with ATVs

- Defined by Wis. Stat. 340.01 (2G) ... as an engine-driven device which has a net weight of 900 pounds or less ...
- Authorized for use along highways by Wis. Stat. 23.33 (4) (c) 1m. Land Surveyors Exception
- Increases production up to 40%.
  - Average walking production = 1.2 km/hr
  - Average ATV production = 1.7 km/hr
WI-HMP Primary GPS Survey Observation Guidelines

- At least 3 occupations of stations on different days
- 5 ½ hour occupations for each session; one must have a different satellite constellation
- 5-digit weather code required for each session
- Images or rubbings of stations are taken for each occupation
WI-HMP Secondary and Local GPS Survey Observation Guidelines

- At least 2 occupations of stations on different days
- All adjacent stations must have a repeated baseline
- One hour occupations for each session; each must have a different satellite constellation
- 5-digit weather code required for each session
- Images or rubbings of stations are taken for each occupation
Reduction, Adjustment, and Published Positions

- **Bench Marks (BM’s)**
  FGCS 2\textsuperscript{nd} Order - Class 1, Published on North American Vertical Datum of 1988 (NAVD 88 (2007))

- **GPS Stations**
  Horizontal FGCS B-order or 1\textsuperscript{st} Order accuracy and GPS derived vertical 2-cm positional accuracy (not leveled).

- **All published datasheets are available at:**
  [www.ngs.noaa.gov](http://www.ngs.noaa.gov)
WI-HMP Phases

Status as of December 3, 2007
WI-HMP Phases
Status of WI-HMP

- Phases 1, 2, 3, 4, and 5: Fully Completed; Project Data Available on NGS Web
- Phase 6A: Leveling Completed (Awaiting Finalization of Adjustment); GPS Primary Survey Completed (Including Adjustment); GPS Secondary and Local Survey of Field Observations Completed (Adjustment Underway); Scheduled Publication in 2008
- Phase 6B: Field Observations for Leveling, GPS Primary, and GPS Secondary and Local Surveys Completed; Scheduled Publication in 2008
- Phase 7A: Monuments Constructed; Witness/Guard Posts Installed; Field Observations for Leveling and GPS Surveys Planned for 2009
Status of WI-HMP

- Phase 7B: Monuments Constructed; Witness/Guard Posts Installed; Field Observations for Leveling and GPS Surveys Planned for 2010
- Phase 7C: Mark Recoveries Completed; Bench Mark Reconnaissance Completed; Station Reconnaissance Partially Completed
- Phase 8A: Reconnaissance of Existing Bench Marks Completed; Reconnaissance of New Level Lines Completed; Reconnaissance of Primary Base Stations Completed; Monumentation, Leveling and GPS Surveys Planned for 2008
- Phase 8: Reconnaissance of Existing Bench Marks Completed; Reconnaissance of New Level Lines to be Determined
Status of WI-HMP

- Statewide WISconsin Continuous Operating Reference Stations Network (WISCORS): Developing Twenty-Five (25) CORS Sites in Eastern Portion of Wisconsin; System Operational in early summer of 2008
Level Network – Phases 1 through 5
Adjustment of Vertical Control

✔ Prior to WI-HMP
  • A majority of original leveling was performed in the 1930’s
  • NAVD 88 (1991) adjustment based on old leveling data with no consideration given to frost heave or disturbance
  • Adjustment performed in June 1991

✔ WI-HMP
  • Based on recent leveling (last 9 years)
  • Adjusted in April 2007
  • Constrained at LaCrosse and Dubuque
  • Change at IL near Kenosha = 2 cm (0.07 ft)
  • Changes ranged from −0.60 ft to +0.68 ft
  • New adjustment is named NAVD 88 (2007)
Dane Co Densification

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Funding: Sources and Status

- Funding sources have included State Transportation Funds, State Planning Research (FHWA), and NGS/NOAA Grants.
- Federal sources have provided about 2/3 of funding.
- FY 04-06 received $2.6 million per year from NGS/NOAA.
- FY 07 received $1.2 million from NGS/NOAA.
- FY 08 receiving $300,000 in conjunction with an NGS/NOAA cooperative agreement.
Funding for WI-HMP, 1998-2008

Funding over the past 11 years includes:

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<th>Source</th>
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<td>State Planning Research (FHWA)</td>
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Planned Leveling (Phase 8A)

Notation: Yellow = Phase 8A, Blue = Phases 3 & 6A
Proposed CORS Zone 2

Black Lined Circles are Existing CORS

Blue Lined Circles are Proposed CORS in Zone 2
Benefits of CORS Network
(Implementation of Technology Advancement to Height Mod)

✓ Eliminates the need and cost for another GPS receiver that acts as a base
✓ Eliminates the resource time associated with equipment setup at the base site
✓ Greatly enhances consistency of coordinate determination
✓ Eliminates the need for permanent monumentation of the local GPS network
✓ Reliability and redundancy is ensured

Hence, Wisconsin Continuously Operating Reference Stations Network (WISCORS) is Being Implemented
Concept of CORS Network

- Utilizes network Real-Time Kinematic (RTK) solutions to provide high accuracy GPS positioning for wide areas
- At least four GPS reference stations are needed
- Users connect into system using wireless connection
- Software acknowledges the user’s field position and allows them to operate as though there is a reference station next to the rover
- Software uses reference stations to calculate virtual reference station position for the rover
Implementation of WISCORS

- Continuous Operating Reference Stations (CORS) are established at approximate 50 km spacing
- CORS will be connected to a framework of elevations on monuments along corridors that connect HARN and Primary Base stations
- Plan is to establish 35 permanent CORS throughout the eastern portion of Wisconsin
- Site conditions dictate if concrete pillar or building mount monument is used
- CORS sites include public educational buildings, county facilities, municipal facilities, and a park
- Acquisition of Trimble GPS hardware and software is complete
- First 25 sites will be operational by early summer of 2008
Development of Pilot Project for WISCORS

- Goal was to determine spacing requirement of permanent GPS base stations while achieving 2-cm three-dimensional positioning accuracy standard.
- Pilot network consisted of two permanent sites (Franklin and Watertown) and two temporary sites (Germantown and Palmyra).
- Equipment utilized on the project included a Trimble GNSS R8 receiver for the rover and Trimble NetR5 receivers for the bases.
- Results indicate 2 cm accuracy standard in horizontal and vertical (orthometric height) components are achievable on a reliable basis.
# Sample of Results

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Average = -0.010
Std Dev = 0.013

Please Note: Measurement Units in Metric
CORS Site Considerations

- Clear view of horizon above 10°
- Distance from GPS antenna to GPS receiver has to be less than 250 ft
- Distance from GPS receiver to Ethernet hub has to be less than 300 ft
- Security of site
- High speed internet on-site or can be installed
- Prefer concrete pillar monument, second option is to use a building mount
- Location of other CORS within 50 km
WISCORS Zone 1 Configuration
CORS Concrete Pillar Monument
Construction of WAEE CORS
(Building Concrete Base)
Construction of WAEE CORS
(Building Concrete Base)
Cold Weather Protection of CORS
Construction of BEDA CORS
(Building Obelisk)
Construction of WAWN CORS
(Boring, Trenching, and Installation of Underground Conduit for Antenna Cable)
Construction of WAWN CORS
(Trenching and Placement of Underground Conduit)
CORS Building Mount Monument
Construction of STBA CORS
(Installation of Building Mount)
Construction of BEDA CORS
(Installation of Service Enclosure)
Construction of BEDA CORS
(Installation of Ground and Lightning Suppressor)
Construction of WAWN/WATH CORS
(Installation of Data Enclosure)
Construction of BEDA CORS
(Installation of Antenna Cable)
Construction of WATH CORS
(Installation of Leveling Mount and Antenna)
CORS: Questions from user meetings

✓ What hardware manufacturer and model are used for CORS stations? *Trimble NetR5 receivers with Zephyr Geodetic 2 antennas*

✓ Do you currently use Glonass on any of the stations? **Ans:** Yes, on all except for possibly DERE and JALE

✓ In what format do you broadcast corrections? **Ans:** RTCM and CMR

✓ Will there be an access charge, and if so, how much? **Ans:** Most likely there will be a charge, expect it to be less than $500 per year

✓ Have you researched cell carriers to determine which have the best coverage, and best service plan? **Work continues on carriers and coverage issues**
CORS Questions (cont.)

✓ Will the system provide real-time corrections and ability to access data for post-processing? **Ans: Yes**

✓ Can you use two rovers with a single login? **Ans: No,** *the username/password will allow access to only one rover at any given time*
WI-HMP Mark Maintenance

- Installed 3 witness posts around each monument
- Established “866” number to report endangered, damaged, or destroyed monuments
- Created the “Preservation of Geodetic Survey Stations Committee”

GPS Stations: Orange 4”x4” Plastic Guard Posts

Bench Marks: White “T” Plastic Witness Posts
WI-HMP Mark Maintenance

- Approximately 40 marks are recovered every week through the mark maintenance program.
- Mark recovery activities include locating mark; verifying and updating description; taking photographs of mark and site; replacing destroyed guard or witness posts; clearing weeds and debris surrounding mark; and submitting information to NGS.
- Approximately 3,800 marks have been established and published through Phase 5.
- An additional 2,800 more marks have been or will be surveyed through Phase 7.
- About 1,400 more will be used in Phase 8.
Challenges That Lie Ahead

- **Issue:** Pressure by other entities (especially federal) to reduce or eliminate passive monumentation. **Determination:** Find a compromise on a level of monumentation that meets the needs of users and environmental conditions. We are actively working with the user community to develop a solution that is satisfactory to all.

- **Issue:** Communication in CORS environment is problematic. **Determination:** Engage GPS manufacturers in a dialog to resolve the issue...they have a vested interest...no communication and working system, no sale of equipment.
Challenges That Lie Ahead

✓ Issue: Instability of grant program from year-to-year.
  Determination: Need to increase awareness of funding issues among users and develop an agreement within the affected community that will ensure needed resources are available and are devoted to the development, coordination, and monitoring of the grant program.

✓ Issue: Long-term maintenance of WI-HMP and CORS.
  Determination: Solicit shareholders on solutions to sustaining the necessary resources.
Contact Information

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NGS CORS activities in Wisconsin...

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