Is There a Need of Marked Points in Modern Geodetic Infrastructure?

Lars E. ENGBERG, Mikael LILJE and Jonas ÅGREN Sweden

Key words: geodetic infrastructure, benchmark.

SUMMARY

Traditionally, the geodetic infrastructure was built up by triangulation networks, traverse networks and levelling networks. All detail measurements were connected to the nearest point in these networks. Heavy resources have been spent on maintenance of the networks to keep the infrastructure up to date. The modern geodetic infrastructure, however not the levelling networks, are based on GNSS techniques.

The use of GNSS has widely been implemented, sometimes with the motive that "with Network-RTK (or VRS) there is no more need of marks on the ground, we will have all coordinates in the air". Sometimes this declaration entices the management into reducing funds for maintenance. We do not believe in this academic fiction. It is not possible to guarantee sustainable reference frames without marks in the ground.

In Sweden, where we have a nation-wide CORS network, SWEPOS™, operating since many years and supporting the Swedish ETRS89-realization, SWEREF 99. We also have a new levelling network, with 50 000 benchmarks, supporting the RH 2000 height system and from the project RIX 95 more or less 10 000 benchmarks with SWEREF 99-coordinates. We have come to the conclusion that it is not necessary to keep all these benchmarks updated.

For the active frame (SWEREF 99) we can reduce the maintenance to a few hundred points that will make it possible to keep a check on all future alterations.

For the passive frame (RH 2000) we will keep focus mainly on benchmarks on bedrock as well as nodal points in the network.

In addition we have to use more resources for data collection and analysis of time series etc.

Is There a Need of Marked Points in Modern Geodetic Infrastructure?

Lars E. ENGBERG, Mikael LILJE and Jonas ÅGREN Sweden

1 BACKGROUND

Traditionally, geodetic networks have been built up hierarchical by points of various importance or orders. This approach was a consequence of available technologies for measurement and calculation. For example, angle and distance measurement needs optical sights between stations and without computers the number of points in a network is limited.
The development of satellite methods like GPS brought in its train a revolution some twenty years ago. All at once it was possible to measure, determine coordinates, over long distances with high accuracy. It started with static methods that after hours of observations gave us base lines with accuracies of just a few ppm.
Now, the network-RTK (VRS) technology give us the possibility to determine coordinates in real time (just a few seconds) with mean errors in 2D of roughly 15 mm and in height roughly 25 mm.
The height component that you get from GNSS is primarily “the height above the ellipsoid” and for several reason this “height” is inconvenient in practical applications. We still need gravity related heights in most cases.
This paper intends to describe the current situation we have in Sweden and our thoughts about the future regarding the administration of our geodetic infrastructure in the future to secure the usefulness of our reference systems. The paper summarizes some conclusions from an ongoing project at Lantmäteriet (the Swedish mapping, cadastral and land registration authority) (Engberg et al, 2010).

2 THE NATIONAL GEODETIC INFRASTRUCTURE IN SWEDEN

2.1 Introduction

In Sweden, the responsibility for geodetic control networks is divided between local authorities (about 290 local authorities exists) and Lantmäteriet. The main cause for this is mostly different aims of the systems. The responsibility for Lantmäteriet is to establish ground control for official mapping in small scales. The local authorities establish control networks for urban developments. (Lilje, 2004)
Lantmäteriet is the national geodetic authority but has no power against municipalities and other authorities. Lantmäteriet can not do anything other than give proposal and advice to the local authorities concerning their reference systems. Lantmäteriet is responsible for all national geodetic networks. The local authorities are responsible for their own networks.

2.2 SWEREF 99

The reference system used nationally must meet several criteria. It must be modern in such way that positioning using modern technologies should be possible without destroying the high accuracy that the use of modern instrument can achieve. It should make it possibly to exchange data with neighbouring countries and other users within the country easy and efficient that means the connection must be well known or we should work in the same reference frame. Choosing an ETRS89 solution approved by the IAG subcommission for Europe (EUREF) and originating from recent observation data, would give us good possibilities to get a reference frame that could last for a long time. The Swedish system SWEREF 99 was approved by EUREF in the year 2000 as a national realisation of ETRS89. The introduction of SWEREF 99 as the national reference system for GPS in Sweden was done during 2001 and in 2007 it was introduced as our national system for surveying and mapping. Most local authorities are changing from using local coordinate system to adopt SWEREF 99 also as their local coordinate system. (Jivall, 2001)

In Sweden, we have decided to define SWEREF 99, our realization of the European ETRS89, with help of the twenty fundamental stations in the network of permanent reference stations (SWEPOS). Therefore SWEREF 99 has what we call an *active* reference frame. This means that there are no defining marks in the ground except those twenty fundamental stations. On the other hand the antennas, receivers and also software are more or less parts of the reference frame.

2.3 RH 2000

Sweden released the new national height system RH 2000 in 2005. It is based on 25 years of levelling using the motorised levelling technique. The system is defined to agree with the European Vertical Reference System (EVRS), implying for instance that normal heights are utilised. Due to the postglacial rebound, it is important that the observations are reduced to a common reference epoch. The reference epoch was chosen to 2000.0. The computation was made in collaboration with the other Nordic countries under the umbrella of the Nordic Geodetic Commission (NKG) and in co-operation with EUREF. As the new height system fits very well with the systems of our neighbouring countries, the sharing of height information and cross-boundary work become easy tasks.

The new Swedish height system, RH 2000, that is a part of the European EVRS is defined through the 50 000 benchmarks from the third precise levelling. This is quite the contrary to SWEREF 99; RH 2000 is what we call a *passive* reference frame. (Svensson et al, 2006)

2.4 Geoid Model

SWEN08_RH2000 is a geoid model that has been adjusted to SWEREF 99 and the height system RH 2000. The model includes a correction for the postglacial land uplift and an interpolated, smooth representation of the GNSS/levelling residuals to make the transition from heights above the ellipsoid in SWEREF 99 to heights above sea level in RH 2000. (Ågren et al, 2008)

2.5 RIX 95

RIX 95 was a national project, which aimed at creating high quality connections between local, national and global reference frames. With these connections we could study different transformation formulae and determine appropriate parameter-values. This project also gave us around 10 000 points with coordinates in SWEREF 99. Some 300 of these points (also by Lantmäteriet called SWEREF-points) were determined directly from the fundamental stations based on 48 hours observations.

2.6 SWEPOS™

SWEPOS is the national CORS of Sweden. It is in IOC operation since 1998 and run by Lantmäteriet. Today (Jan, 2010) the SWEPOS network consists of almost 190 permanent reference stations for GPS and GLONASS (GNSS). Today SWEPOS is used as the basis for the Swedish national reference system, SWEREF 99 and beside many surveying and navigation applications also used for meteorology, timing applications and machine guidance. The stations in the SWEPOS network are either of Class A or of Class B. The Class A stations are established on bedrock and the Class B stations are using an antenna mounted on top of a building. SWEREF 99 is determined by a subset of the SWEPOS Class A stations.
SWEPOS Network-RTK service is based on the VRS-concept (Virtual Reference Station) and GSM//GPRS are used as distribution channels for the RTK data. The interstation distances are in average 70 km. Since 1 April, 2006 data for both GPS and GLONASS is provided in the format RTCM ver 3.0. The expected position accuracy is 0.03 m horizontally (95%) and 0.05 m vertically (95%). (Jämtnäs, 2010)
In order to guarantee continuity to time series all Class A stations will be supplied with two pillars, antennas and receivers. These time series will monitor geodynamic movements such as land up-lift.

3 ACTIVE VS PASSIVE REFERENCE FRAMES FOR HORIZONTAL POSITION

As said above, we have chosen an active reference frame for realisation of SWEREF 99. An alternative approach could have been to let all 10 000 points, from the RIX 95-project, be the realisation of SWEREF 99. Then we had got a passive reference frame instead.
The table below shows the pros and cons for the two different approaches.

	Active	Passive
Updating of points; no need/need	+	-
Rational and simple use of GNSS	+	-
Short wave geodynamic movements	-	+
Discrepancy between network-RTK and RIX 95 determinations	-	+
Altered marks	+	-
Replacement of software	-	+

A great advantage with the active frame is the absence of a resource-consuming work to keep all points in the passive frame update. The most important advantage with the passive frame is the reduction of all short-wave geodynamic movements and more or less the independence of software alterations in the control centre. These advantages for solution with the passive frame will only occur if you always connect all measurements to nearby RIX 95 points.

Another complication with the active frame is the post-glacial land up-lift that varies from 0 to maximum around 10 mm/year. We have to use a land up-lift model for reductions back to the epoch 1999.5.

3.1 Consolidation Points

By defining SWEREF 99 as an active reference frame we are exposed to rely on SWEPOS' positioning services like network-RTK. All alterations of equipment and software as well as movements at the stations will in the end affect the coordinates. In order to be possible to keep a check on all these alterations we have introduced consolidation points. For this purpose the SWEREF-points from the RIX 95-project are used. They are all marked in bedrock and most of them well suitable for GNSS measurements.
These points, about 300 in total, are remeasured in a yearly programme where 50 points are measured every year.
So far, we have decided that it is not possible to use SWEPOS Class B stations because the antenna is placed on top of a building. If you see changes in the coordinate, is it due to geodynamical movements or movements of the building?

4 ACTIVE VS PASSIVE REFERENCE FRAMES FOR VERTICAL POSITION

Our new height system RH 2000, as said above, has a classical definition; all benchmarks from the third precise levelling. Actually it is not all benchmarks but all benchmarks that are consistent with their neighbours.
We have decided not to use height above the ellipsoid, easily measured with GNSS, because of its practical disadvantages. We still need gravimetric heights and there is of course a possibility to combine height above the ellipsoid with a geoid model to get it but then we will introduce model-shortcomings in the height system.
Hopefully we will be able to make better geoid models and also the GNSS technology will give us higher accuracy in the vertical direction in the future. If so, we may have to reconsider our decision.
Traditionally, we have had a yearly programme visiting a large number of the benchmarks and replacing the destroyed points. We have now reconsidered visiting all points to focus mainly on benchmarks on bedrock as well as nodal points in the network.

5 SUMMING-UP

Formateret: Engelsk (Storbritannien)

In order to guarantee all users sustainable geodetic reference frames we still have to maintain marks in the ground.
For the three-dimensional reference frame SWEREF 99 we introduced the consolidation points. In total there is 300 points and we plan to remeasure 50 points every year, which means that all points will be remeasured every six year. Data from two sessions (24 h) in combinations with data from the fundamental stations should be used for the calculation of coordinates and all points should also be levelled.
For the vertical reference frame RH 2000 we will not maintain all benchmarks but for certain a number of benchmarks in every levelling line preferably those marked in bedrock.

REFERENCES

Engberg, L. E., Lilje, M. and Ågren, J. (2010) Om den nationella geodetiska infrastrukturens utveckling och framtida förvaltning. Internal PM (In Swedish)

Jivall L (2001) SWEREF 99 – New ETRS89 Coordinates in Sweden LMV-rapport 2001:6 Gävle 2001

Jämtnäs, L., Emardson, R. and Jonsson, B. (2010) Quality Assessment of Network-RTK in the SWEPOS™ Network of Permanent GNSS Stations, XXIV FIG Congress, Sydney 2010

Lilje, M. (2004) Changing the Geodetic Infrastructure FIG WW Athens 2004

Svensson, R., Ågren, J., Olsson, P.-A., Eriksson, P.-O. and Lilje, M. (2006) The New Swedish Height System RH 2000 and Geoid Model SWEN 05LR, XXIII FIG Congress, Munich 2006

Ågren, J., Kiamehr, R. and Sjöberg, L. E. (2008) Computation of a New Gravimetric Geoid Model over Sweden Using the KTH method, FIG WW, Stockholm 2008

BIOGRAPHICAL NOTES

Lars E Engberg

Mr Engberg obtained his masters degree from the Royal Institute of Technology in Stockholm 1973. He has been working as a lecturer in geodesy at the School of Surveying for many years. Between 1989 and 1996 he was at the City Surveying Department in Stockholm and responsible for the establishment of an improved reference network in Greater Stockholm. Since 1996 he is working at the Geodetic Research Department at Lantmäteriet. He was involved in a national project aiming to implement the new reference frame SWEREF 99 as a national standard as well as in INSPIRE data specifications. He is also engaged as an international adviser.

Mr. Mikael Lilje

Mr Lilje is the Head of the Geodetic Research Department at Lantmäteriet (the Swedish mapping, cadastral and land registration authority). He graduated with a M.Sc. with emphasis on geodesy and photogrammetry from the Royal Institute of Technology (Stockholm, Sweden) in 1993. He has been working at Lantmäteriet since 1994, mainly at the Geodetic Research Department. He is also incoming chair of FIG Commission 5 as well as chair of the FIG Working Group on “Reference Frames in Practice”.

Jonas Ågren

Dr. Jonas Ågren, graduated in 1994 from the Royal Institute of Technology (KTH) in Stockholm as a land surveyor with emphasis on Geodesy and Photogrammetry. He then worked with GPS and reference systems at Lantmäteriet until 1998. He then continued his studies and obtained his doctoral degree from KTH in 2004. Since then he is working with geoid determination, absolute gravimetry and geodynamics at Lantmäteriet.

CONTACTS

Lars E. Engberg

Geodetic Research Department
Lantmäteriverket
801 82 Gävle
SWEDEN
Tel. +46 26 63 30 37
Fax +46 26 61 06 76
Email: Lars.E.Engberg@lm.se
Web site: http//www.lantmateriet.se