Advantages when Changing to a Nationwide Reference System – Experiences from Umeå, a Municipality in Northern Sweden

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SUMMARY

The new national reference frame SWEREF 99 will replace the local reference frames leaving us with a more homogenous reference frame. Most of the local authorities are now changing to use the national reference frame also locally to make use of GNSS in their own organisation and harmonise their data with the existing regional and national data. A lot of work remains for most of the municipalities in Sweden, but some parts have already introduced the new reference frame. Umeå is one of those and experiences from the work with the exchange as well as advantages gained from using a nationwide system are presented.

SAMMANFATTNING

Det nya nationella referenssystemet SWEREF 99 kommer att ersätta de lokala referens-systemen och resultera i ett mer homogent system. De flesta kommuner byter nu till det nya referenssystemet även lokalt för att kunna använda GNSS i sin organisation och för att få data att överensstämma såväl regionalt som nationellt. Mycket arbete återstår för många kommuner i Sverige, men några har introducerat det nya systemet. Umeå kommun är en av dessa och erfarenheter av bytet samt lönsamheten av att använda ett rikstäckande referens-system presenteras.

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1 BACKGROUND

Sweden consists of some 300 municipalities, all of them more or less using their own unique co-ordinate system. Most of them are now changing to use the national reference frame, SWEREF 99, also locally to make use of GNSS in their own organisation as well as harmonising their data with the existing regional and national data. Today, almost one fifths of the municipalities have implemented SWEREF 99 and this paper will present experiences from one of them, Umeå.

1.1 The new National Reference Frames in Sweden

Sweden introduced the three-dimensional reference frame SWEREF 99 in May 2001. It is based on the permanent GPS stations that exist in Sweden, Norway, Finland and Denmark. The solution was adopted by the IAG sub-commission of Europe (EUREF) as an ETRS 89 solution in 2000 and it is based on ITRF 97 epoch 1999.5.

SWEREF 99 will be the new national reference frame and hopefully it also will replace the local reference systems leaving us with more homogenous situation on local levels. For historical reasons there exist several hundreds of more or less local reference systems based on various backgrounds.

Changing national and local reference frames affects all co-ordinate users from low-accuracy GIS-applications to high-accuracy scientific investigations. Most of the applications need “plane co-ordinates” and for that reason also a map projection. Decisions concerning map projections connected to this new system were taken in 2003, one national, SWEREF 99 TM, and a system of zones SWEREF 99 dd mm, for large scale mapping (Engberg & Lilje, 2002). In the beginning of 2007 Lantmäteriet changed to the new system in all data bases.

Lantmäteriet recommends the local authorities to tie their local networks to the nationally or, preferably, change to use the national reference frame and supports all municipalities with e.g. transformation parameters and correction models (Kempe et al, 2006).

The work with the introduction of the new height system, RH 2000, among municipalities, is also in progress. Many municipalities have started, in co-operation with Lantmäteriet, the process of recalculation and analyse of their local networks, with the aim of replacing the local height systems with RH 2000 (Svensson at al, 2006).

Lantmäteriet cannot force the local authorities to act, but we can support them with recommendations. In parallel, many local authorities are also looking over the situation with their horizontal co-ordinate systems. We clearly see a trend that most local authorities will change to SWEREF 99 and RH 2000, or at least make sure that they have good transformations between the different systems.

1.2 The Municipality of Umeå

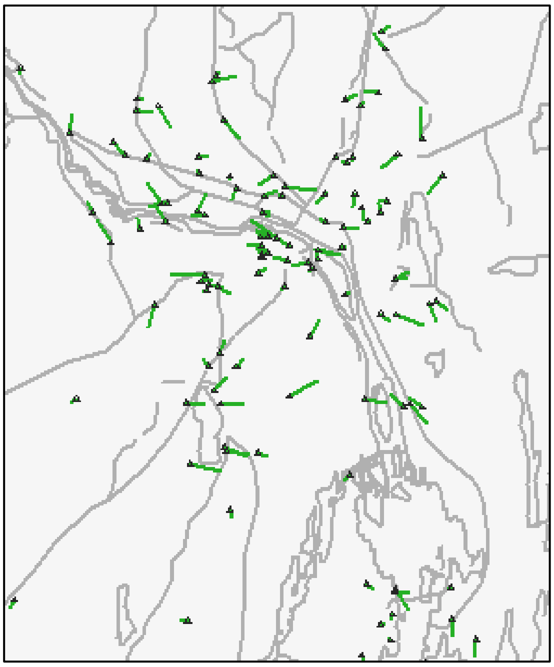
Sweden is divided into three parts and the northernmost is called Norrland. The largest city of Norrland is Umeå and it is located 663 km north from Stockholm. The area of the municipality Umeå is 5 253 km^2 and the number of inhabitants are 111 000. In this paper the name Umeå refers to the municipality and not to the city.
Umeå has used a local reference system for plane co-ordinates for many years. Some smaller villages in the municipality had their own local systems as well. In total, we have used about 10 different horizontal co-ordinate systems. Throughout the years there has been efforts making the network more stable to improve the quality in the local reference system.

The heights in Umeå have also been presented in a local system. Networks were built in different stages, mainly between 1963 and 1997. Each net separately adjusted to the national height system RH 00. Therefore tensions arose in the joints between the parts which caused inconveniences. With supplementary measurements the network in the population centre became more homogenous. By introducing the new national height system RH 2000 we have a chance of making the entire network straighten and locate any deformations.

2 THE CHANGE OF REFERENCE SYSTEM

The discussion of changing reference systems in Umeå began about 2003 after a political decision made in Umeå. The project began in 2004 by making an inventory of the archives of observation data in the community planning office. In March 31 2007 Umeå started to use the new reference systems SWEREF 99 and RH 2000 successfully when making measurements and presenting maps.

2.1 The Change of Plane System to SWEREF 99 20 15



The work started with an analysis of the control network. Known defects and uncertainties were reviewed. To get common points in both systems we used old reliable often used points. To get co-ordinates in SWEREF 99 at all common points we used GPS technology. The method of static measurement was preferred to RTK-measurement. The static method results in higher precision and is more suitable for surroundings partly blocking the view for the satellites.

For plane co-ordinates we use the projection zone SWEREF 99 20 15 in Umeå to get small distortions as working in large scale applications.

After the first round of measurements analysis was made by Lantmäteriet and transformations were made with direct projection (Engberg & Lilje, 2006) combined with a correction model (Kempe et al, 2006) as well as with only an ordinary two-dimensional similarity (Helmert) transformation. The residuals in the second cases were not that high, RMS 2.8 cm. After these tests we decided not to use a correction model because the individual residuals at the common points could not with certainties represent the tensions in the existing control network.
Helmert transformation could be used because of the fact that the central meridian in SWEREF 99 20 15 practically coincides with the old central meridian (99 20° 18′ 29.8″). The choice of Helmert transformation instead of direct projection also made it easier for CAD/GIS software to transform data.
In the final determination of the transformation formula more than 200 control points were used. When the formula was tested with 350 control points the residuals were randomly directed and there were no signs of systematic errors. The results of the tests showed that reliable marks such as control network points were very good but more uncertain marks like boundary points were not that good. The boundary marks were often slightly moved or they could possibly been placed with bad precision. After the analysis we consider the results acceptable.

2.2 The Change of Height System to RH 2000

The cooperation with Lantmäteriet was of great importance to succeed with the introduction of a new reference system for height as well as for the plane system. The work initiated with digitizing old levelling observations. Some complementing measurements with sections of

levelling to connect smaller height networks had to be done. Separated points also needed to be connected. Some results were not satisfying because of moved benchmarks between different measurement epochs. Extensive works of levelling were made and weaknesses in the network were eliminated.
In the adjustment of the central network 48 points in the national network were used as known points and 906 new points determined. The standard error of unit weights was 2.7 mm/√km.
The average difference between the old height system RH 00 and the new national system RH 2000 is about one meter and that is the same amount as the land uplift in this area during the last 100 years. Due to the connection between the old networks and the new national network it is now possible to work in a homogenous and common system throughout the municipality.

2.3 Implementation in the Data Bases

In the remaining phase of the entire project, the work consisted in informing all the users of co-ordinates in Umeå for example;

- Other municipality administrations
- Authorities
- Companies and consulting firms

There were several information meetings throughout the year before the exchange and press releases in connection with the actual change. There was also a lot of work in transforming all databases to the new reference systems and to modify all software.

3 ADVANTAGES

3.1 Use of Modern Technology

The control network and all details are now positioned in a more homogeneous and accurate reference frame. Now, it is much simpler to use GPS without any transformations at all and with network-RTK the work will be more efficient.

We can also use network-RTK for height determination in some applications because of the direct use of the national geoid model SWEN05_RH2000 will give us height accuracy around 3 cm (mean error) in the national height system RH 2000.
The circumstances mentioned above leads to lower costs

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3.2 Better Accuracy without Transformation

Traditionally, when we used GPS we had to make transformations with empirical parameters which gave us low accuracy in the end. Now, with the new system implemented we do not need to make any transformation at all, just the projection to get plane co-ordinates or the geiod model to change from ellipsoid heights to geoidal heights.

The working routine is now more efficient. We no longer need different transformation formulas and there is no risk of confusion.

3.3 Uncomplicated Exchange of Geographical Data

Umeå exchange geographical data with a number of different authorities and consultants in the society. Having the same reference system as the rest of the country makes that exchange uncomplicated. The system will be seamless over the municipal border.
In the future there will be more data exchange even on the European level e.g. INSPIRE and the introduction of those new systems will of cause facilitate that exchange.

4 EXPERIENCES

When carrying out a project like this it is good to have an agreed and written time plan. It is difficult to estimate the time consumption, but try to approximate the work that needs to be done.
The horizontal network as well as the height network can always be better when you make new measurements and adjustments. Decide what distortion is acceptable for your application otherwise you will never get through with this project.

If the entire network has tensions in different directions you might need a correction model. But if the tension points in one direction you can use a more simple transformation. Umeå used the Helmert transformation and that made it easier to transform the geographical databases and it was also simpler to modify the software.

The appearance of the new co-ordinates changed entirely compared to the old system, so there was no risk of mixing them up, except from the height information. The average height values were one meter higher in the new system compared to the height values in the old system. So a mix up between the height values from the different systems of heights is very easily done. In city planning and for example when placing lines for sewer system the height information has a crucial importance. Apart from given information about the exchange of reference systems we changed the visual appearance of the height values in all maps and in the database so that the user easily can see the differences and avoid a mix up.
Any larger planning projects in progress had to pay attention to the exchange. All documents containing co-ordinates had to be transformed to the new reference system. Careful consideration will be given to specified user needs and requirements. In a transitional period we will offer assistance with that kind of work.

5 CONCLUDING REMARKS

A large project like this, results in a lot of work and other projects might need to be put aside. Despite the effort the exchange of reference systems required, the result was definitely worth it. There was no reason to postpone this project. Making this exchange was inevitably with the technical development, for example making the use of GPS more efficient.

There are also more and more suggestions that the work conducted both on national level and on local level also can be used in the neighbourhood, region or Europe. Therefore, it is important to implement a reference frame and map projection that will be applicable European corporation like INSPIRE.

It is important to have a well functioning cooperation between the municipality and the National mapping authority (NMA), since both gain profits of the work. During the project both support each other with data, information, knowledge and experience.

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BIOGRAPHICAL NOTES

Kerstin Hegner

Mrs Hegner graduated in 2002 at the Royal Institute of Technology as a Land Surveyor with emphasis on Geodesy and Photogrammetry. In 2001 she worked for the City of Stockholm. In 2002 she worked one year in the Swedish Armed Forces for the Airforce. Since 2003 she is working for the municipality Umeå in the community planning office as geodetic facilities assisting manager.

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. At present, he is involved in a national project aiming to implement the new reference frame SWEREF 99 as a national standard. He is also engaged as an international adviser.

Mr Engberg is a member of the Swedish Association of Chartered Surveyors, the Nordic Geodetic Commission as well as the Swedish Cartographic Society.

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