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## DISCUSSION DOCUMENT

### Should GNSS in NRTK mode be used for Boundary Surveys in Ireland?

#### Introduction:

The Irish Institution of Surveyors (IIS) proposed standards for boundary surveys in Ireland in a green paper (Prendergast *et al.*, 2008) and these standards now need review after a year of operation. The original standards proposed were:

- CRS - boundary surveys and boundary maps to be on Ireland's new coordinate reference system ITM.
- Survey Control - GNSS baseline (on or adjacent to the property) to a 95% confidence level (2 sigma) - static mode observations post-processed using RINEX data from nearest GPS station initially recommended
  - Absolute accuracy  $\leq$  +/- 100 mms
  - Relative accuracy between GNSS stations  $\leq$  +/- 10 mms to be confirmed by EDM distance
  - Relative accuracy of traverse stations (if required)  $\leq$  +/- 10 mms
- Boundary Features - 67% confidence level (1 sigma)
  - Relative accuracy of boundary features to be  $\leq$  10% of the width of the feature (subject to a minimum of +/-25mms), for example 10% of a 3m wide earth bank = 300mm, but 10% of block wall (100mm wide) = 10mm, so in this case the minimum of < +/- 25mm applies.
- Boundary Markers (for boundaries which are to be registered as conclusive)
  - Relative accuracy of boundary marks to survey control  $\leq$  +/- 10mm at a 95% confidence level

Two workshops were arranged to inform this review process:

- a) Workshop 1 - whether GNSS equipment in NRTK mode is suitable for boundary surveys (28<sup>th</sup> September 2009). This report documents the results of the first workshop.
- b) Workshop 2 - surveyors different interpretations of the original standards and their appropriateness (29<sup>th</sup> October 2009).

NRTK results are improving all the time, so it would be better to permit the use of these new technologies if surveyors can benefit and be more efficient with their time on site. The intention of workshop 1 is to get ideas for a suitable survey procedure in this regard and also to highlight the specific needs of boundary surveying to GNSS suppliers. It was also noted that Dr Paul Denys of Otago University in New Zealand is currently investigating the use of NRTK for cadastral surveys in New Zealand, so the IIS will contact him to collaborate on this project. Additionally INSPIRE have recently published the final version of the data specification for cadastral parcels (INSPIRE, 2009) so there is a need to ensure that the revised standards are INSPIRE compliant. The final product of this review process will be the publication by the IIS of revised standards for boundary surveying in Ireland in spring 2010.

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**Reliability (consistency) of NRTK Results:**

System suppliers (Leica, & Trimble) state that coordinates to cm accuracy (in plan) are possible when using GNSS in NRTK mode. Coordinate accuracies are a function of many variables, the main ones being the density of GPS network stations in the vicinity, the availability of mobile communications, satellite geometry, use of correct survey procedure, impact of earth influences (troposphere, ionosphere, tide loading, etc), and knowledge and skill of the surveyor in identifying and eliminating bad satellites and data from the computations. Some of these variables can be controlled, but many cannot, and can only be estimated and corrections applied accordingly.

Gordini *et al.* (2006) state that individual (single epoch) NRTK observations can diverge from the true position by up to 200mm in easting and northing and the accuracy of height values can be larger by a factor of 2 to 3. However if multiple epochs of data are captured, then significantly improved coordinate accuracies are possible.

In a study carried out in the UK by Newcastle University and the Survey Association, Edwards *et al.* (2008) recommended the following procedures be used for acquiring accuracies of +/- 10-20mm in plan and 15-30mm in height for survey control at a 67% confidence level (1 sigma):

- DOP values of  $\leq 3$  should be used to enforce improved satellite geometry
- Two 3 minute observation windows (180 epochs each) separated by 40 to 45 minutes are recommended for survey control, especially when surveying at the extent of the network, or when the mean distance to the four nearest active GNSS stations is large, or in places of significant terrain height differences.
- In places close to the coast the two observation windows should be separated by 6 to 6.5 hours to minimise the effects of ocean tide loading.

However, except for the provision of survey control, surveying of boundaries is rarely carried out in the open and is normally carried out in challenging areas where multipath from hedges, trees and buildings is commonplace. Therefore surveyors should select an appropriate survey methodology once the conditions on site have been assessed and should consider adopting standard terrestrial survey techniques instead of NRTK when conditions dictate so. Surveyors also need to be particularly careful when surveying boundary features in challenging areas since Edwards *et al.* (2008) state that the coordinate quality (CQ) indicators of GNSS equipment can be overoptimistic in these areas by a factor of 3-5.

The workshop emphasised that the responsibility for accuracy lies with the surveyor, not the system supplier, so survey procedures need to be robust enough to trap and eliminate sources of error.

The workshop proposed the following be adopted as best practice:

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- Two observation windows should be captured separated by a gap of at least 30 minutes. Therefore the points observed should be marked to allow re-occupation.
  - All NRTK observations should use either a bi-pod or tripod to ensure good centring
  - That the internet link between NRTK equipment and service provider be broken between the two observation windows to enforce a re-initialisation.
  - That the spread of the 1<sup>st</sup> and 2<sup>nd</sup> round results from the two observation windows should differ by no more than +/- 15mm in either easting or northing, and the final result to be the averaged value.
  - GNSS equipment should be configured to reject DOP values >3 and dimensional controls limiting CQ values to less than 50mm (+/- 25mm??) be considered.

Finally, the question was raised whether NRTK (using this double windowing technique) could be considered for providing survey control for the boundary survey? The current position is that a normal post processed RINEX solution should be used which takes station proximity and the need for gross error checks into consideration.

#### **Association of NRTK observations to the Survey Control:**

The point was made that each NRTK observation was independent from previous and subsequent NRTK observations, so the initial proposal in the IIS green paper to permit NRTK use for boundary features needs to be reviewed. The workshop proposed that the following survey procedures should be considered for confirming NRTK observations of boundary features, and these survey procedures will be investigated and reported on in a second discussion document early in 2010.

- Using a total station to check a percentage (10%?) of the points surveyed using NRTK
- Recording multiple observations of points using NRTK
- Recording multiple observations of survey control at start and end of NRTK survey
- It may be possible to validate the NRTK results by post-processing using RINEX/CORS/NRTK data downloaded from service provider websites afterwards.

#### **Traceability of NRTK coordinates:**

For boundary surveys there is a need to supply raw observation data to enable:

- Confirmation of survey results by the surveyor prior to certification of survey.
- Re-computation and confirmation of survey results during IIS audit of boundary surveys.
- Re-computation and confirmation of survey results during PRA validation of surveys of boundaries registered as conclusive.

Both Leica and Trimble representatives at the workshop stated that they can supply corrections data for the time of the observations, but due to the different NRTK processes neither of them may be able to record this data directly on the GNSS receiver. It may be more feasible to request the data in a usable and verifiable format from

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the service provider after the survey for the times during which observations were taken. This facility needs to be tested and an appropriate data format and indexing system needs to be investigated for storage of this data.

Independent verification of privately operated NRTK services may be necessary to ensure standards are achieved and maintained. Ideas in this regard include:

- There is a free software package called 'TEQC' available from UNAVCO (part of NASA/JPL) at <http://facility.unavco.org/software/teqc/teqc.html>, which could be used to verify the quality of GNSS observations. NRTK providers should be requested to provide a log of raw data suitable for this verification purpose. This would allow professional bodies such as the IIS & the SCS to check the NRTK system quality status independently of the vendors & service providers.
- In addition the IIS should request from the vendors how they propose to provide verification of their NRTK data and how they could participate in a process to have their data verified by a third party.

Finally boundary survey reports need to include a description of the computation methodology, so that survey results can be confirmed.

**Other Issues:**

- Point of Beginning - the workshop proposed that the origin of the ITM coordinates for the survey control should be specified and it was recommended that the report of the boundary survey would need to specify which GPS network was used (OSi Passive network, OSi Active network, or Trimble VRS Now Network). It was stated that only one of these networks (OSi Passive network) had been independently quality assured by EUREF which certified its accuracy at +/-20mm in x, y and z relative to the European stations. Although it was generally believed that the OSi Active network had an accuracy of +/- 10mm in x, y & z, the workshop was pleased to be informed that EUREF has recently been contracted by OSi to independently evaluate the quality of the OSi Active Network. A 90 day observation campaign by OSi/OSNI has already begun which will be processed using the industry leading Bernese software. OSi expect to achieve full EUREF certification for all their network stations. This means that the Trimble VRS Now network will soon be the only network not to be independent quality assured, (and others if extra service providers enter the market), and this may impact on their suitability for meeting any standards adopted.
- Availability of RINEX data - the accuracy of coordinates computed by post-processing GNSS observations is directly related to the distance to the GPS station used. It was noted that the density of stations could be much improved if RINEX data was available for both the OSi active network and the Trimble VRS Now network. However, RINEX data for the OSi Active network is available from the OSi website free of charge, but RINEX data from the NRTK private networks (Leica/Trimble) is only currently available via a subscription service. The combined coverage of these two networks needs to be examined for complementarity and to identify any potential gaps.

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- Responsibility for Standards - Ireland now has two NRTK services (SmartNet & VRS Now) provided by Leica Geosystems and Trimble and there is now a need to nominate a national authority to set and monitor standards for these networks. The workshop was of the opinion that Ordnance Survey Ireland (OSi) should take on this additional task. However, is OSi in a position to be independent if they are already closely associated with one of these NRTK providers?
  - Elimination of Doubt - boundary surveys are performed both for land registration and for court appearances, so it is essential that attainment of adopted standards can be proved without doubt. This means that traceability of all survey and computational methods is necessary just in case the surveyor is challenged in court. The provision of RINEX data and NRTK corrections for a 'virtual station' introduces an opportunity for the legal profession to challenge which could be difficult to defend or counter. Strong arguments to support such a defence may be necessary.

WP Prendergast, Chair IIS Commission on Land Registration in association with S Tritschler and G Delaney.

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### Workshop Attendees

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Andrew Moore, Survey Instrument Services, Dublin  
Andy McGill, Ordnance Survey Ireland  
Mike Skicko, Leica Geosystems UK  
Dave Dawson, Leica Geosystems UK  
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