MEASUREMENT METHODS REGARDING THE QUOTATIONS OF A PERMANENT GNSS STATION IN ALTITUDINAL SYSTEM MN 75

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Abstract: *The scope of the paper is to benchmark in the system of* ***normal altitudes****, with reference plan* ***The Black Sea 1975 (ed. 1990)****, the GNSS permanent functioning stations and to search based on a comparative study the possibilities of use of the GPS technology for this type of works.*

To achieve the benchmarking of the GNSS permanent working stations (RN-SGP)for integrating them in a national altitude system two complementary type of works are necessary, that do not have to be executed successively, in field operation could have been done in reverse order.

The first operation *consists in sending a benchmark from two points of levelling of the national-network or local network at two or three points that should be materialized during the listing and benchmarking operation*

These points will be established on the spot depending on the visibility. Points will be materialized on the ground.

The second operation *consists in the transmission through polar levelling of the benchmark to the permanent station. After permanent station sites descriptions, for sure one will meet on the spot the following two situations:*

a) The variant where ground targeting is possible directly to the permanent station.

b) The variant where is no possibility of direct targeting. In this situation it is mandatory to materialize at least one point to which can be covered from the ground and to have visibility between this point and the permanent station.

Keywords: *GNSS permanent station, normal altitude system,*

1. Introduction

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The 49 stations from ***RN–SGP*** installed until now, are provided with GNSS equipment produced by ***Ashtech, Leica and Topcon***, the types of antennas are ***Ashtech ASH701945B_M, Leica AT504, Leica AT504 GG, Leica AX1202*** or ***Topcon CR-G3,***with standardized dimensions and performing.

To achieve this work, starting from the need to achieve a precision of +/- 30mm for antennas marking, a manufacturing project was made in the CNGCFT level, describing to the manner of implementation, of technical, human and material means necessary and of the work stages.

The listing SGP antennas has been agreed to be achieve by the short distance polar levelment, less than 200m in this case, done in two or three points materialized on the ground with metal stakes (witness) placed in positions from which to see the antenna , stakes that were benchmarked by geometric levelling precision through levelling lines scored in geometrical landmark of orders I-IV.

In parallel to classical methodology, and with GPS technology on one of the stakes, usually noted on the number 1, aiming to establish under what conditions of accuracy one can determine the difference in level and benchmark at the reference point of the antenna (ARP) of the permanent station compared with the classical method.

2. Field operations

2.1. Land recognition

Based on inventories of benchmarks required by the National Geodetic Fund (FNG), in field were recognized the pikes of geometrical, approx. 4-5 points at each GSP, regardless of the order of lines in which are included, but subject to the condition of being as easily accessible and to be at a smaller distance from the permanent station.

One can understand that due to the large percent of destruction of the pikes, that means marks of type A and B, RNG, type IV terminals, etc., from the lines of geometrical levelment, this goal was not always respected and in extreme cases where all the steaks were destroyed instead were used buried steaks, type RNA IGFCOT (Steak of Depth Levelment) or ground steaks type I-III, DTM or IGFCOT, from which to mark the witness pikes..

Starting with the measurements of stage IV it was decided that where the steaks of geometric leveling are situated at about 1-1.2 km and they are suitable to be stationed with GPS technology and if the distance is greater, to be stationed in SGP marker for surveying and two receivers to be placed on the points listed to ensure a geometry in order to study the degree of accuracy and distance until you can provide an accuracy comparable to that imposed on those works or similar ones.

During the recognition of the work, there have been done descriptions of sites for witness stakes planted, and their picture, a picture of the stake and four pictures on the cardinal direction points (obstructions) for each of them.

In the file created for each GSP was prepared a "Draft of planting" on which was set the

Final position of the network consisting of witness stakes and marks of geometric levelling of the antenna that was quoted.

2.2. **Geometric levelling**

After carrying out the reconnaissance work, depending on the geometrical levelling pikes of Ord-IV lines identified in the field and through the materialisation of witness metal stakes that were rated for the GSP-sized antennas, one has switched to the execution of precision geometric levelling for their listing.

Surveying measurements were made as the methodology, in terms of geometrical levelling of ord.II, in which differences in level of 4 values are obtained, two on each direction, and has-been imposed a tolerance of ***+/-2mm*** $\sqrt{Lkm}$.

The surveying team, used a spirit level ***Zeiss Ni002***, with a 3m Invar, with dual scale and measurements were made with equal portions of up to 35m, corresponding to its levelling of ord. 0.

Observations were recorded in specific books for levelling precision, two surveying books for each section (one on each direction), books that were made to field calculations, checking compliance with tolerance and calculating the differences in average level , lengths of sections, the tolerance level and the difference between difference of level to and fro.

Depending on the number of benchmarks found and their distance from the SGP, rating was performed by suspended road windings by closed (polygon) road windings, taking all the measures for the results to be entered in order of their levelling executed tolerance and the order of the line which were part the used pikes .

To determine the differences of height, telescope axis of the targeting instrument from the point marked on the ground, is measured by surveying levelling poles with invar band.

2.3. Trigonometrical levelling

As in very rare situations, you can transmit the ARP's benchmark by the polar distance method which is widely accepted for this kind of work, and ensuring accuracy comparable with the method of geometrical levelling of the III ord. ***(+/-10mm*** $\sqrt{Lkm}$)and better for distances up to 200m.

The mode of listing was inspired by listing the descent to the ground triangulation points of city networks, where these are located on the pilasters on tall buildings, but in this situation the zenith observations from witness pegs to the GSP antennas, were not mutual but only from ground to antenna, targeting being executed on a target sights consisting of a collant with a cross with a horizontal wire located at ***3 cm*** of the base , which was applied on the antenna to its base, on the directions on which could be observed from the control points.

Accuracy of results is directly influenced especially by the precision with which the device and measured the height of the signal (target elevation) were measured, and the scoring accuracy.

The observations have been made with ***Leica TCR 1203*** observation station, in three levels of height of the apparatus with three pointing in each level, that is that for each station minimum nine values of level difference have been done from the witness metal stake to the ***BCR*** and to the ***ARP*** antenna.

For each GSP was given a notebook in which are registered field observations and calculations for the 9 series of level differences measured in each of the 2 witnesses metal stakes, from which were determined the rates from above.

The spread of individual values ranged from differences in level has been situated at a minimum of **1.0 mm** in witness pike nr.1 ***(SLO1)*** and maximum of **5.4 mm** in witness stake nr. 2 ***(SLO2)***, by chance both in the levelling network of the antenna of ***SGP Slobozia.***

Regarding the spread of these individually obtained values, very good in principle for this kind of measurements, the spread between the rates transmitted from the antenna of the two witnesses stakes geometrically ranged has varied between **0 mm** at ***SGP Lehliu*** and **6 mm** at ***SGP Buzău***, the general dominant value being **2 mm** at the other stations.

2.4. GPS Observations

In parallel with conventional technology, GPS technology was used by stationing one of pickets, usually the one at No. 1, aiming to determine under what conditions one can accurately determine the difference in level at the antenna reference point (PRA) of the permanent station compared with the classical method. This action was carried out in parallel with the polar execution control pike No. 2, the period of observation was 2 hours and the equipment used is a kit Trimble 4000 SSE with all the necessary annexes.

As noted before, close stakes positions were chosen primarily on grounds of being as close and see the antenna's of the SGP and not take into account the obstructions which adversely affect the GPS observations. After the first step it was recommended to choose an area with no obstructions, one would plant even a third metal stake that though it does not see the antenna SGP it should be rated as the others, in order to take out height antenna with most attention and according to the existing form and especially at the beginning and end of observations period.

To study the possibilities of implementing SGP listing with GPS technology in all campaigns of measurements one have materialized one or two stakes at greater distances, up to 1834 km at ***SGP Timişoara.***

3. Processing of measurements.

After field work, geometric and trigonometric levelling observations were calculated in the field books and have made the necessary checks to ensure the quality of observations and also if tolerances were met.

In the office the calculations were verified and centralized for each SGP, the summary tables in which analysis and calculations have been done.

Regarding the GPS measurements, after completion of field work phase, the observations were downloaded from the receivers and were centralized on the sessions, the calculations were checked and antenna heights were checked from DGC (Department of Geodesy and Cartography) the observations from each SGP and every session. ID of the witness stakes was derived from the ID of the SGP, one has changed the last letter with the figure 1, 2 or 3, according the stationed pike.

Processing of GPS observations were performed with TGO v1.0 software.

Listing of the 49 permanent stations GNSS was performed in 7 stages of measurements, the 8th round is listing of the permanent station GNSS Bucuresti. Since from one stage to another, the system design of routes and the geometric and trigonometric levelling have improved, in the following we shall present the conclusions emerged from measurements of phases IV, V, VI, VII, and the geometric levelling route done in Bucharest, as an Annex. Also, in these latter stages GPS observations were made not only in position 1 where polar measurements were made but also at longer distances.

Some statistics on these measures will cover all stages of measurements.

3.1. Comments on the measurements made

Based on ellipsoid rates obtained by GPS technology, and shares obtained by the classical technology on peg 1, in the Comparative ***Table of obtained SGP levels with levelling differences determined with GPS technology and classic technology***, have been calculated the differences of level at the ***ARP*** through the two methods, their values being between ***-13mm*** at ***SGP BISTRIȚA NÃSÃUD*** antenna and ***-15 mm*** at ***SGP DOROHOI*** antenna.

The differences obtained have been calculated between the ARP levels obtained through classic means and through GPS technology, the values of the differences to the distance of about 1km, being between **-7*mm*** at **SGP DOROHOI** and ***+38 mm*** at **SGP DOROHOI** station.

3.2. Conclusion

The scope of the paper is to benchmark in the system of **normal altitudes**, with reference plan **The Black Sea 1975 (ed. 1990)**,the GNSS permanent functioning stations and to search based on a comparative study the possibilities of use of the GPS technology for this type of works.

The results obtained with the two technologies, classic and GPS, with small exceptions, are very good, the differences between the levels determined with the classic technology , as a reference and the levels obtained with the GPS technology for the GNSS permanent stations for the 4 stages of measurements, are very good and demonstrated by the fact that the maximum value in absolute value is***–15mm*** and thus not exceeding the tolerance demanded by the beneficiary, which is ***+/-30mm***. Starting and analysis of the data obtained at this stage, statistically, in the following table are going to be presented in percentage, the differences obtained through the two technologies, in stage VII.

Table 1

Nr.	Spacing	No. of SGP	Percent
1	0- 5mm	1	20%
2	5-10mm	2	40%
3	10-15mm	2	40%
4	15-30mm	-	-
5	30-35mm	-	-
Total		**5**	**100%**

As we can see at all the 5 SGPs , that is ***100%*** of the ***SGP*** benchmarked through the two technologies during the current stage, the spacing is under ***+/-15mm***, the maximum value being at ***SGP Dorohoi***.

A statistic of the first seven stages, the spread rates determined from points close , under 200m by the two technologies are presented in the table below:

Table 2

Nr.	Spacing	No. of SGP	Percent
1	0 - 5mm	21	48%
2	5-10mm	7	16%
3	10-15mm	9	20%
4	15-30mm	3	7%
5	> 30mm	4	9%
Total	**44**	**100%**	

By analysing the ***tab.2***, we can draw the following conclusions:

- at a rate of 48% of the stations listed, the difference between the SGPs rates sites determined by the two technologies is under ***+ /-5mm***, a percentage of ***91%*** of the stations listed have accuracy below ***+ / -30 mm,*** the difference of ***9%*** i.e. 4 out of 44 stations listed up to now, are not falling in the imposed tolerance of ***+ / -30 mm*** and it is sure that this is due to misconduct cases reported above;
- out of these stations one has a difference of 51 mm (ARA1) and is therefore affected by errors, and two have differences that overpass by little the imposed tolerance, namely up to +32 mm.

These two statistical tables relating to the ARP's shares of the antennas determined by witnesses placed at distances up to 200m from the SGP, and after stage IV we can conclude that at larger distances up to ***1km*** and even over 1km, listing with GPS technology can be used, leading to good results in terms of compliance with a tolerance to ***+ / -30 mm***.

From the data obtained in ***phases IV, V, VI and VII*** (29 values, 8 of which at this stage) in the table below is presented statistically the following situation:

Table 3

Nr.	Spacing	No. of SGP	Percent	Nr.
1	00-10mm	12	41%	D<1.4km
2	10-20mm	6	21%	D<1.2km
3	20-30mm	5	17%	D<2.1km
4	30-35mm	4	14%	D<2.9km
5	35-40mm	2	7%	D<0.4km
Total		**29**	**100%**	

It appears that about ***79%*** of measurements performed, but ***100%*** of those with the sides up to 2.1 km have been in the assumed tolerance of ***+ /-30mm (tab.3).***

It is to be noted that the 4 SGP sites, respectively BEIUŞ, FÃGET (st.VI) and CIUC and DOROHOI (st.VII) are beyond the correct tolerance up to ***+ /-35mm,*** that represents 14%

of total SGP sites listed so far with the GPS technology, from greater distances than about 500m

Over passing of the imposed tolerance, if the case of the first two stations, is due to their failure of functioning during the determination of heights to the ARP of their antennas, and the following two, one of the distances from the point of cl. B, ***BT04*** is ***2.9 km***, but it should be noted that tolerance is not exceeded at any of the 4 stations, with more than 2mm.

It should be noted that in these last 4 stages, in which has experienced the listing with GPS technology of the permanent stations, in compliance with tolerance of + /-30mm, the points listed geometrically located at greater distances of 0.20 km, up to about 2,9 km were used outside the points quoted geometrically and 5 ***Class B GPS points of the network*** of Romania, executed in 2003, were quoted as geometrical points in the phase of the year 2007, when work triggered to achieve a geometric qvasigeoid, when they were geometrical listed 48 Class B or C points, placed uniformly across the country.

Of these 5 points, ***BT04*** point has exceeded with only ***1mm*** the tolerance at ***2.94 km*** and points ***TM04 and NT04*** have exceeded the tolerance with ***2mm at 2.38 km*** the first and the second with ***7mm at 0.35 km.***

The other two points, respectively ***BN03*** and ***HR03,*** the first located at ***0.28 km of SGP Gheorgheni*** exceeds by far the tolerance, with the difference of ***0.210 m*** and the second situated at ***2.38 km from Bistrita SGP*** also exceeds the tolerance, with the difference of ***0.118 m.***

These 2 points are not the only points which give these large of the differences and allow us to reaffirm that they are not wrong geometrical levels but the ellipsoidal level errors, which have values determined separately from the SGP that are located in the sites with about 5 years before put them into operation.

We consider that all these points of the class B network, reported at the completion of the class C network in counties during 2007 and 2008 and the specific work of antennae benchmarking at SP GNSS, of the last year, must be the object of a special paper dedicated to the verification and redetermination.

As in all stages of measurements already done, the quasi-geoids ondulations were calculated from the ellipsoid ***GRS80*** with the formula:

$$H_{ETRS89}=H_N+\zeta \qquad (1)$$

In which :

- H_{ETRS89} the ellipsoid level GRS80, determined through the GPS technology;
- H_N the normal level to the quasi-geoids, determined through precision levelment;
- ζ the height of the quasi-geoids to the ellipsoid;

It is noted that after seven stages of measurements, 44 of SP GNSS antennas from the counties (tab.2) were rated by two methods. Listing was made from 73 witness points and GPS stationed, of which ***44 points*** were evidenced by metal stakes and placed at ***max. 0.2 km*** of the antennas to be quoted by a ***short polar distance levelment*** and ***29 points*** were located at greater distances, on average, ***about 1.0 km*** and more, with a maximum of up to ***2.9 kilometres*** from the antenna and consisting of metal stakes as new points, that are located in positions with very good GPS location and quoted by geometric levelling, or Class B terminals from the ETRS89 network, geometrically listed in 2007 or now located in areas close to the GSP sites in each county in question. .

If for short distances, up to ***0.20 km,*** the conclusions presented are clear, at greater distances, a statistic that can be looked upon in tab.3, gives us the possibility to state that approximately ***80%*** of measurements fall within the tolerance of ***+ / - 30mm*** when the distance provided by the GPS listing station from SGP varies between ***0.3 km*** and ***2.1 km***, and differences in values for about ***60%*** of measurements are very good, that is in ***+ / - 20mm***.

We shall make a comparison and analysis of the rates determined through classical method, with ***GPS technology*** and with ***Transdat v3.03*** and do assessments on these results.

We have analyzed each SGP rates and of the witnesses from which the levels have been determined by the three methods, reference being obtained by classical methods of shares geometric and trigonometric levelling and which will be compared and discussed the other two methods

From the differences of the three methods of levelling, the values are in ***– 17mm*** at the level of ***SGP DORO*** obtained through GPS technology at a distance of 0,05km from the steak ***DOR1*** and ***+37mm*** at the level ***SGP PINT***, obtained from de cl.B, ***NT04*** point, obtained through GPS technology at a distance of 0,35km.

The 15 levels differences, besides that from ***SGP PINT*** obtained from ***NT04***, have values under ***the tolerance of +/- 30mm,*** with the exception of the difference of +36mm from DOR3 and of the difference of +32mm from CIU3, both at relatively long distances.

The extreme values for the other SGP-s, are between ***+0,108m*** in steak ***BIS4*** and ***+0,302m*** in ***SGP PINT***. It is possible that there differences to appear not to the levels determined with the GPS technology but to the calculation mode of ***Transdat v3.03*** in the domain of level transformation.

Of the 4 counties that are part of Phase VII, 3 are located in the north central area of the country and include ***Bistrita Nasaud, Harghita and Neamt*** and one is isolated in the north-east of the country, bordering with the Republic Moldova, namely ***Botosani County***.

The medium differences on the three coordinates, are between *-0,129m* and *+0,097m* on X axis, between *– 0,148m* and *+0,196m* on Y axis and between *-0,22m* and *+0,37m* on H level, as it should be normal with the largest difference on the level, the largest values being at ***SGP Piatra Neamț***.

Bistrița Năsăud County, the most western of the counties of this stage, has one ***SGP at Bistrița***. The two variants of ***Transdat v3.02*** and ***v3.03*** an the ***Helmert transformation*** have generated values of the plan coordinate differences that are between ***-0,8cm*** and ***+8,9cm*** on ***X*** and between ***+7,4cm*** and ***+5,5cm*** on ***Y*** and values between ***+14,0cm*** and ***+9,0cm***, on the height.

The number of points with common coordinates on one county is of ***12 points*** disposed in an uniform way on the surface, and the ***Transdat***, in ***v3.02*** and ***v3.03***, has generated differences of ***+9,7cm*** on ***X***, ***-1,9cm*** on ***Y*** and ***-5,0cm*** on ***H***.

Between the levels at ***v3.03*** of the precise determined level, the difference is of ***+12,6cm***, an almost identical value with the one that is the failure of the difference of the two methods of levelling, on the B class terminal ***BN03***, that is ***+11,8cm.***

We recall that probably to stabilize the value of converted coordinates from one version to another of the application ***Transdat***, will occur when in the network one will not introduce new common points.

We can state that the values obtained with ***the Helmert transformation*** remain the most precise and consistent values to old or new zone points and their values do not change, even if common points are introduced in the county, in the neighbouring counties or in the network.

Harghita County, situated in the centre of this stage, has ***two SGP***, one ***at Gheorgheni***, in the north, and one at ***Miercurea Ciuc***, in the south.

The two variants of ***Transdat v3.02*** and ***v3.03*** an the ***Helmert transformation*** have generated values at ***SGP Miercurea Ciuc*** of the plan coordinate differences that are between

-0,7cm and ***+4,9cm*** on ***X*** and between ***-9,6cm*** and ***+0,5cm*** on ***Y*** and values between ***-29,0cm*** and ***-24,0cm***, on the height.

Between the levels, at ***v3.03*** to the precise determined mark, the difference is ***+20,0cm***, value almost identical with the wrong one, difference between the two levelling methods, on the class B terminal, ***HR04***, that is ***+21,0cm*** situation already signalled and with its cause somehow defined**..**

The number of points with common coordinates at the county level, is about ***10 points*** almost uniformly disposed on the surface of the county, and ***v3.02and v3.03*** have generated differences of ***-2,1cm*** on ***X***, ***+10,1cm*** on ***Y*** and ***+4,0cm*** on ***H***.

At ***SGP Gheorgheni***, we had no possibility of ***Helmert transformation***, and ***v3.02*** and ***v3.03*** have generated differences ***-2,7cm*** on ***X***, ***-1,7cm*** on ***Y*** and ***-17,0cm*** on ***H*** these values being generated by 10 common points disposed at the level of the county**.**

Neamț County, the most eastern of the counties of this stage, for both versions of ***Transdat*** has used 11 common points.

The two versions of ***Transdat v3.02*** and ***v3.03*** and the ***Helmert transformation*** have generated values of plan coordinate differences of ***-12,9cm*** and ***-6,6cm*** on ***X,*** between ***+18,7cm*** and ***+19,6cm*** on ***Y*** and values between ***+37,0cm*** and ***+15,0cm***, on the height.

Between the levels of the ***SP GNSS*** antenna, at ***v3.03,*** of the precise determined level the difference is ***+30,0cm***, almost identical value with the wrong difference between the two methods of levelling, on the class B terminal, ***NT04***, that is ***+24,0cm***, the geometrical level of this terminal being predetermined and now being correct and usable in any work.

Between ***v3.02 and v3.03*** of ***Transdat*** have been generated coordinate differences ***+6,3cm*** on ***X***, ***+0,9cm*** on ***Y*** and ***-22,0cm*** on ***H***, the correct value being the one from v3.02.

Botoşani County, is a north-east situated county, and from ***Transdat***, ***v3.02*** at ***v3.03***, has beneficiated of the increase of common points from ***9 points*** to ***41 points*** as a results of the achievement of the class C network, and of the mounting in 2008 of the ***SP GNSS Botoşani***.

Between the two versions of ***Transdat v3.02*** and ***v3.03*** and ***Helmert transformation,*** the differences of coordinates are ***-0.2cm*** and ***+5.8cm*** on ***X***, between ***-14,8cm*** and ***+2,7cm*** on ***Y*** and ***-3,0km*** and ***+1,0cm***, on level ***H***.

There are differences between the results obtained using the two versions of ***Transdat*** and their values have similar behaviour to those found in Suceava County, in the earlier stages.

From the analysis of the mode of change from ***Transdat v3.03***, to ***v3.02***, we can draw the following conclusions :

- Introducing of new points with coordinates that are in common, in the grid similar to ***Nadcon*** grid of U.S., produce regional effects with significant differences between the two versions and have no particular explanation especially for planimetry coordinates, but which may have differences falling within the tolerances that are in the precision of triangulation network of ord.I-IV.
- The transformed coordinate values in the areas of common ground density of about ***1 pct/200 skm***, lead to coordinates with similar values and differences with the ***Helmert transformation***, especially in plane coordinates.
- Any new point introduced in the network with common coordinates, produces system influences and modifies the transformed coordinates with the new version.
- In these circumstances it is clear that the ***Helmert transformation*** is very good, because all the rates that are determined by Helmert method, are directly comparable with the rates determined directly.

In the following we are going to do a statistical analysis on ***5 groups*** of distances, from ***0,15km*** to ***2,9km***, from 500 to 500m, for 29 level differences, determined through GPS technology and measured in stages ***IV - VII***.

Out of the 29 differences, 24 differences from the first four groups fall within the tolerance of ***+ / - 30mm*** the situation being the following on groups of distances:

- ***gr. I,*** distances from ***150m to 500m***, has four differences with values between ***-7mm*** to ***+26 mm*** with a medium difference value of 13.3 mm;
- ***gr. II***, distances from ***500m*** to ***1000m***, has nine differences with values between *-16mm* to *+17mm* with a medium difference value of ***7,1mm***;
- ***gr. III***, distances from ***1000m*** la ***1500m***, has eight differences with values between *-29mm* to *+29mm* with a medium difference value of ***13,4mm***;
- ***gr. IV***, distances from ***1500m*** to ***3000m***, has three differences with values between *+25mm* to *+31mm* for a distance of ***2,9km***, with a medium difference value of ***28,0mm***;

In ***gr.V*** there are 5 distances, from the 29 analysed, that overpass the tolerance of ***+/-30mm***, with values between 2mm and 8mm.

In ***gr.VI*** we have the two cl.B points with wrong ellipsoid marks, with the values mentioned before , levels that influence the precision of the geometrical quasi-geoide that is in train of construction.

Analyzing this group of measurements, we can say with certainty that for distances up to ***1500m,*** with normal precautions of design and location of control points and of measuring the antenna height with certainty, differences in level measured by GPS technology provides easy fit into tolerance ***+ / - 30mm***. For longer distances, up to about ***3000m,*** the above entry in tolerance can be achieved in good condition by taking additional measures in the design phase. However for listing permanent GNSS stations located during the year 2009 it is advisable to keep the same method used for determining the levels during 2009.

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