Development of the Precise Levelling Network in Estonia

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Network configuration

The Estonian precise levelling network (Fig. 1) with slight modifications repeats the network established by Department of Cadastre in 1933 – 1943 and remeasured by the Estonian Academy of Sciences and Soviet organizations in 1948 – 1991 (Table 1). Lines in the West-Estonian islands were added during the Soviet period.

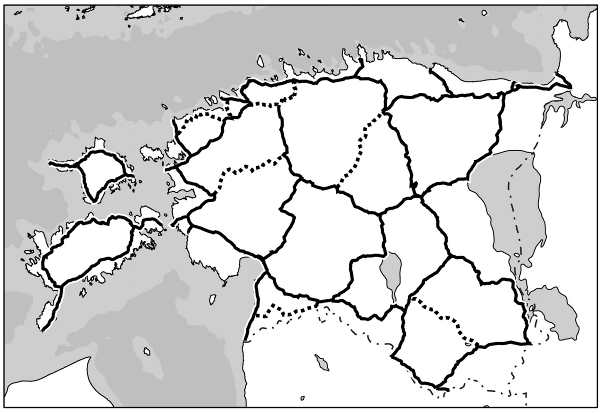

Fig. 1. The Precise Levelling Network of Estonia. The new lines are dashed.

Some of the lines were measured more frequently in order to study the differential movements of the blocks of the crystalline basement. The network was extended to the West Estonian islands in 1940, 1958, 1963, 1971, 1979, 1980 and 1981 using different techniques: geometric levelling, hydrostatic levelling and sea level observations. The details can be found in Тамм (1988) and references therein.

Lines of the new network were planned to be located along roads, for this reason the lines in the North-East and in the South-East of Estonia along railway lines were replaced. The network was densified in some regions (Fig. 1, dashed lines). The lines with the total length of about 2900 km form 15 polygons, 13 in the Estonian mainland and 2 on the West – Estonian islands.

Reconstruction of the network, Fourth Levelling of Estonia considering the accuracy and periods of early measurements, is carried out under the contract with Estonian Land Board.

	Period of levelling	Length of the levelling lines [*km*]	Random errors, η [$mm / \sqrt{km}$]	Systematic errors, σ [mm / km]
1	1933 – 1943	6 loops in mainland, 1814	0.32	0.03
2	1948	Line Narva – Tallinn – Ikla, 505	0.50	0.05
3	1970	Line Narva – Tallinn – Ikla, 574	0.53	0.06
4	1981 – 1983	1380	0.71	0.10
5	1951 – 1969	2067	0.48	0.08
6	1970 – 1991	2208	0.46	0.04

Table 1. Levellings performed in 1933 – 1991.

1 Department of Cadastre, Estonian Ministry of Agriculture
2 – 4 Main Board of Geodesy and Cartography, USSR
5 – 6 Institute of Astrophysics and Atmospheric Physics, Academy of Sciences

Preparation of lines

By the reports of inspection about 50 % of old benchmarks are destroyed. Some of them, still existing, are not usable because of location, stability or construction. Those are the main reasons, not the precision of early levellings, for new campaign.

Because in Estonia the bedrock is located at great depth, the use of it for monumenting is very complicated or impossible. For the reason the soil is used for monumentation. When the soil is used, the deformation it's seasonally freezing (lifting of the benchmark) and deformation under the benchmark (sinking of the benchmark) should be considered. Wherever they were near the surface, the solid sedimentary rocks (limestone, sandstone, dolomites) were selected for monumentation. In Fig 2 the construction of fundamental and ground benchmarks is shown.

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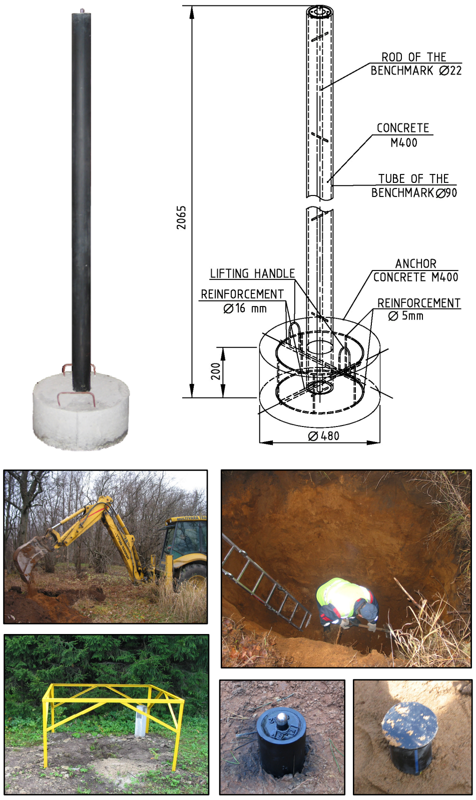

Fig. 2. Construction of new fundamental and ground benchmarks.

For a low thermal conductivity and friction drag, a tube of the benchmark was made from plastic. Stainless steel was used for the inner rod.

In case of stable buildings available, the wall benchmarks (Fig. 3) were established. They are made from stainless steel and painted for security reason.

About 2100 km of lines have been prepared in the Estonian mainland since 2004. Distance between the benchmarks, altogether 1302, is 2 km on average. From the benchmarks 599 are new. Preparation of lines in the West – Estonian islands will be completed in 2006. Some new lines in the Estonian mainland will be added in 2007.

Fig. 3. Wall benchmark.

Concept of the Integrated Georeference

It can be shown that the integrated use of different geodata provides qualitatively new results. According to the Concept, developed in 1996 (Rüdja 2002a, 2002b), the Integrated Georeference in Estonia connect the networks of different kind for combination and for the long term monitoring of geometrical and physical observables with emphases on scientific use and on practical georeferencing. Establishment of the Integrated Georeference started with reconstruction of the National Geodetic Network performed by us in 1996 – 1998.

Into the lines of precise levelling in the Estonian mainland 338 points of the National Geodetic Network and Densification Network, 52 points of the gravity remeasurement network and 9 tide gauges stations are included. They are shown in Fig. 4 – 6, respectively. Distance between the "GPS points" included is about 5 km.

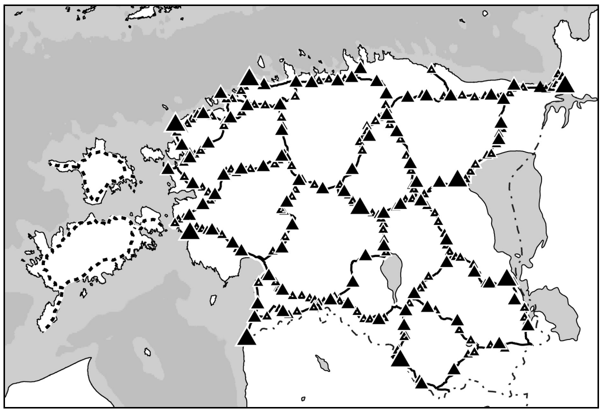

Fig. 4. Points of the National Geodetic Network and Densification Network included into the levelling network in the Estonian mainland.

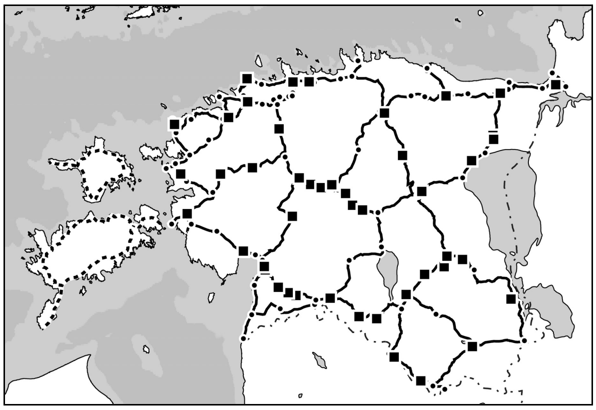

Fig. 5. Points of the gravity network included into the levelling network in the Estonian mainland.

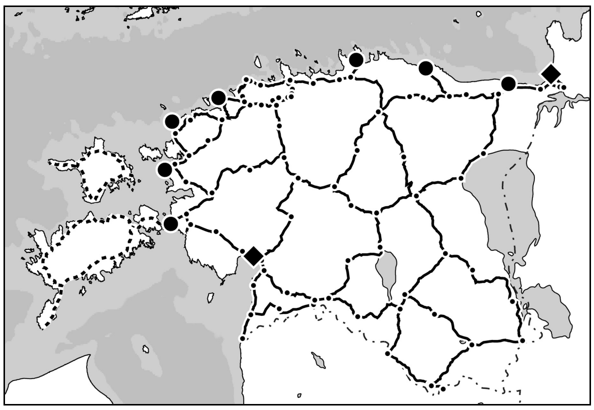

Fig. 6. Tide gauge stations included into the levelling network in the Estonian mainland.

Levelling

Reconstruction of precise levelling network started with the pilot project carried out by company working under the contract with ELB in 2001. Based on project the main aspects of the levelling technology were developed. The technique applied is the conventional foot levelling (double run). Zeiss/Trimble DiNi 12 digital levels and invar staffs from NEDO are used. The rods and levels are regularly calibrated at the Finnish Geodetic Institute. In every second section the direction of levelling relative to the direction of the line is changed (A – B, B – A). The "Rote hose" method (BFFB – FBBF) is applied. The minimal sighting height is 70 cm and the maximum distance from the instrument to the rod is 40 m. Differences of sighting lengths are kept within 20 cm in stations and within 50 cm in sections. Period from September to December was selected as the only period for levelling. Depending on productivity requirements August much less suitable for precise levelling was included since 2005. For keeping of target accuracy the sighting lengths were reduced to 30 m and mid-day pause was extended to three hours in that case. Air temperature, vertical thermal gradient, humidity, air pressure, wind speed and the temperatures of the invar scales are measured (Fig. 7). They are automatically stored using data loggers during the levelling. Additional data, like road characteristics and cloudiness of the sky etc., are recorded using pocket PC. Each single record is stored into the levelling database developed.

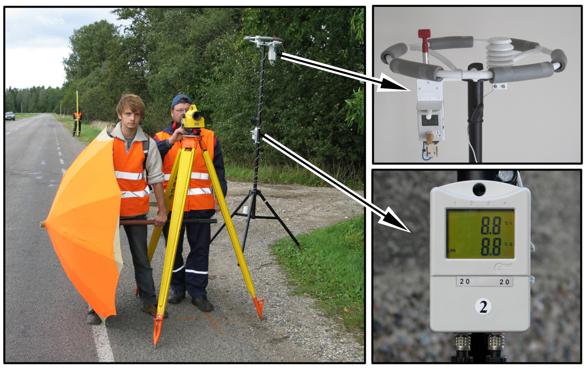

Fig. 7. Levelling. The meteoinstruments in use

Technology was applied in measurement of precise levelling network of Tallinn in 2003 – 2004. Altogether 340 km were levelled (Fig 8) with precision comparable to estimation shown later on. Part of the network will be included to the state levelling network (Fig. 1) after completion. Levelling of main lines of the network started in 2004. Since that, more than 550 km have been levelled. In spite of sunny autumn in 2005, the inner consistency of measurements is promising. In Fig. 9 histogram of discrepancies in measured height differences in stations (BF minus FB) and in Fig. 10 normalized differences in sections (the differences between forward and backward levelling of the section divided by the length of sections) are presented. Those are based on 519 km double run levelling performed by the three field teams in 2005. Random and systematic errors calculated from the differences between forward and backward measurements (Jordan *et al.* 1956) are: $\eta = 0.19$ mm, $\sigma = 0.04$ mm. The misclousure in the two loops with perimeter of 281 and 300 km are -2.41 and -2.59 mm, respectively.

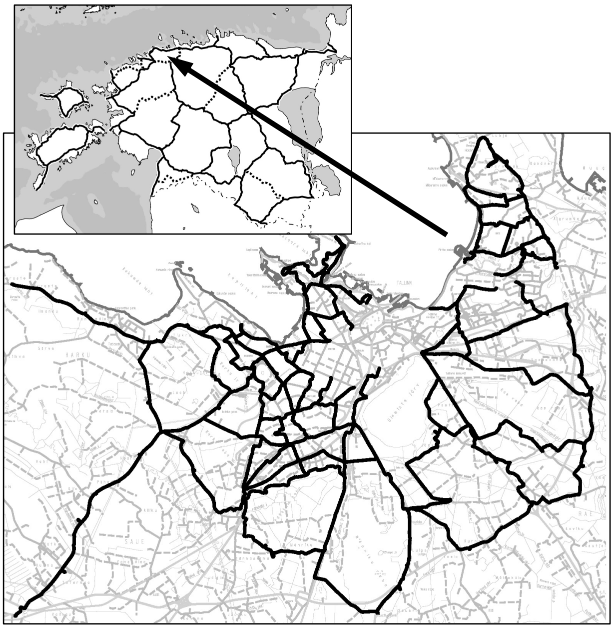

Fig. 8. Lines of the precise levelling network of Tallinn measured in 2003 – 2004.

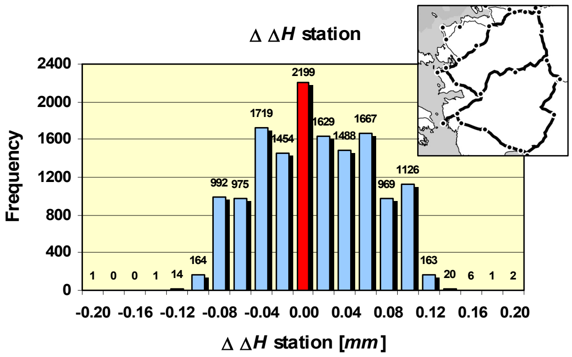

Fig. 9. Distribution of discrepancies in measured height difference in stations.

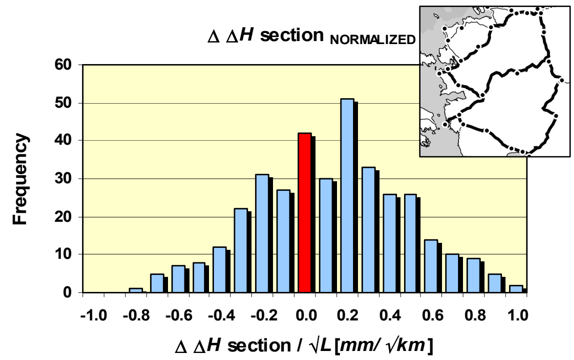

Fig. 10. Distribution of discrepancies in measured height difference in sections (normalized).

References

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