Kartverket

Appendix 1

Technical specification for the gravimetric survey

of the Federation of Bosnia and Herzegovina

Statens kartverk
Projects in Western Balkan countries
Case no. 18/28533
SK project no. TIN Balkan Geoide
NMFA project no. RER-17/0008

Table of Contents

1 Introduction

The Federation of Bosnia and Herzegovina (FBH) has a started a new high precision leveling (HPL3) project. The first phase of this project included reconnaissance and stabilization of the fundamental and other benchmarks, i.e., height points, which was completed in 2017. The second phase includes a gravimetric survey of the HPL3 network and a detailed gravimetric survey of the FBiH.

2 Summary

2.1 Deliverables

Table 1 gives an overview of the services (measurements and documents) to be provided by the contractor. A detailed description is given in the following chapters.

Table 1. Overview of services to be provided

Positional descriptions of the HPL1 and HPL2 benchmarks			
No	Description	Quantity	Quality (std dev)
1.1.	GPS RTK measurements	350	0.5 m
1.2.	Provide new positional description (Annex 2)	350	
The HPL3 network gravimetric survey			
2.1.	Gravimetric measurements on HPL3 network points	2700	0.18 mGal
2.2.	Provide "Gravimetric Measurement Minutes" (Annex 1)	2700	
The FBiH detailed gravimetric survey			
3.1.	Gravimetric measurements on the detailed gravimetric points	1500	6 µGal
3.2.	GPS RTK measurements	1500	0.5 m
3.3.	Provide "Gravimetric Measurement Minutes" (Annex 1)	1500	

Data processing			
4.1.	Preliminary processing of the measurements	1	-
4.2.	Gravimetric survey network adjustment	1	-
4.3.	Provide Technical report of data processing	1	-

2.2 Information provided to contractor

1. Absolute gravity station information
2. Basic Gravimetric Network points.
3. Preliminary HPL1 and HPL2 coordinates.
4. Coordinates of all HPL3 points.
5. Coordinates of points for detailed gravimetric survey.
6. WMS service for digital orthophoto.

3 The HPL1 and HPL2 benchmarks

A list of preliminary coordinates will be provided to the contractor.
Deliverables:

- A schematic description of each point (old benchmark detection minutes)
- The new positions must be obtained as the mean of 60 RTK measurements (GNSS).
  - Standard deviation must be better than 1 m/0.5 m/0.1 m

4 The HPL3 network gravimetric survey

The high precision leveling (HPL3) network constitute of a set of points, from interconnected leveling lines, separated by 300 – 1,300 meters. It consists of the following points (Figure 1):

- fundamental benchmarks – 32 points
- vertical benchmarks (pillars) – 77
- vertical benchmarks – 883
- horizontal benchmarks – 1620

All points are to be measured by a gravimeter; measurement method described in chapter 7 Measurements specification.

A list with coordinates of all benchmarks, in ETRS89 and the state coordinate system (SCS), will be provided to the contractor. The benchmarks have coordinates with an accuracy better than 1 meter, both in position and height.

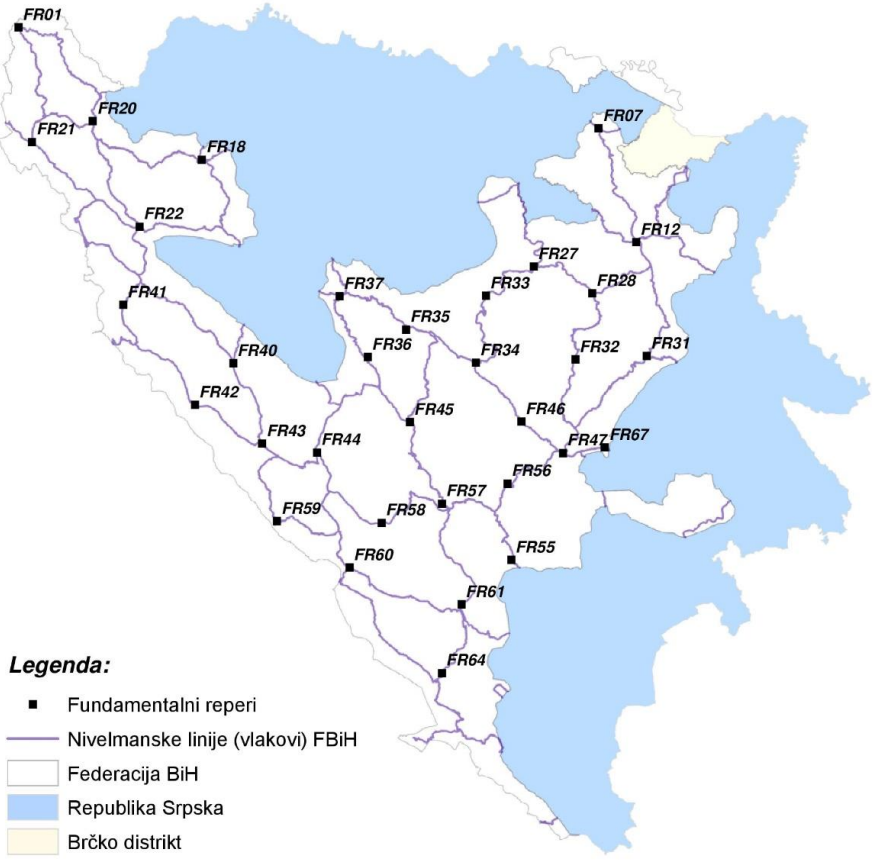

Figure 1: FBiH Leveling Network

5 The FBiH detailed gravimetric survey

The FBiH detailed gravimetric survey consists of data from the Spatial Reference Network in addition to the detailed gravimetric survey points.

The Spatial Reference Network data points, shown in Figure 2, consists of:

a) zero-order (8 EUREF89 campaign points);
b) first-order (16 BIHREF2000 campaign points);
c) second-order (30 Basic Gravimetric Network points);
d) third-order (141 complementary Basic Gravimetric Network points).

The zero-order and first-order Spatial Reference Network points consist predominantly of first-order trigonometers and the GPS campaigns were carried out and the coordinates were determined in the ETRS89 system. They will be provided to the contractor.

The second-order and third-order Spatial Reference Network points have been stabilized over the last 5 (five) years, they are accessible by car, and the coordinates for them shall be determined in the ETRS89 system in the RTK mode with 60 RTK measurements on each point. The positional description with nearby coordinates (accuracy 5m) will be provided to the Contractor.

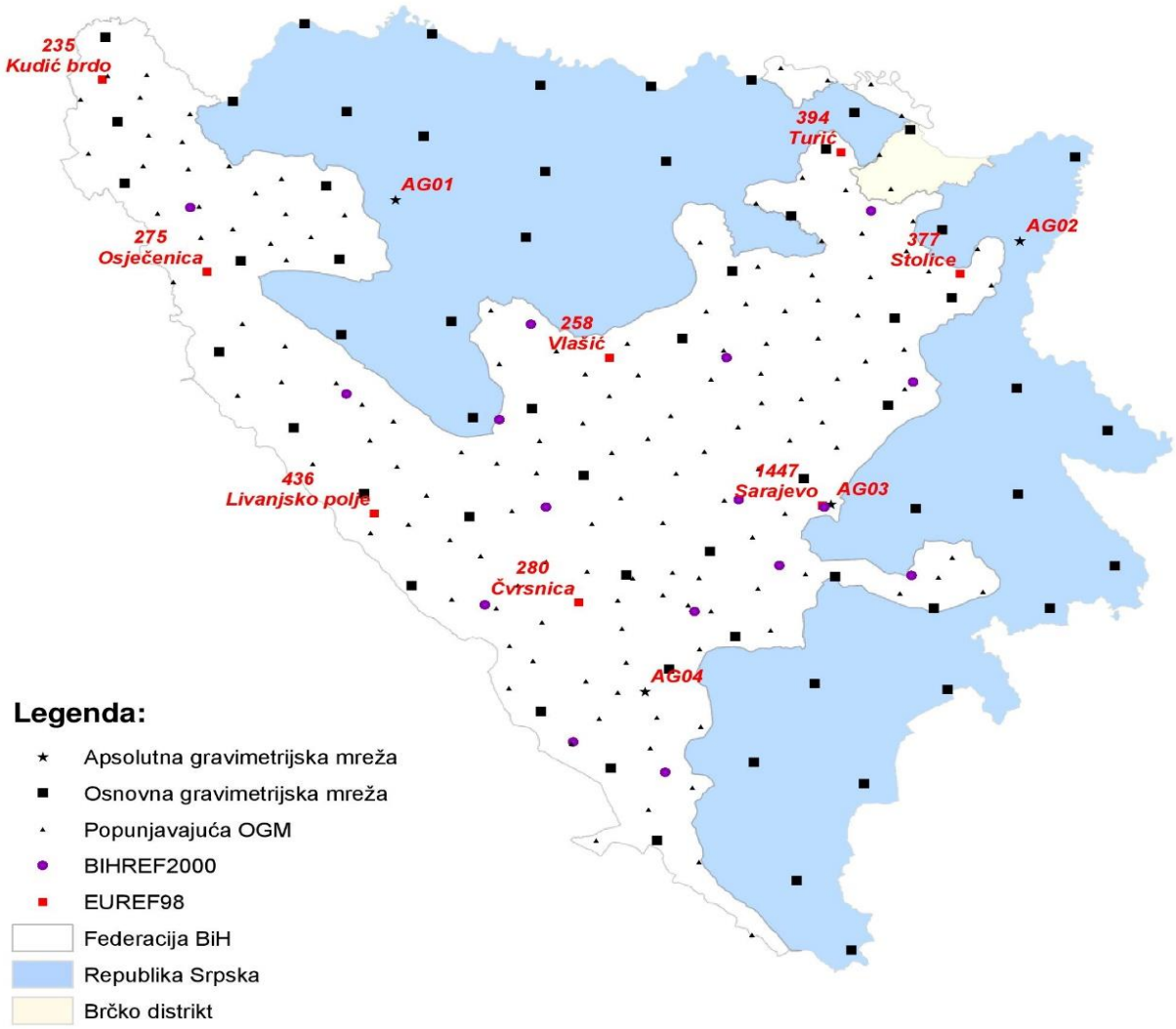

Figure 2: Spatial Reference Network

The

Detailed Gravimetric Survey covers a portion of the trigonometric points used for the horizontal transformation (grid transformation), portion of the urban GNSS network points, and portion of the state survey points used in control of the horizontal transformation points.
The horizontal transformation points and urban GNSS network points were defined by means of the static satellite measurement method. When choosing these points, it was made sure that they were accessible by car and situated close to the designed positions. The points were defined on the digital orthophoto (DOP) base layers, where the areas suspected of being landmine infested were taken into account, as well as the terrain and network configuration in itself (Figure 3).

All points are to be measured by a gravimeter; measurement method described in chapter 7 Measurements specification.

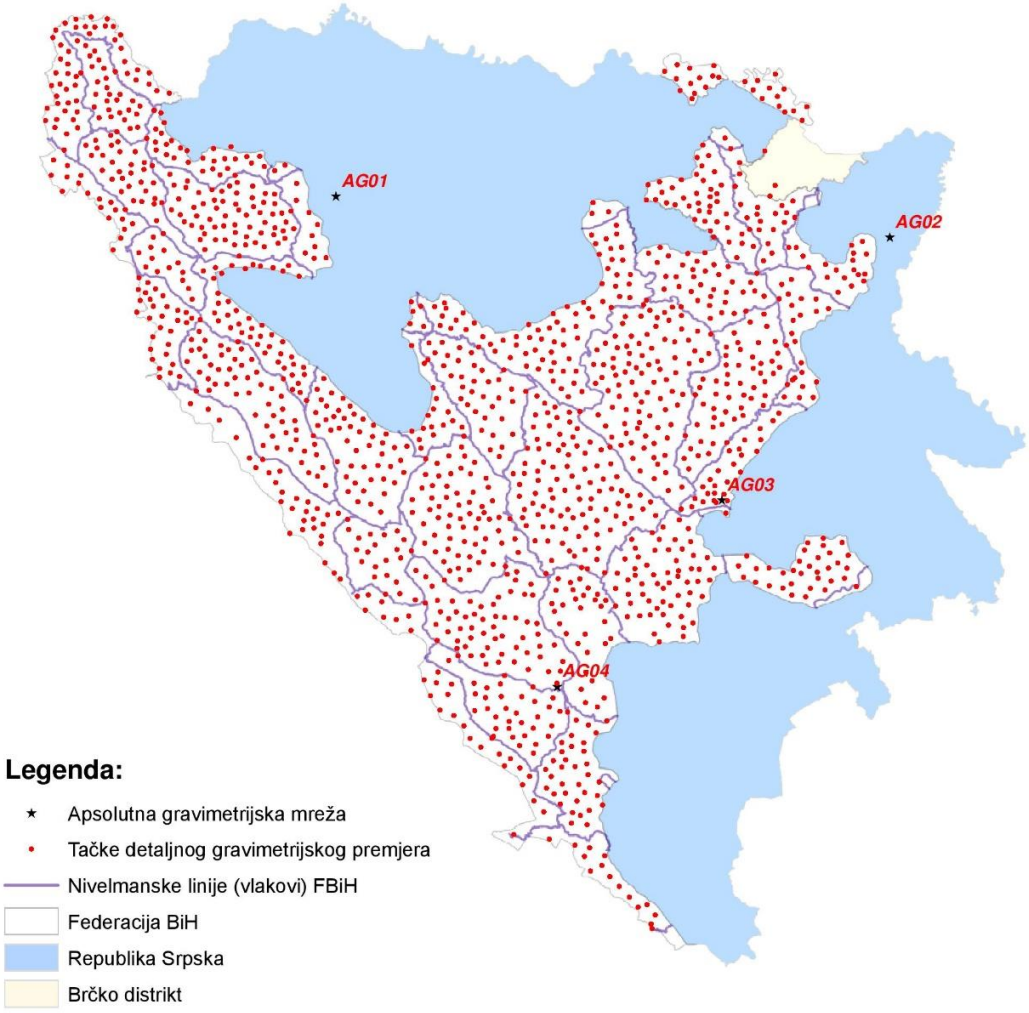

Figure 3: Detailed Gravimetric Survey point distribution

6 Available gravity networks

Two gravity networks have already been measured. They will be used for calibration of the gravimeters and as starting point for the gravimetric surveys.

6.1 Absolute Gravimetric Network

The Absolute Gravimetric Network points were determined in the period of September/October 2013 under the Capacity Building for Improvement of Land Administration and Procedures in BiH Project (CILAP). The gravity value was determined at four stations by means of a Swedish absolute gravimeter Micro – g Lacoste FG5 #233, while gravitational gradient was monitored by means of a Swedish relative gravimeter Scintrex CG – 5 #740. The measurements were performed at four points (Figure 4) and their coordinates are shown in Table 2.

These absolute gravimetry points must be used in the calibration of all gravimeters used in the FBiH gravimetric survey.

Figure 4: Absolute gravimetry points

Table 2: Absolute gravimetry point position coordinates

Point number/name	Latitude (WGS84)	Longitude (WGS84)	Normal height (m)
AG01 Banja Luka	44° 43' 49.088"	16° 54' 38.734"	320.805
AG02 Bijeljina	44° 36' 50.802"	19° 06' 22.477"	202.509
AG03 Sarajevo	43° 52' 31.931"	18° 26' 09.537"	726.784
AG04 Mostar	43° 20' 54.015"	17° 47' 36.295"	96.277

6.2 The Basic Gravimetric Network points

The Basic Gravimetric Network were implemented in the period of September/October 2014 throughout BiH. The network consists of 60 third-order spatial reference network points (30 in FBiH and 30 in RS) positioned 30 to 50 kilometers apart (Figure 5).
This network is the basis for the BiH gravimetric survey as starting and ending point of the gravimetric measurements (sessions, polygons, etc.) must be linked to the Basic Gravimetric Network points.

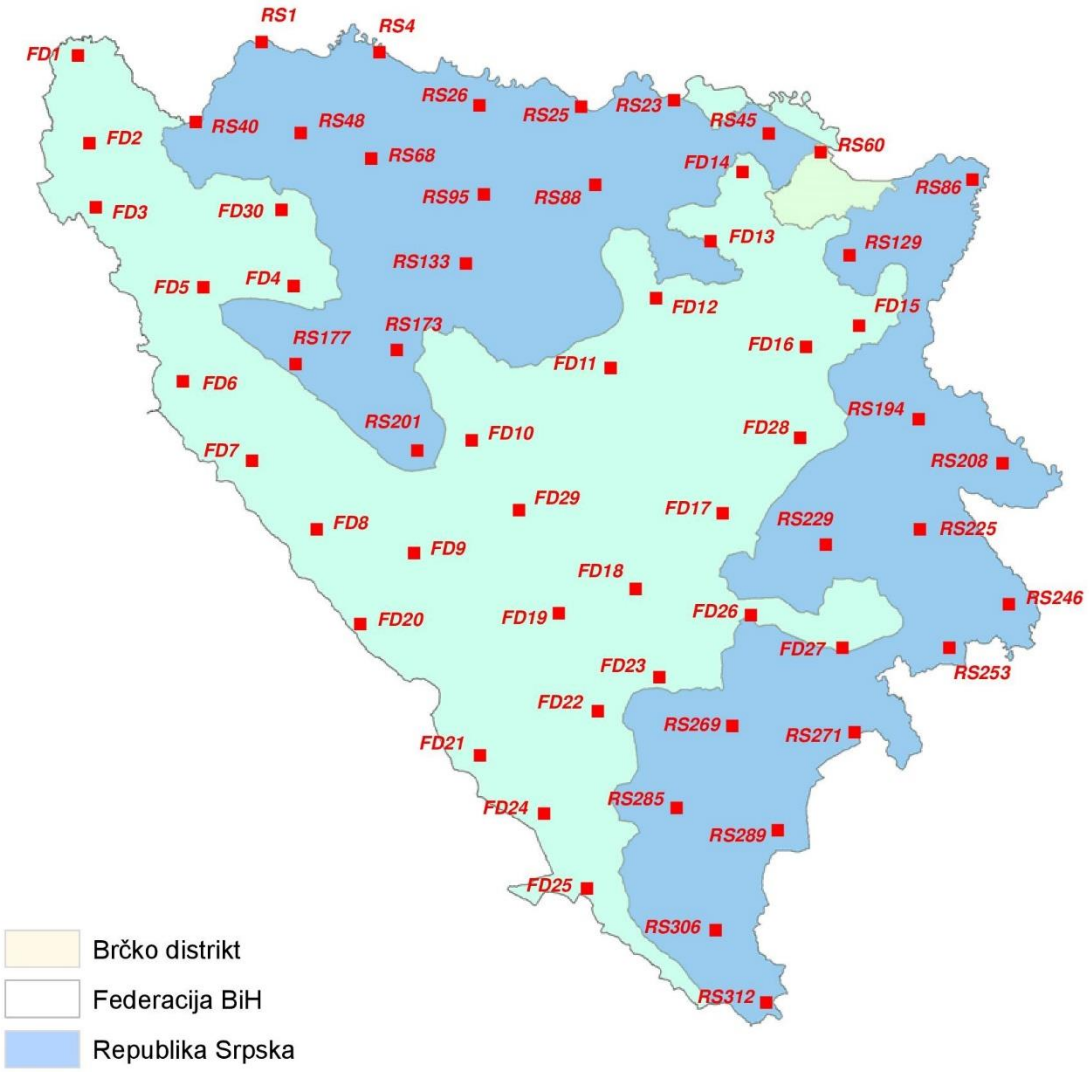

Figure 5: BiH Basic Gravimetric Network

7 Measurement specification

In this chapter we will give the preferred measurement procedure, both regarding gravity and GNSS measurements.

7.1 Instrument calibration (gravimeter)

Each gravimeter must be calibrated before, after, and every three months during one season of measurements. If unforeseen variations occur in the gravimeter drift/scale, the gravimeter must be calibrated in the interim too. The meaning of the calibration is to match the gravimeter's mGal (gravimeter's scale) to the absolute mGal.
The calibration must be determined by measuring between two of the existing absolute gravity stations, e.g AG02 and AG03. The calibration sequence start in e.g AG02, then AG03, AG02, AG03, and ending in AG02. The distance between AG03 and AG02 is 164 kilometers, and travel time is approximately 4 hours. Therefore, all measurements should be performed during one day (in the duration of ca 20 hours). Two drivers are recommended.

The calibration measurements should be performed in 6 cycles at each point, with 60 measurements performed in each cycle, one measurement per second. The measurements should be performed with the following adjustments:

- for the Earth's tidal waves,
- for the instrument's tilt,
- for the gravimeter drift,
- the seismic filter shall be activated,
- measurements should be in the UTC time scale,

and the adjustment due to the altitude of the gravimeter's measuring system should be calculated.

These calilbration measurements will give a calibration factor, K, given as

$$K = \frac{\Delta g(\text{absolute})}{\Delta g(\text{measured})}$$

where: Δg(absolute) – gravity difference between two absolute points, AG02 and AG03.
Δg(measured) – mean gravity difference obtained by relative gravimeter between two absolute points, AG02 and AG03.

The contractor must, prior to the start of the detailed gravimetric survey, provide a report on the instrument calibration.

After all measurements have been completed and gravity differences obtained on the entire survey, prior to the adjustment of the network all calculated variations must be multiplied by the estimated calibration factor, K.

7.2 The HPL3 network gravimetric survey

For the leveling network the double measurement method – one measurement in both directions – with daily return to the starting point (a Basic gravimetric network point) must be used. This will exclude one-sided errors and will control leaps in the gravimeter drift (Figure 6).

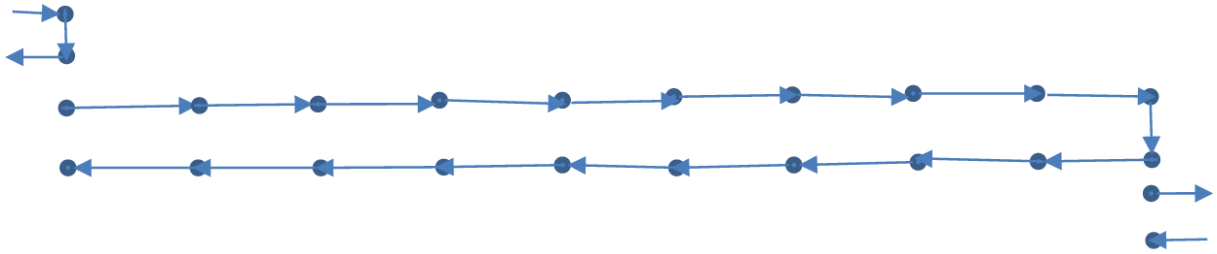

Figure 6: Line (profile) method of measurement with double measurement of each HPL3 benchmark

The gravimetric measurements:

- Must start and end within the same day (one session) on a Basic gravimetric network point.
- Two measurements of each benchmark, one in each direction see Figure 6.
- Must have at least one overlapping benchmark between two sessions, i.e., at least one benchmark of the previous session must overlap with one benchmark of the next session.
- A „Gravimetric Measurement Minutes“ (Annex 1) must be written for each benchmark.
- The accuracy of the gravity values after adjustment, on the benchmarks, must be better than 0.18 mGals.

7.2.1 Determine coordinates

In addition to the gravimetric survey, the coordinates must be determined in both systems (ETRS89 and SCS) for 350 HPL3 benchmarks inherit from the HPL1 and the HPL2 networks. Their coordinates must be determined by a dual-frequency GPS device in RTK mode with 60 measurements if it is possible to place a rod/tripod directly on the point.
In case of a horizontal benchmarks, where it's not possible to directly place a rod/tripod on the benchmark, two points in the immediate vicinity of the benchmark shall be identified (60 RTK measurements on each) and the coordinates and height of the benchmark shall be determined by classical methods of measurement (terrestrial - polar method).
For the benchmarks from the HPL1 and the HPL2 networks, the old benchmark detection minutes will be provided, but the contractor must make new HPL3 positional description. (Annex 2).

For the areas where the RTK measurements are not possible, the coordinates of the points must be determined by post-processing of the vectors and reports on their processing must be provided. The results should be in the range of 0.5 meter accuracy.

7.3 The FBiH detailed gravimetric survey

The main operating principle in the gravimetric survey consists of the measurement of the gravimetric survey polygons situated within the Basic Gravimetric Network polygons. The measurement

- The start and end of a measurement loop shall always be at a Basic gravimetric network point (RS or FBiH)
- a penultimate measurement in one session must be at another Basic gravimetric network point(RS or FBiH).
- „Gravimetric Measurement Minutes“ (Annex 1) must be written for each point.
- The loop will be closed when the gravimeter returns to the first measured point of the session/day (a Basic gravimetric network point.). This is to remove any drift of the gravimeter.
- In exceptional cases, when it is not possible to measure in the penultimate measurement at the Basic gravimetric network point., such measurement may also be performed in a stable place (concrete surface and similar, marked by a color spray or a bolt) that can be found again and measurement must be mandatorily performed in it some other day. In a repeated measurement of such point, it must be made sure that such repeated measurement is not the penultimate one in the session, but that it is instead in the middle of the measurement loop.
- An example of the described measurement method is given in Figure 7.

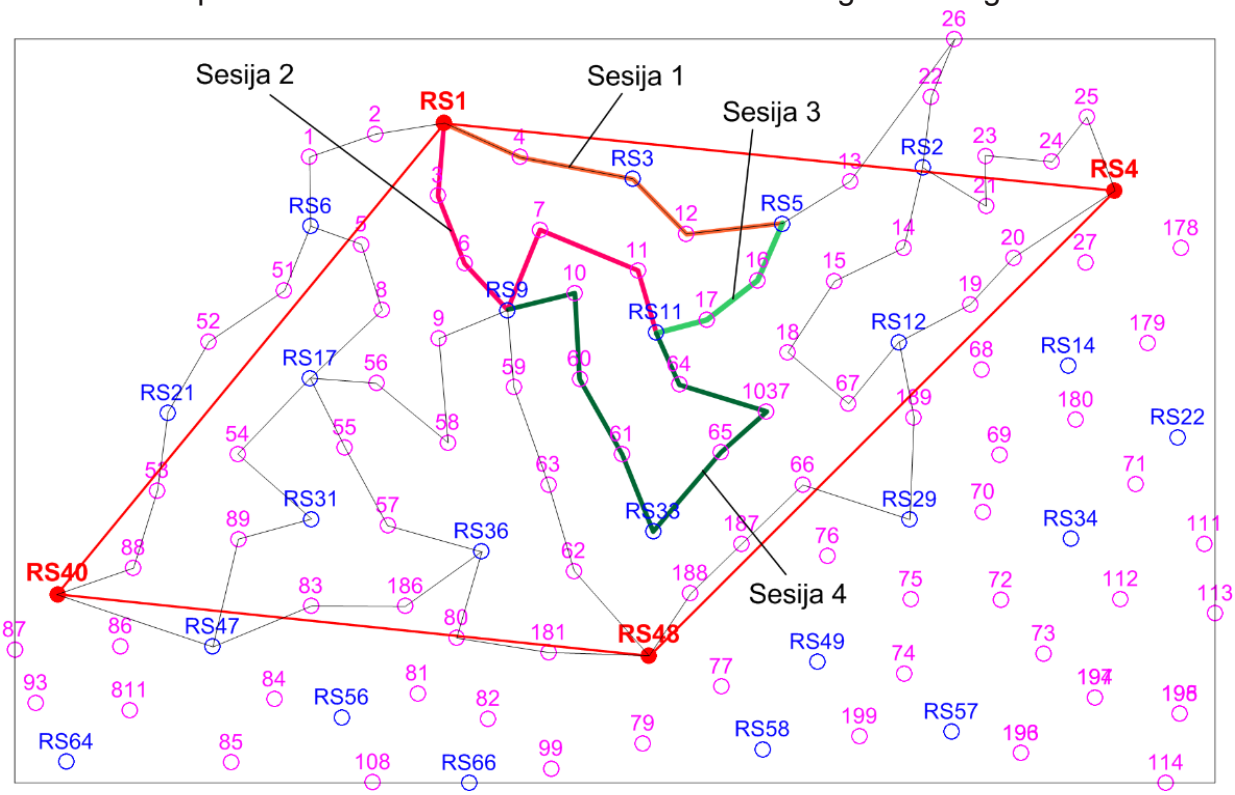

Figure 7: Principle of measuring gravity values in gravimetric survey. Sesija = sessions/loops.

Example: the session start with measurement at RS1, then e.g. point 4, RS3, 12 and RS5, before returning to RS1. The procedure must be repeated with session 2 and so on. In a few days, all points within a polygon of the Basic Gravimetric Network will be measured and linked to the Basic gravimetric network (BGN) points that have absolute accelerations.

The Basic Gravimetric Network polygons will represent independent units that can be preliminarily adjusted for control of measurements. Once the measurements have been completely finalized, the entire gravimetric survey network will be adjusted relying on all Basic Gravimetric Network points as given points. In this way, we are able to maintain control of measurement by smaller units given the large number of points covered by the gravimetric survey.

7.3.1 Determine coordinates

The coordinates must be determined in the ETRS89 system for the detailed gravimetric survey points that have not been determined from earlier measurement campaigns. The measurements must be performed by a dual-frequency GPS device in RTK mode with 60 measurements.

7.4 General instrument and measurement advices

The main systematic impact, whose elimination shall be determined by the application of a specific measuring method, is the gravimeter drift. The gravimeter drift entails the phenomenon of a stationary gravimeter reading variation over time, occurring due to the changes in the properties of its quartz spring. The main causes of the changes in the properties of the gravimeter's spring are the temperature oscillations, transport of the instrument and so called natural aging of the quartz.

Due to the gravimeter drift, the reading of its graduation becomes the function of time. This is the main reason why the precise moment of time shall be recorded on each reading. The aforementioned function of time can be arbitrarily complicated, but it is mainly linear in modern gravimeters.

The determination of the gravitational acceleration differences between the two gravimetric survey points shall consist of their sequential measurements by means of a relative gravimeter.

Under this project it is implied that gravimeters that have the ability to automatically calculate adjustments for the tilt of the instrument by axes and adjustments for tidal impact due to the Sun and the Moon shall be used for the measurements.

7.4.1 *Instrumental parameter settings*

Before the start of the measurements, the parameters on the gravimeter shall be set, i.e., they shall be selected within the following options:

- automatic rejection of readings that may be considered gross errors option (set YES),
- field adjustment calculation option (set NO),
- so called seismic filter utilization option (set YES),
- original reading data memorization option (set YES).

The measurement parameters shall be set by selecting the following values:

• Read time: 60 s
• Cycle time: 75 s
• # of Cycles: 4
• Start delay: 5 s

7.4.2 Station procedure

Once the instrument parameters have been set, the procedure at each gravimetric point of the network should consist of the following:

- gravimeter shall be placed over the gravimetric point fixed to the gravimeter's tripod and leaving it for several minutes in order for the spring system to settle down. before the start of the measurements, the latitude and designation N for northern hemisphere and the longitude and designation E (east of Greenwich) of the measuring point rounded to one decimal place shall be entered, e.g., 44.7N and 18.4E. Here the position may be obtained from the instrument's GPS.
- gravimeter shall be leveled with the positional screws on the tripod. The leveling can be achieved with the accuracy of 1" with the digital spirit level visible on the instrument's display if the instrument is brought to the working vertical area of 10".
- height of the gravimetric instrument shall be measured. The height shall be measured from the upper surface of the bolt's spherical calotte to the gravimeter's reference point. The gravimeter's lower edge is usually chosen as the gravimeter's reference point, but it can also be a completely arbitrary place on the casing of the instrument, provided that measurement is done in the same place at each point. The height of the gravimeter shall be measured up to a centimeter.
- 4 readings of the gravimeter shall be performed, of which the three best readings shall go in further data processing. Measurement at the point shall be considered good if at least 3 readings on the gravimeter do not vary more than 12 microgals, i.e., if the variation between the smallest and the greatest value of the reading is within the limits of 12 microgals for at least 3 measurements. If the required accuracy is not achieved in one measurement cycle, the measurement at the point shall be repeated.

In order to achieve sufficient accuracy in the BiH gravimetric survey, a series of procedures whereby the impact of a large number of systematic and random error sources is eliminated or minimized to the largest extent shall be applied.

The following shall be done during the gravimetric survey:

- strive to follow the same routine when setting up the instrument and reading it;
- avoid shocks when taking the instrument out of vehicle and mounting it on tripod, making sure that the instrument is not impacted;
- when gravimeter is transported by vehicle, it shall be placed on a soft surface in order to reduce the impact of vibrations due to transport, as well as fixed from all free sides in order to prevent it from flipping over during transport;
- when gravimeter is mounted on tripod and leveled, wait 2 minutes for the system to stabilize before performing the readings;
- protect the instrument from the effects of traffic, strong crosswinds, etc., during the measurements, i.e., pay attention primarily to the vicinity of traffic;

7.5 Minutes description

Minutes shall be kept during the measurements. The following most important data shall be entered in the minutes at each station:

- polygon number and session number,
- operator name,
- number of gravimetric point whereat measurement is done,
- measurement date and time (hour, minute, second),
- instrument reading in 55th second of measurement,
- reading adjusted for solid Earth tides,
- height of instrument measured in above described manner,
- comments relating to site, weather conditions and impacts, or other circumstances occurring during measurement that may be relevant to results obtained.

7.6 Position description

New position description should contain:

- number of HPL3 point
- number of HPL3 line,
- operator name,
- type of benchmark (vertical or horizontal),
- textual description,
- date of measurements,
- coordinates in ETRS89 and SCS,
- sketch of the nearby environment with written distances from characteristic points.

8 Data processing

The data processing shall be carried out in two phases:

1. Preliminary processing of the measurement results
2. Gravimetric survey network adjustment

8.1 Preliminary processing

Preliminary processing of the data from the measurements made should be performed with a view to obtaining the definitive gravitational acceleration differences between the BiH gravimetric survey points and evaluating the accuracy of the measurements made and the results obtained.

The following must be done in the first phase of the preliminary processing:

- calculation of the adjustment for the height of the instrument,
- calculation and elimination of the gravimeter drift,
- obtaining the final values of the readings at the point in the acceleration units.

Calculation of the adjustment for the height of the instrument

The adjustment for the height of the gravimeter's measuring system for the points whereat no gravitational acceleration vertical gradient has been measured shall be calculated using the following formula:

$$\delta g_i = -0{,}30877(1 - 0{,}00139 \cdot sin^2\varphi) \cdot 10^{-5} \cdot (-i)\left[\frac{m}{s^2}\right]$$

where:

i is the height of the measuring system in meters, it is negative for the points below the gravimeter, while it is positive for the points above the gravimeter.

Calculation and elimination of the gravimeter drift

Calculation and elimination of the gravimeter drift shall be done by making the difference of the readings adjusted for the height of the gravimeter based on the mean value from 4 measurements at the starting point and the mean value from 4 measurements at the end point and then calculating according to the linear law the adjustment for the drift for each point measured according to the measurement time.

The final values of the readings at the point shall be obtained after the adjustment for the gravimeter drift. This means that once this adjustment has been introduced we shall get the values of the readings directly in the acceleration units (mGal).

The following shall be done in the second phase of the preliminary processing:

- calculation of the final measurement values at the point,
- calculation of the acceleration difference,
- calculation of the polygon closure.

Calculation of the final measurement values at the point

The final measurement value at the point shall entail the averaged value from four readings performed by the gravimeter. The final values of the readings, i.e., the readings obtained after the first phase of the preliminary processing shall be averaged. The four readings performed by the gravimeter at the station shall be averaged by the simple arithmetic mean.

The standard deviation of one reading and the standard deviation of the arithmetic mean shall be evaluated from the deviations of specific readings from the arithmetic mean using the standard formulas. These two standard deviations shall be quality indicators that shall be compared against the relevant monitoring and control parameters from Table 2.

Table 3: Maximum allowable variations for monitoring and control of the gravitational acceleration difference measurement process in the FBiH gravimetric survey

Parameter	Value
Maximum standard deviation of the mean from four gravimeter readings at a station	6 μGal
Maximum acceleration difference error by one side of the polygon	15 μGal

Maximum non-closure of the polygon from N sides	Nx15 μGal

Calculation of the acceleration differences

The sum of gravitational acceleration differences between the points, starting and ending in a Basic Gravimetric network point, will be used to calculate the polygon non-closure of one side of the polygon.

Calculation of the polygon closure

The closure of the gravimetric survey polygon shall be performed by a simple algebraic addition of all related gravitational acceleration differences. The closure of the gravimetric polygons should theoretically amount to zero. Due to the impacts of the systematic and random error sources, the values other than zero will be gotten for the closure. They shall be a measurement quality indicator that shall be compared against the relevant monitoring and control parameters from Table 3.

8.2 The gravimetric survey network adjustment

The gravimetric survey network adjustment shall be performed by the application of the least-squares method. The least-squares method shall entail those solutions of a consistent, but undetermined system, which shall minimize the quadratic form.

The gravimetric survey network adjustment shall be carried out in two phases:

- preliminary adjustment,
- definitive adjustment.

The preliminary adjustment

The preliminary gravimetric survey network adjustment shall be performed primarily with a view to establishing the quality of the absolute and relative gravimetric determination.

The preliminary network adjustment shall be performed using the free adjustment model with the following main characteristics:

- measured quantities shall be all measured gravitational acceleration differences between the network points,
- unknown quantities shall be absolute gravitational accelerations at all gravimetric survey network points and points whereat absolute accelerations were determined,
- datum defect of the network shall be eliminated by minimization of the part of the trace of the covariance matrix of unknown parameters relating to the Basic Gravimetric Network points with the absolute gravimetric determinations.

The following statistical tests shall be performed within the preliminary gravimetric survey network adjustment:

- presence of gross errors in measurements test,

- consistency of the accelerations at the gravimetric survey points with the absolute accelerations at the Basic Gravimetric Network points test.

The quality control of the free gravimetric survey network adjustment with regard to the aforementioned statistical tests shall be performed with the parameters shown in Table 4.

Table 4: Parameters for the quality control of the preliminary adjustment of the FBiH gravimetric survey

Parameter	Value
Maximum absolute value of the standardized adjustment of the gravitational acceleration difference	3
Maximum increments of the values of the absolute gravitational accelerations at the gravimetric survey network points	60 μGal

The final adjustment

The final gravimetric survey network adjustment shall be performed once the preliminary adjustment has confirmed the quality of the absolute and relative gravimetric determinations made. It is particularly important to establish by the preliminary adjustment the consistency of the absolute gravimetric determinations with the network.

The final network adjustment shall be performed using the non-free adjustment model with the following main characteristics:

- measured quantities shall be all measured gravitational acceleration differences between the network points,
- unknown quantities shall be absolute gravitational accelerations at all network points, with the exception of the points whereat absolute gravimetric determinations were made,
- datum defect of the network shall be eliminated by setting the unknown parameter constancy conditions relating to the points with the absolute gravimetric determinations. These points to that effect shall be the datum (fixed, i.e., given) points in the adjustment.

The general mathematical model adequacy and presence of gross errors in measurements statistical tests shall be performed within the definitive gravimetric survey network adjustment. The preliminary and definitive FBiH gravimetric survey network adjustments shall be performed using the instrument manufacturer's commercial software package or software package of its own making with the aforementioned measured data manipulation, datum defect elimination method selection, and statistical testing features.

Once the values measured have been adjusted for known systematic errors, the processing of the measurement data may start. In doing this, a distinction shall be made between the functional and stochastic model.

Before the aggregate final adjustment, an adjustment shall be performed within the lines inserted between the points with known gravitational acceleration, between the points from the BiH Basic Gravimetric Network and points with absolute gravitational acceleration.

An adjustment report shall be developed on the preliminary and final FBiH gravimetric survey network adjustments. In addition to the general information on the project name, calculation date, software package name and version, the contents of the report on the preliminary and final evaluation of the absolute gravitational accelerations at the network points shall consist of at least the following results:

- list of the names of the gravimetric survey network points with their approximate absolute gravitational acceleration values,
- indicator of the datum points of the gravimetric network (fixed point or trace minimization point),
- list of the names of the end points of the gravimetric sides, with the measured values of the gravitational acceleration differences and their weights, i.e., standard deviations,
- list of the adjustments to the measured values of the gravitational acceleration differences, standardized adjustments to the gravitational acceleration differences, and gravitational acceleration difference internal reliability indicators,
- list of the evaluated absolute gravitational accelerations at the network points with the evaluated standard deviations,
- evaluated value of the standard of the unit of weight,
- overall number of measurements, overall number of unknowns, overall number of datum conditions,
- method of elimination of the datum defects, number of the degrees of freedom,
- minimum, average, and maximum values of the standard of the evaluated absolute gravitational accelerations,
- minimum, average, and maximum values of the standard of the evaluated gravitational acceleration differences,
- results of the statistical tests performed.

9 Documentation and reports

The following three documentation must be provided by the contractor.

1) Report on instrument calibration:

- describing how the instrument calibration was made (tehnical report), and its result.

2) Once the preliminary processing of the measurement results has been completed, a report comprising three sections shall be made:

A) the determination of the final measurement results,
B) the determination of the gravitational acceleration differences,
C) the polygon closure.

A) A report on the determination of the final measurement results shall include the following data:

- station name,
- list of the original instrument readings,
- list of the adjustments for the height of the gravimeter,
- list of the adjustments for the gravimeter drift,
- list of the adjustments for the lunisolar high tide impact,

- list of the adjusted instrument readings,
- final measurement value at the station,
- standard deviation of one reading and arithmetic mean.

B) A report on the determination of the gravitational acceleration differences on gravimetric sides shall include the following data:

- names of the gravimetric side stations,
- value of the gravitational acceleration difference,
- standard deviation of the gravitational acceleration difference.

C) A report on the polygon closure shall include the following data:

- list of the stations of the gravimetric sides closing the polygon,
- list of the gravitational acceleration differences of each gravimetric side,
- value of the polygon non-closure.

3) The contractor shall deliver „The FBiH Gravimetric Survey“ Report, which shall include:

A. Positional descriptions of the HPL1 and HPL2 benchmarks included in the new HPL3 leveling network
B. An analysis of the measured gravitational accelerations (preliminary processing)
C. The gravimetric survey network adjustment

Section A shall include:

- Technical report;
- Original GPS measurements;
- Original terrestrial measurements;
- Measurement post-processing templates (in digital form);
- HPL3 – benchmark positional description – Annex 2 (in digital form);
- HPL3 – benchmark positional description – Annex 2 (in analog form);
- Database.

Section B shall include:

- Technical report;
- Gravimeter calibration report;
- Original GPS measurements;
- Original terrestrial measurements;
- Original gravimetric measurements;
- GPS and terrestrial measurement post-processing templates (in digital form);
- Gravimetric measurement minutes – Annex 1 (in digital form);
- Report (spreadsheet) on the calculated adjustments for the height of the instrument (in digital form);
- The gravimeter drift calculation and elimination template (in digital form);
- Report (spreadsheet) on the calculation of the final values of the readings at the point for each measurement (in digital form);
- Report (spreadsheet) on the calculation of the final values of the multiple measurements at the point with an accuracy assessment (in digital form);

- Report (spreadsheet) on the comparisons of the individual and mean values with the permitted tolerances from Table 2 (in digital form);
- Report (spreadsheet) on the determination of the gravitational acceleration difference between the points (in digital form);
- Polygon closure report.

Section C shall include:
- Technical report;
- Report (spreadsheet) on the comparison of the gravitational acceleration at the gravimetric survey points with the absolute acceleration at the Basic Gravimetric Network points after a free adjustment;
- Report (spreadsheet) on the comparison of the individual specific gravitational accelerations with the limits from Table 3 after a free adjustment (in digital form);
- Report (spreadsheet) on the final gravitational acceleration values with an accuracy assessment after an indirect adjustment (in digital form);
- Report on the performance of the statistical tests;
- Database.