ISTANBUL TECHNICAL UNIVERSITY

Civil Engineering Faculty

Geomatics Engineering Department

Geodetic Infrastructure and Networks

Project
F20C
Ezgi Yaman

CONTENTS

1. INTRODUCTION

1.1 Aim of the Project

This project aims to establish a high-precision GPS Network within the F20-C sector to increase control point density in the study area can be seen in figure 1 and 2. By installing permanent monuments, the project provides a reliable geodetic reference framework for future engineering initiatives and thematic mapping applications. To ensure technical integrity, a rigorous strategy emphasizing accuracy and reliability has been implemented from the initial design phase.

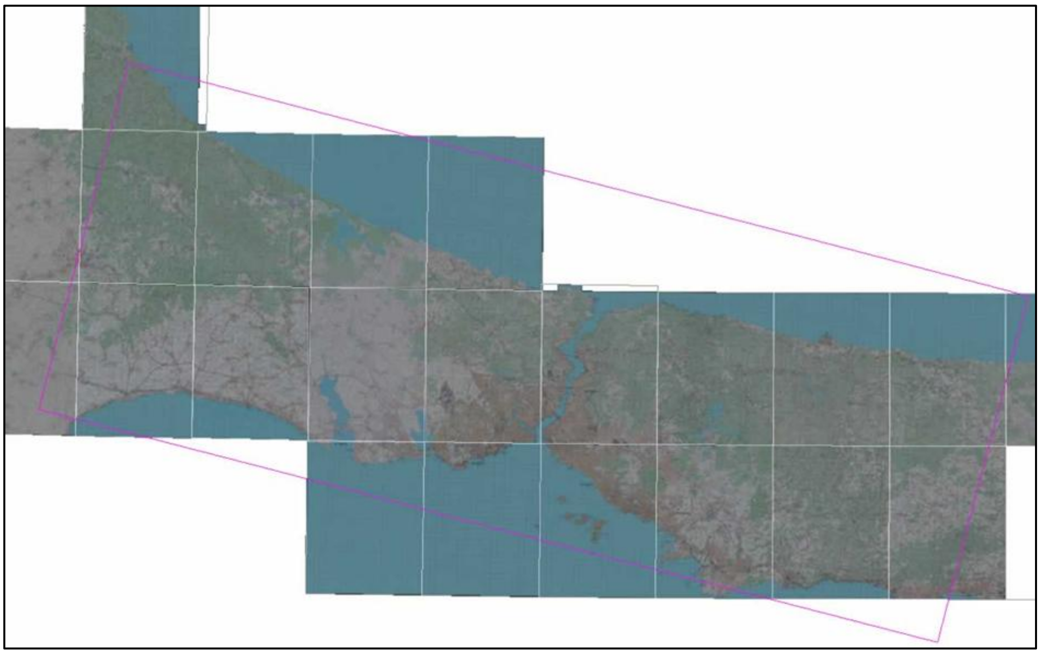


Figure 1 – Study Area

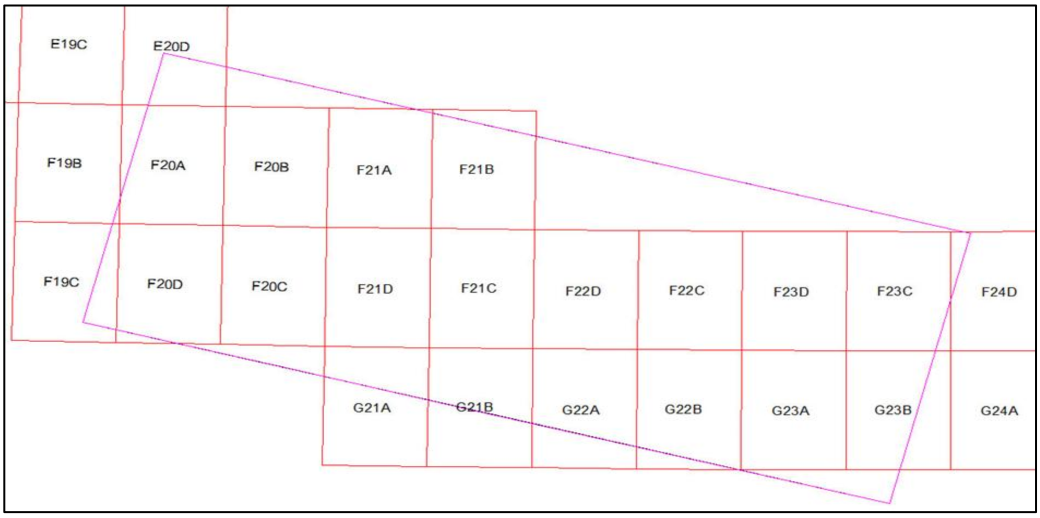


Figure 2 – Study Area, gridded by map sheet numbers

1.2 Project Tools

The following resources and technical specifications are utilized within the scope of this project:

- Cartographic Reference: 1:50,000 scale topographic map sheets.
- Geodetic Data: Coordinate lists of C1-order control stations belonging to the Istanbul GPS Triangulation Network (IGNA).

- Regulatory Standards: Procedures conducted in accordance with the "Regulations for Large Scale Mapping and Map Information Production" (BOHHBUY).

- Hardware and Instrumentation: Two dual-frequency geodetic-grade GPS/GNSS receivers with compatible antennas and accessories. Also, high-precision total station with auxiliary survey tools.

- Logistics: A dedicated vehicle for field operations and site accessibility.

1.3 Technical Specifications for Control Stations According to 'BÖHHBÜY'

The observation and design criteria for C1, C2, and C3 order stations are governed by the Large Scale Mapping and Map Information Production Regulations (BÖHHBÜY). The specific requirements are detailed below:

1.3.1 Rules for C1 order control stations

a) Baseline Length: The distance between stations should be approximately 30 km.
b) Satellite Availability: A minimum of 5 satellites must be tracked simultaneously.
c) Recording Interval: Data must be logged at an interval of 15 seconds or less.
d) Elevation Mask: A minimum elevation angle of 10° required.
e) Observation Duration: Continuous recording for at least 2 hours is mandatory.

1.3.2 Rules for C2 order control stations

a) Baseline Length: The average length should be approximately 5 km, with individual baselines not exceeding 15 km.
b) Satellite Availability: A minimum of 5 satellites must be tracked.
c) Recording Interval: Data logging interval must be 15 seconds or less.
d) Elevation Mask: A minimum elevation angle of 10° must be maintained.
e) Observation Duration: A minimum of 60 minutes is required between known pillars; for unknown stations, two separate sessions of 30 minutes each are necessary.

1.3.3 Rules for C3 order control stations

a) Baseline Length: The maximum allowable distance is 10 km.
b) Satellite Availability: A minimum of 5 satellites is required.
c) Recording Interval: Data must be recorded every 15 seconds or less.
d) Elevation Mask: The elevation angle must be at least 10°.
e) Observation Duration: For bases up to 5 km, a 20-minute session is sufficient. For observations between unknown points, two independent sessions of 30 minutes each are required.

f) Solution Requirements: At least two independent baseline solutions must be obtained to ensure reliability.

2. PROCESSES

2.1 Provided C1 points

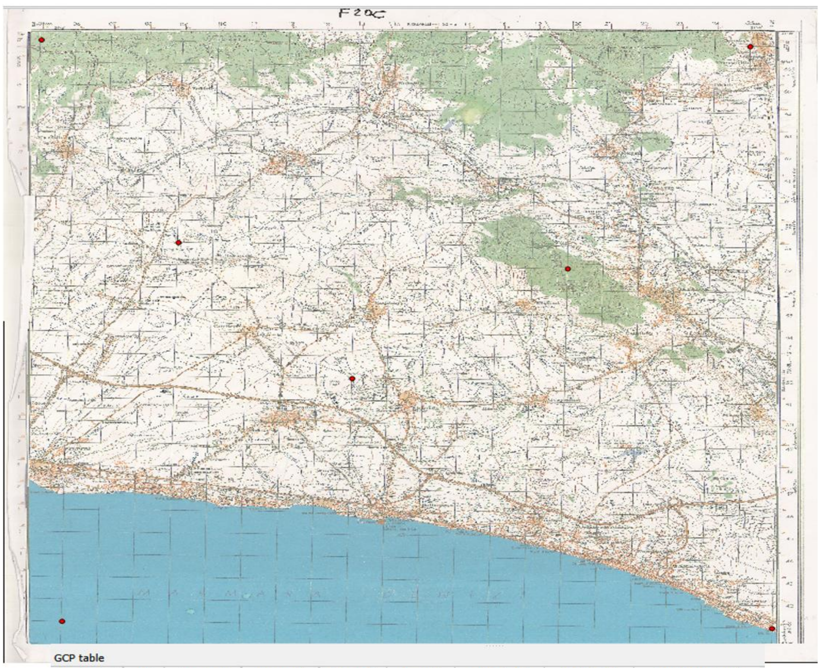
Instructor of the homework provided the students with C1 points within the Istanbul with degree, minutes, second unit. But for workability of the applications. The teams have to convert this unit to the degree unit. The formula that will be used in converting each point is in the formula 1.

$$\text{Degree} = \text{Degree} + (\text{Minutes} / 60) + (\text{Second} / 3600)$$

Formula 1: Formula of converting degree, min, sec to Degree

2.2 Georeferencing of Topographic Map

Georeferencing will be done on QGIS application. For this step 6 points that on the grids did select and their coordinates did read from the map. Their location and rediuals can be seen in figure 3.



GCP table

Enabled	ID	Source X	Source Y	Dest. X	Dest. Y	dX (pixels)	dY (pixels)	Residual (pixels)
✓	0	28.252541	41.245880	28.252520	41.245900	-0.433522	-0.409072	0.596055
✓	1	28.490967	41.243119	28.490950	41.243100	-0.281414	0.557945	0.624897
✓	2	28.259421	41.011603	28.259440	41.011600	0.551165	-0.258625	0.608826
✓	3	28.498277	41.008675	28.498278	41.008650	0.160238	0.284659	0.326660
✓	4	28.298584	41.164191	28.298570	41.164200	-0.238383	-0.286168	0.372449
✓	5	28.429585	41.153633	28.429585	41.153630	0.132652	0.006297	0.132802
✓	6	28.357046	41.109421	28.357046	41.109410	0.109263	0.104965	0.151513

Figure 3 - Georeferenced map

2.3 Provided Points on Georeferenced Map

The provided coordinates have all points in Istanbul. However, in this study the area is within the map F20-C points will be used for further steps. All points with in the Istanbul can be seen in the figure 4. And the points that will be used by the team can be seen in the figure 5 and the table of the points in figure 5 is in the table 1. After obtaining the georeferencing the data and raster data. We need to transform current datum (WGS84), which is angular unit, to the metric datum (TM30).

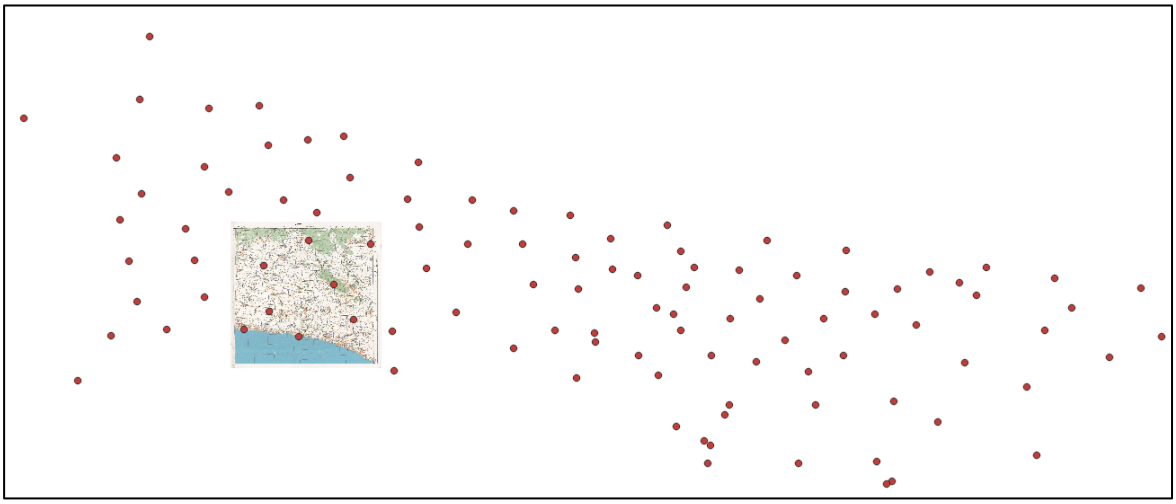


Figure 4 - All the points that provided to us

Figure 5 - Points within the study area (On map F20-C)

Point No	Y	X	Latitude	Longitude	h
F201H006	358613.42	4556446.36	41.14626	28.42973	363.4677
F201H007	355984.41	4557135.66	41.18081	28.30024	270.8779
F20-G003	362572.17	4547617.06	41.05183	28.36533	41.0585
F2010017	360595.56	4555909.02	41.22081	28.49631	74.6441
F2010018	364095.01	4554611.62	41.22737	28.38284	149.0201
F2010019	356885.46	4559158.86	41.08185	28.46542	219.7697
F2010020	357286.01	4555189.97	41.09714	28.3107	143.1878
F2010021	359414.57	4554616.18	41.06386	28.26503	115.1086

Table 1 - Table of the points within the study area

2.4 The C1 Order Network and Points

When determining the positioning of C1 stations, primary consideration must be given to ensuring straightforward accessibility and maintaining a specific altitude for clear visibility. In addition to these physical requirements, it is crucial to preserve signal integrity by steering clear of obstructed or high-interference zones, specifically wooded areas and power generation facilities, which are known to disrupt stable connectivity.

If it is a C1 order Control Station; numbering will be as follows:

- [1:100000 plate code] + [1] + [0001] => F201H001

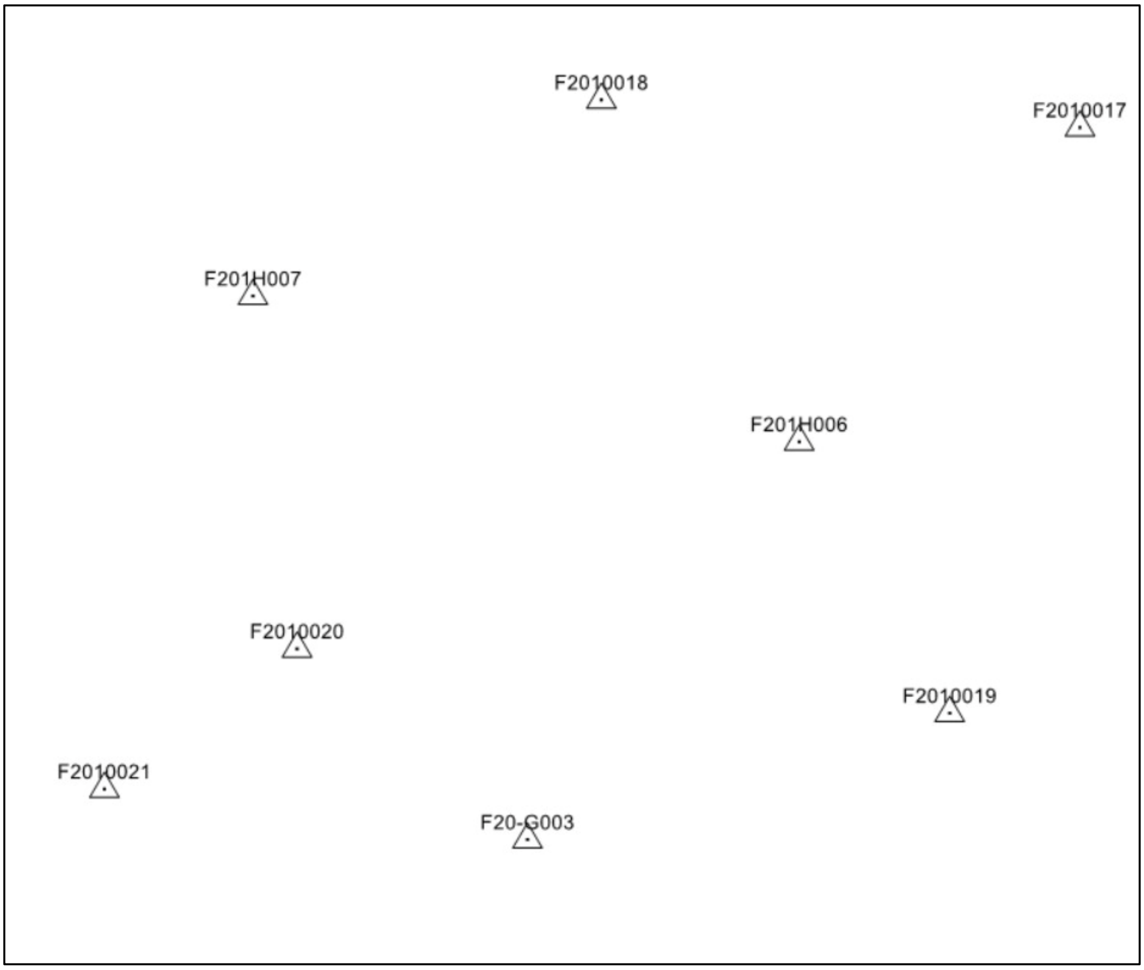


Figure 6 - C1 Points

2.5 The C2 Order Network and Points

In accordance with the guidelines specified in the current BOHBÜY, 12 C2 control stations were integrated into the map based on spatial data obtained from C1 stations. In the project, a 'Reconnaissance Sketch' was used to clearly show both the existing stations and the grid lines of the map, while a 'Progress Sketch' was specifically dedicated to managing the triangulation network and data collection processes.

If it is a C2 order Control Station; the numbering will be as follows;

- [1:100000 plate code] + [2] + [0001] => F202H001

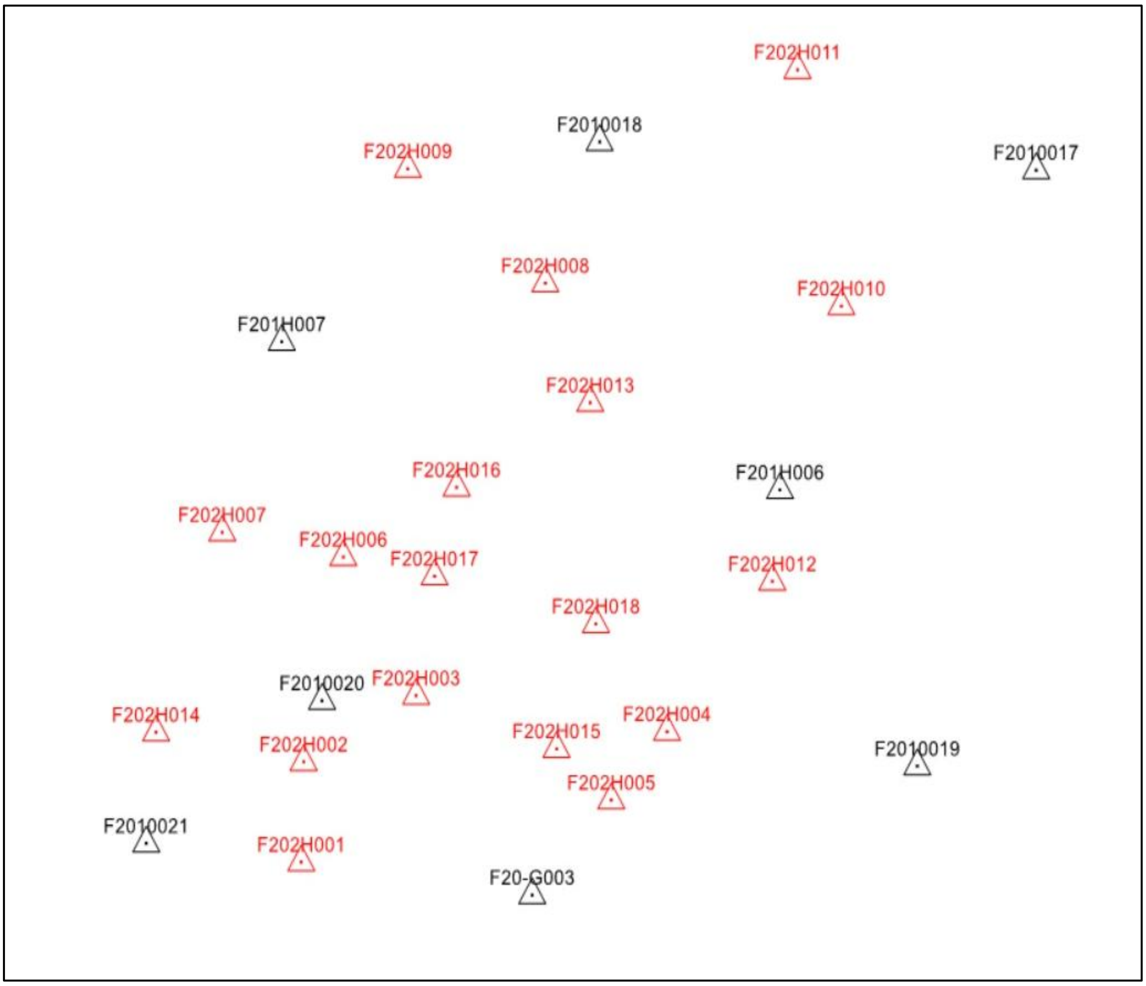


Figure 7 - C2 Points

2.6 The C3 Order Network and Points

Building upon the C1 and C2 infrastructure, C3 order stations were designed to expand the network's coverage. The placement strategy required that each C3 station have visible contact with at least one station from the C1, C2, and C3 levels. To ensure stability and accessibility, these stations were generally installed at previous densification points, within cemeteries, on government property, or adjacent to main roads.

If it is a C3 order Control Station; the numbering will be as follows;

- [1:100000 plate code] + [3] + [0001] => F203H001

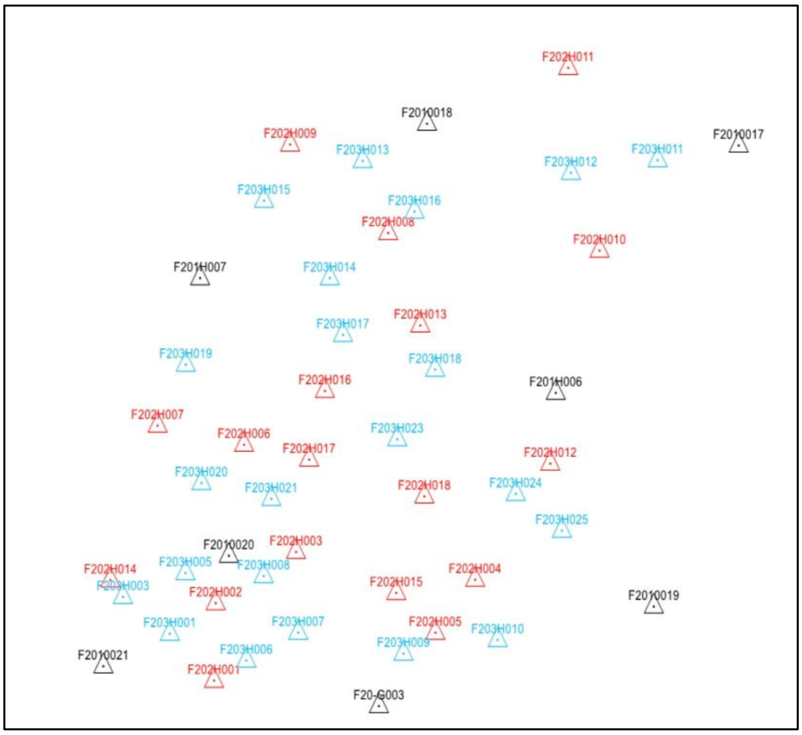


Figure 8 - C3 Points

Point ID	Y(m)	X(m)	Point ID	Y(m)	X(m)
F20-G003	362572.17	4547617.06	F203H001	356220.75	4550164.65
F2010017	373907.93	4566185.66	F203H003	354809.91	4551424.06
F2010018	364406.58	4567084.92	F203H005	356738.87	4552184.94
F2010019	371045.22	4550798.27	F203H006	358545.11	4549220.70
F2010020	358076.63	4552736.50	F203H007	360149.39	4550121.89
F2010021	354165.80	4549115.47	F203H008	359128.34	4552038.72
F201H006	368175.53	4558004.91	F203H009	363359.32	4549362.35
F201H007	357379.32	4562046.51	F203H010	366248.37	4549761.72
F202H001	357543.22	4548565.07	F203H011	371426.27	4565738.29
F202H002	357644.02	4551159.39	F203H012	368770.46	4565359.57
F202H003	360133.98	4552827.84	F203H013	362421.04	4565876.04
F202H004	365595.55	4551793.57	F203H014	361341.43	4561968.78
F202H005	364345.99	4550041.44	F203H015	359380.38	4564602.61
F202H006	358613.42	4556446.36	F203H016	363972.27	4564149.38
F202H007	355984.41	4557135.66	F203H017	361707.73	4560064.55
F202H008	363154.78	4563451.92	F203H018	364502.38	4558847.20
F202H009	360215.67	4566470.10	F203H019	356885.46	4559158.86
F202H010	369598.40	4562741.45	F203H020	357286.01	4555189.97
F202H011	368751.43	4568875.64	F203H021	359414.57	4554616.18
F202H012	367964.86	4555639.13	F203H023	363301.97	4556539.61
F202H013	364077.37	4560339.16	F203H024	366891.28	4554642.76
F202H014	354436.70	4551988.02	F203H025	368278.26	4553386.15
F202H015	363174.83	4551394.60	F202H016	361121.51	4558201.26
F202H017	360595.56	4555909.02	F202H018	364095.01	4554611.62

Table 2: Table of Points

2.6 The Reconnaissance Sketch

The draft of the expedition was prepared in figure 8. An exploratory sketch, usually used for planning or surveying reasons, is a rough sketch or diagram that shows the layout or characteristics of a region. For this, the Projection parameters were configured using the Netcad software. The coordinates of the C1 points on the ground were determined with Excel application and the necessary coordinate transformations were performed. The projection parameters are configured in the program using the terrain map as a geographical reference. An affine transformation was used in this process. Later, intensification works were started, which resulted in the creation of C2 and C3 points. Care was taken to install the points in easily accessible places and to place them in the most cost-effective way.

The points were given names in accordance with the rules, starting from the north and going clockwise. Then, each base dissolving action was finished by using higher-order networks (dots) to build bases from C1 through C3.

C1 and C2 control stations were assigned and care was taken to match the baselines between the control stations according to BOHHBUY. The distribution of control stations has been uniform. To improve understanding, each station is symbolized and colored differently.

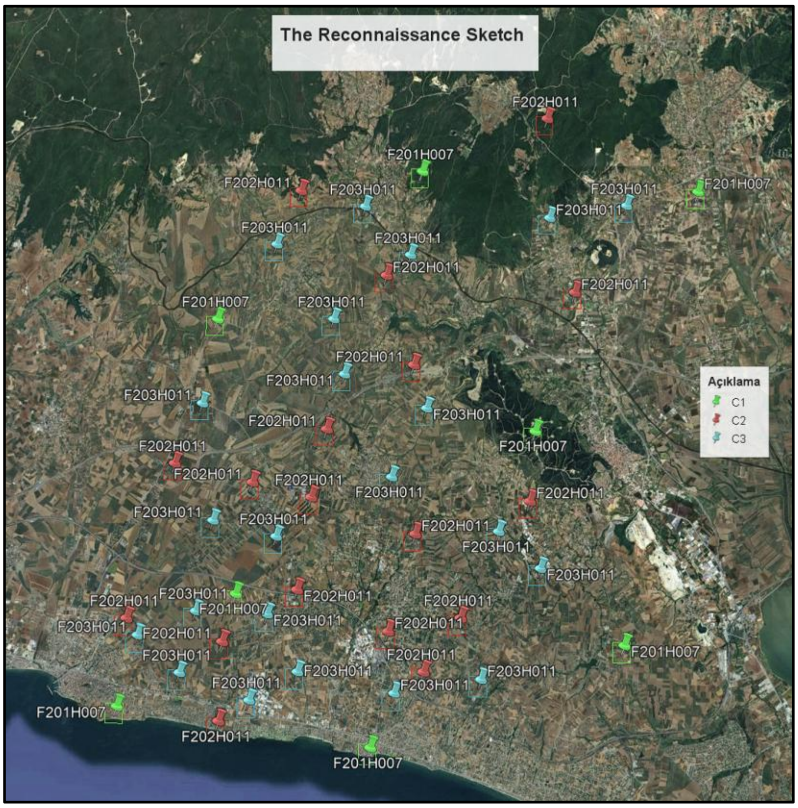


Figure 8 – the reconnaissance sketch

2.7 The Progress Sketch

A progress sketch is a drawing used to represent the current state of the project or the progress of the project. A progress sketch is a representative drawing that shows pending tasks and problems, not for the purpose of showing completed work. The progress sketch also needs to be updated regularly, as pending tasks or problems change as the project progresses.

Below is the progress sketch prepared for the geodetic network densification design project carried out on the F20-C sheet. While drawing the progress sketch, BOHHBUY was taken as a basis and drawn accordingly.

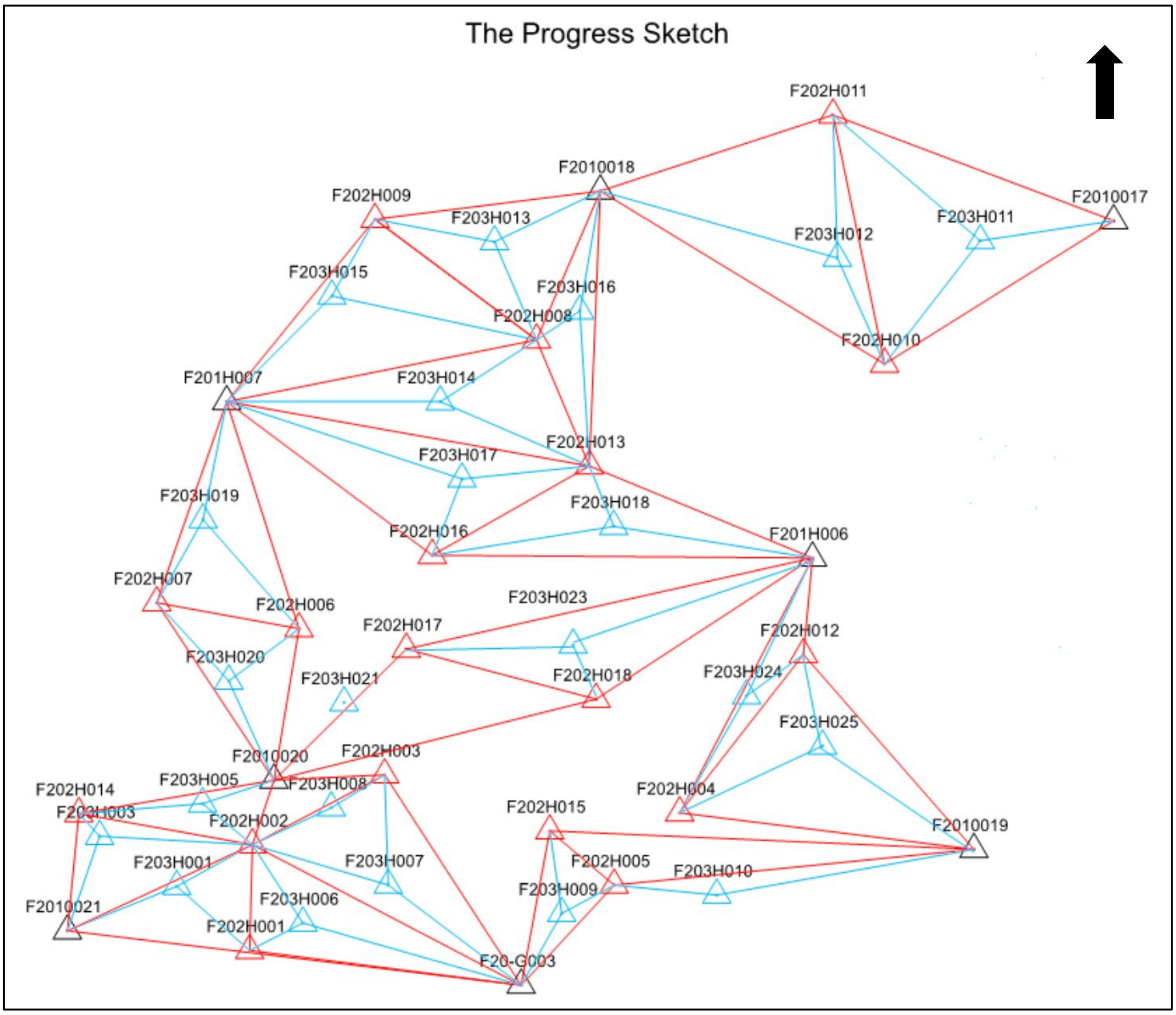


Figure 9 – The Progress Sketch

2.8 The Session plan

This session plan serves as the operational framework for the GNSS survey. It outlines the hierarchical progression from reference stations to target control points. Each session specifies the baseline configurations, required observation durations (20 to 60 minutes), and estimated travel times to ensure efficient data collection and field management across the two-day schedule. The session plans are given in tables 3 and 4.

Reference 1	Reference 2	Solved	Session	Observation Time (min.)	Travel Time + Observation Time (min.)	Day
F2010017	F2010018	F2020011	1	60	70	1
F2010017	F2010018	F2020010				
F2020010	F2020011	F2030012	2	20	30	
F2020010	F2020011	F2030011				
F2010018	F201H007	F2020009	3	60	70	
F2010018	F201H007	F2020008				
F2010018	F201H007	F2020013	4	60	70	
F2020009	F2020008	F2030015	5	20	30	
F2020009	F2020008	F2030013				
F2020013	F2020008	F2030014	6	20	30	
F2020013	F2020008	F2030016				
F201H007	F201H006	F2020016	7	60	70	
F2020013	F2020016	F2030017	8	20	30	
F2020013	F2020016	F2030018				
F201H007	F2010020	F2020007	9	60	70	
F201H007	F2010020	F2020006				
F2020007	F2020006	F2030019	10	20	30	
F2020007	F2020006	F2030020				
F2010020	F201H006	F2020017	11	60	70	
F2010020	F201H006	F2020018				
F2020017	F2020018	F2030023	12	20	20	
F2020017	F2020018	F2030021				

Table 3 – The session plan of first day

Reference 1	Reference 2	Solved	Session	Observation Time (min.)	Travel Time + Observation Time (min.)	Day
F201H006	F2010019	F2020012	13	60	70	2
F201H006	F2010019	F2020004				
F2020012	F2020004	F2030025	14	20	30	
F2020012	F2020004	F2030024				
F20-G003	F2010019	F2020005	15	60	70	
F20-G003	F2010019	F2020015				
F2020015	F2020005	F2030009	16	20	30	
F2020015	F2020005	F2030010				
F20-G003	F2010021	F2020001	17	60	70	
F20-G003	F2010021	F2020002				
F20-G003	F2010020	F2020003	18	60	70	
F2010021	F2010020	F2020014	19	60	70	
F2020001	F2020002	F2030001	20	20	30	
F2020001	F2020002	F2030006				
F2020002	F2020003	F2030007	21	20	30	
F2020002	F2020003	F2030008				
F2020014	F2020002	F2030003	22	20	30	
F2020014	F2020002	F2030005				

Table 4 - The session plan of second day

2.9 Cost Calculation

The total cost of the geodetic network densification project conducted on the F20-C sheet has been calculated by considering personnel expenses, technical equipment usage, monument construction, and logistical expenditures as can be seen in table 5.

- Total Duration: The total project duration is 18 hours and 10 minutes, encompassing all field operations and inter-point transportation.

- Equipment: To ensure maximum precision and efficiency, 6 dual-frequency GPS/GNSS receivers were utilized during measurement activities.

- Transportation: 1 automobile was used for site access and logistics throughout the project.

- Infrastructure Establishment: 18 new C2-order monuments and 25 new C3-order control points were established in accordance with BOHHBUY (Large Scale Map and Spatial Data Production Regulation) standards.

- Technical Team: The field and office work were executed by a team of one survey engineer and 4 instrument operators.

- Unit Prices: Cost calculations were based on the 2025 unit price schedules provided by the Chamber of Survey and Cadastre Engineers (HKMO) and İller Bankası.

	Count	Unit Cost (TRY)	Total Cost (TRY)
Choosing a location for C1 order points	8	₺4,214.12	₺33,712.96
Choosing a location for C2 order points	18	₺1,580.30	₺28,445.40
Searching for C2 order points	18	₺814.69	₺14,664.42
Searching for C3 order points	25	₺407.35	₺10,183.75
C2 order point (pillar)	18	₺46,915.61	₺844,480.98
C3 order point (concrete)	25	₺13,604.85	₺340,121.25
C2 order point measurement and calculation	18	₺9,059.23	₺163,066.14
C3 order point measurement and calculation	25	₺4,363.71	₺109,092.75
Computer	2	₺162.35	₺324,70
Dual frequency geodetic type GNSS receiver	12	₺796.91	₺9,562.92
Engineer Fee (1 person)	18	₺378.40	₺6,811.20
Technician Fee (2 people)	36	₺306.56	₺11,036.16
Map employee (2 people)	36	₺188.00	₺6,768.00
Coordinate Transformation	8	₺20.52	₺164.16
Fuel	50	₺53.15	₺2,657.50
Food and beverage expense	6	₺400.00	₺2,400.00
		Total	₺1,583,592.29

Table 5 – Cost of the job

Except for the fees related to the use of the TUSAGA-Active System, VAT is not included in the prices of other products and services in the list.

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