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Determining the Intensity of the Magnetic Field in a Development Site by Magnetic Prospecting: The Case of the Passager District

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ABSTRACT

This study focuses on the statistical analysis and geophysical interpretation of data from a magnetic survey conducted in the Passager district. The main objective is to characterize variations in the magnetic field and identify areas of geophysical interest for a development project. The results show significant magnetic heterogeneity across the site, dominated by positive anomalies, with important implications for understanding the subsurface.

KEYWORDS: *Determination, Magnetic field, Magnetic prospecting, Intensity, Site.*

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1. INTRODUCTION

Developing a site for a housing estate is a significant undertaking that requires a thorough understanding of the land beforehand. Before any permanent occupation of the space, it is essential to identify the site's physical characteristics, any potential natural constraints, and factors that could influence future development work. Indeed, land intended for development may exhibit heterogeneous subsoil composition, disturbed areas, specific geological structures, or even buried metal objects linked to past human occupation. These factors, if not known in advance, can lead to difficulties during earthworks, foundation work, road construction, or utility installation.

In this context, geophysical surveys are a very useful decision-making tool. They provide indirect information about the subsoil without immediately resorting to excavation or destructive drilling. Their value lies in their ability to quickly cover a given area, highlight lateral variations in the terrain, and direct further investigations toward the most sensitive zones. Thus, before developing a site for subdivision, geophysics can help identify homogeneous areas, disturbed zones, and anomalies that could impact the safety or quality of future developments.

The magnetic method thus appears as a relevant tool for indirectly identifying certain variations in the subsoil. It allows for the measurement of magnetic field intensity and highlights spatial variations that may indicate natural or artificial anomalies. These anomalies can originate from contrasts between geological formations, the presence of materials rich in magnetic minerals, geological structures, but also from buried metallic objects, ferrous waste, pipes, fences, old foundations, or other sources of disturbance related to human activities.

However, the interpretation of magnetic data on a development site must be approached with caution. A variation in the magnetic field does not automatically indicate a major constraint for development. Rather, it suggests an area that warrants further analysis, comparison with field observations, and, if necessary, verification through additional investigations. The main challenge, therefore, lies in distinguishing normal variations in the magnetic field from significant anomalies, and then proposing a coherent interpretation of their probable origin.

Thus, the central issue of this study can be formulated as follows:
How is the intensity of the magnetic field distributed in the Passager district and to what extent can the detected anomalies provide information on the characteristics of the subsoil and the possible constraints to be taken into account before the development of the site to be subdivided?

The following specific questions arise from this main issue:
- What is the spatial distribution of magnetic field intensity in the Passenger district?
- Are there any significant magnetic anomalies at the site?

In relation to the first question, the site's magnetic field exhibits measurable spatial variations . Indeed, the intensity of the magnetic field is generally not perfectly uniform across a given area. It can vary from one point to another depending on the nature of the geological formations, the mineralogical composition of the soil, the depth of the magnetic sources, and disturbances present in the immediate environment. Thus, the measurements taken in the Passager district should reveal areas of low, medium, or high magnetic intensity. Once mapped, these variations will allow us to assess the overall structure of the local magnetic field.

Regarding the second question, we note that certain areas may exhibit anomalies related to subsurface heterogeneities or buried metallic objects . A magnetic anomaly corresponds to a local variation in the magnetic field that deviates from the general behavior observed on the site. It can be of natural origin, when associated with lithological variations, rocks containing magnetic minerals, or specific geological structures. It can also be of anthropogenic origin, when caused by metallic elements such as scrap metal, cables, pipes, fences, buried waste, or old infrastructure. In a development site, these anomalies can reveal disturbed areas that are not always visible on the surface.

The objectives of this research are to:
- to carry out magnetic measurements across the entire study site;
- determine the values of the total magnetic field strength;
- correct the acquired data, including any possible temporal variations.

The general methodology adopted in this study is based on a progressive approach that includes literature review, site survey, acquisition of magnetic data, its processing, mapping, interpretation, and the formulation of recommendations. This approach aims to obtain a reliable picture of the distribution of magnetic field intensity in the Passager district, in order to identify homogeneous areas and sectors with anomalies that may need to be addressed before the development of the site.

2. Theoretical framework on applied geophysics

Applied geophysics is a branch of Earth science that uses the physical properties of rocks, soils, and subsurface structures to address practical problems related to exploration, the environment, civil engineering, hydrogeology, and land-use planning. It relies on the measurement of physical parameters such as electrical resistivity, density, seismic wave velocity, magnetic susceptibility, natural radioactivity, and variations in magnetic and gravimetric fields (Kearey, Brooks & Hill, 2002; Reynolds, 2011).

Unlike direct methods, such as excavations or mechanical soundings, geophysical methods provide indirect information about the subsurface. They are generally non-destructive and allow for the rapid coverage of large areas. Their value lies in their ability to highlight contrasts between different materials or different underground structures (Reynolds, 2011).

The main geophysical methods include electrical, electromagnetic, seismic, gravimetric, magnetic, radiometric, and ground-penetrating radar. Electrical methods are used to study variations in subsurface resistivity; seismic methods analyze wave propagation; gravimetric methods highlight density contrasts; while magnetic methods detect variations in the magnetic field related to the magnetic properties of rocks or metallic objects (Kearey, Brooks & Hill, 2002; Telford, Geldart & Sheriff, 1990).

A. Magnetic field

A magnetic field is a physical quantity that describes the magnetic influence exerted in space by the Earth, a magnet, an electric current, or a magnetized material. In the case of Earth, this is referred to as the Earth's magnetic field or geomagnetic field. This natural field envelops the planet and results primarily from the movement of conductive materials in Earth's outer core. It can be described by several components, including the horizontal component, the vertical component, the inclination, the declination, and the total magnetic field strength (Campbell, 2003; Lanza & Meloni, 2006).

B. Magnetic intensity

Magnetic intensity corresponds to the measured value of the magnetic field at a given point. In magnetic prospecting, it is generally expressed in nanoteslas, denoted nT. Magnetometers used in the field, particularly proton magnetometers, often allow the measurement of the total magnetic field intensity, that is, the overall value of the resulting field at the measurement point (Campbell, 2003; Reynolds, 2011).

C. Magnetic anomaly

A magnetic anomaly is a local variation in the magnetic field relative to an expected average or regional level. It reflects the existence of a magnetic contrast in the subsurface or near the surface. This anomaly can be positive when the measured value is above the reference level, or negative when it is below this level (Blakely, 1995; Telford, Geldart & Sheriff, 1990).

D. Magnetic survey

Magnetic sampling, or magnetic surveying, is a geophysical prospecting method that involves measuring the magnetic field at several points on a site. These measurements can be taken along profiles, a regular grid, or at stations distributed according to site constraints. The objective is to highlight spatial variations in the magnetic field and identify anomalies that may be related to the subsoil or objects present in the terrain (Kearey, Brooks & Hill, 2002; Reynolds, 2011).

E. Magnetic disturbance

A magnetic disturbance refers to any local change in the measured magnetic field compared to its normal or expected behavior. It can be of natural, anthropogenic, or instrumental origin. A natural disturbance may be related to the presence of magnetic rocks, ferromagnesian minerals, iron oxides, or specific geological structures. An anthropogenic disturbance may originate from metallic objects, fences, vehicles, pipes, cables, sheet metal, ferrous waste, or old infrastructure. An instrumental disturbance may be related to improper handling of the instrument, measurement instability, or a temporary external influence (Telford, Geldart & Sheriff, 1990; Reynolds, 2011).

3. Results and analyses

This section presents all the results obtained during the magnetic survey campaign conducted in the Passager district. Analysis of the measured data allows us to characterize the magnetic behavior of the site and identify anomalies that may reveal subsurface heterogeneities or buried man-made structures. The raw data are described, analyzed, and interpreted here to meet the established objectives.

A. Total number of stations measured

The magnetic survey was conducted using a 10 m × 10 m grid, with north-south oriented profiles. Based on the perimeter defined during the initial site survey, the initial acquisition plan anticipated a total of 400 theoretical stations. However, due to constraints encountered in the field, only 181 stations could actually be measured, representing a completion rate of 45%.

This coverage rate, although limited, is nevertheless sufficient for a preliminary magnetic characterization of the site.

Setting	Value
Number of planned theoretical stations	400
Number of stations actually measured	181
Completion rate	45%
Stations not measured	219
Theoretical area covered	~4.0 ha
Area actually surveyed	~1.8 ha
Average point density	1 point / 100 m²

General terms and conditions of purchase

A. Date and duration of the campaign

The field measurements were carried out over a period of four hours, between 1:04 PM and 5:18 PM. The campaign took place over a single day due to the limited availability of the ACZ-8 proton magnetometer, as this equipment was rented.

B. Meteorological and geomagnetic conditions

The measurement campaign carried out on August 12, 2025, took place under weather conditions generally favorable for the acquisition of magnetic data. The measurement period, between 1:00 p.m. and 5:00 p.m. (Kinshasa local time), corresponded to the main dry season, characterized by hot and relatively stable weather.

C. Team and work organization

The field team consisted of two people:

- The main operator, responsible for positioning the magnetometer, triggering measurements and recording the displayed values.
- The assistant, in charge of GPS navigation, marking out stations using the decameter and taking notes in the field notebook.

Constraints encountered during the acquisition

Several constraints affected the progress of the measurement campaign and explain the difference between the number of stations planned and the number of stations actually measured.

A. Time constraint

The limited availability of the ACZ-8 proton magnetometer for a single day was the most significant constraint. The approaching nightfall, combined with the terrain and the area to be covered, prevented access to the entire planned site. This premature interruption limited the number of accessible stations in the southern part of the study area.

B. Built-up areas

A significant portion of the site was occupied by existing buildings (houses, sheds, outbuildings) or enclosed by impassable private fences. These areas were bypassed, resulting in gaps in the measurement grid coverage. Stations located within these plots could not be installed, both due to accessibility issues and to respect property rights.

C. Vegetation cover

Some areas of the site had dense vegetation, including clumps of tall grass, brush, and trees whose canopy hindered the team's progress and made precise sensor placement difficult. These areas were partially avoided or crossed at irregular intervals, which reduced the number of stations in these sectors.

4. Spatial distribution of measurement points

The distribution of the 181 measured stations is not perfectly uniform across the entire site. It reflects both the geometry of the study area and the accessibility constraints described previously.

A. General configuration

The stations are distributed along north-south oriented profiles, with a spacing of 10 meters between points on the same profile and a spacing of 10 meters between adjacent profiles. This orthogonal grid configuration allows for homogeneous coverage in accessible areas and facilitates spatial interpolation of the data.

B. Well-covered sectors

The northern and western parts of the site are the best covered. These areas, characterized by sparse vegetation and less dense land cover, allowed for the implementation of most of the planned north-south profiles. The 10 m × 10 my grid is satisfactorily respected.

C. Partially covered areas

The central part of the site has a more discontinuous cover due to the presence of existing buildings and material storage areas. Some stations had to be relocated or omitted, creating occasional gaps in the grid.

D. Areas with little or no coverage

The southern and southeastern parts of the perimeter were only partially surveyed due to the premature termination of the campaign and the presence of private buildings. These areas constitute blind spots where no magnetic data is available. Interpretation in these areas relies solely on extrapolating data from surrounding stations, which introduces increased uncertainty.

Summary table of measures

The table below presents a representative extract of all the acquired data. The stations are identified by a sequential number, accompanied by their UTM coordinates (East and North), altitude, measured value of the total magnetic field ($F_{mesuré}$) in nanotesla, magnetic anomaly (ΔF) calculated with respect to the IGRF model, and qualitative field observations.

Table 1: Magnetic prospecting data

No.	Line	Station	X (m)	Y (m)	Altitude (m)	F_measured (nT)	F_IGRF (nT)	ΔF (nT)	Observations
1	1	1	558755	9510100	534.9776	31852.0255	32235	-382.9745	
2	1	2	558764	9510100	536.7288	32898.629	32235	663.629	
3	1	3	558774	9510100	538.6746	31997.3595	32235	-237.6405	
4	1	4	558783	9510100	540.4258	33072.125	32235	837.125	
5	1	5	558789	9510100	541.5933	33904.5275	32235	1669.5275	
6	1	6	558798	9510100	543.3445	33343.371	32235	1108.371	
7	1	7	558811	9510100	544.7084	33379.367	32235	1144.367	
8	1	8	558820	9510100	545.3694	31710.0975	32235	-524.9025	
9	1	9	558835	9510100	546.9495	31651.8635	32235	-583.1365	
10	1	10	558845	9510100	547.2057	32243.3085	32235	8.3085	
11	1	11	558854	9510100	547.8668	32746.1095	32235	511.1095	
12	1	12	558863	9510100	548,528	31879.0605	32235	-355.9395	
13	1	13	558869	9510100	548.9688	31297.039	32235	-937.961	

14	1	14	558882	9510100	549,924	33629.5235	32235	1394.5235	
15	1	15	558891	9510100	550.5853	32303.9295	32235	68.9295	
16	1	16	558900	9510100	550.0197	31768.8535	32235	-466.1465	
17	1	17	558909	9510100	548.89	32630.8615	32235	395.8615	
18	1	18	558918	9510100	547.7602	33176.875	32235	941.875	
19	1	19	558928	9510100	546,505	32659.787	32235	424.787	
20	1	20	558940	9510100	544.9988	32751.123	32235	516.123	
21	1	21	558946	9510100	544.2458	30609.916	32235	-1625.084	
22	2	1	558944	9510110	543.7247	35665.8125	32235	3430.8125	
23	2	2	558934	9510110	544.9077	32881.324	32235	646.324	
24	2	3	558914	9510110	547.3721	32160.5	32235	-74.5	
25	2	4	558906	9510110	548.0528	33289.164	32235	1054.164	
26	2	5	558897	9510111	549.0026	32438.0215	32235	203.0215	
27	2	6	558887	9510110	549.1004	34109.633	32235	1874.633	
28	2	7	558875	9510110	548.0401	33092.332	32235	857.332	
29	2	8	558866	9510110	547.3472	33147.0155	32235	912.0155	
30	2	9	558854	9510110	546.4233	34542.7655	32235	2307.7655	
31	2	10	558848	9510110	546.0326	30406.953	32235	-1828.047	
32	2	11	558841	9510110	545.4225	33864.7615	32235	1629.7615	
33	2	12	558826	9510110	544.2679	32992.504	32235	757.504	
34	2	13	558817	9510110	543.5752	31261.955	32235	-973.045	
35	2	14	558811	9510110	543.1134	32309.4395	32235	74.4395	
36	2	15	558798	9510110	541.7148	32180.0215	32235	-54.9785	
37	2	16	558786	9510110	539.3798	30304.6565	32235	-1930.3435	
38	2	17	558777	9510110	537.6286	32372.1525	32235	137.1525	
39	2	18	558768	9510110	535.8774	33304.879	32235	1069.879	
40	2	19	558755	9510110	533.3478	32550.033	32235	315.033	
41	2	20	558747	9510110	531.7573	32471.6875	32235	236.6875	
42	3	1	558755	9510120	531.7181	31135.33	32235	-1099.67	
43	3	2	558764	9510120	533.4693	35398.379	32235	3163.379	
44	3	3	558777	9510120	535.9988	32343.658	32235	108,658	
45	3	4	558783	9510120	537.1663	34982.8635	32235	2747.8635	
46	3	5	558795	9510120	539.5013	33355.3085	32235	1120.3085	
47	3	6	558804	9510120	540.9549	33338.0625	32235	1103.0625	
48	3	7	558811	9510120	541.5183	33348.1055	32235	1113.1055	
49	3	8	558823	9510120	542.4842	33766.5315	32235	1531.5315	
50	3	9	558832	9510120	543.2087	33057.3085	32235	822.3085	
51	3	10	558845	9510119	544.3548	31609.631	32235	-625,369	
52	3	11	558854	9510120	544.9797	33923.3985	32235	1688.3985	
53	3	12	558863	9510120	545.7043	34826.617	32235	2591.617	
54	3	13	558875	9510120	546.6705	34623.301	32235	2388.301	
55	3	14	558885	9510120	547.4756	31903.3495	32235	-331.6505	
56	3	15	558894	9510120	548.1707	32950.2385	32235	715.2385	
57	3	16	558906	9510120	546.7771	33339.574	32235	1104.574	
58	3	17	558915	9510120	545.7319	32087.4475	32235	-147.5525	
59	3	18	558925	9510120	544.5706	31318.9315	32235	-916.0685	
60	3	19	558934	9510120	543.5255	32582.2285	32235	347.2285	
61	3	20	558943	9510120	542.4805	32179.25	32235	-55.75	
62	4	1	558965	9510130	538.9584	31035.504	32235	-1199.496	
63	4	2	558956	9510130	539.9611	33135.4765	32235	900.4765	
64	4	3	558946	9510130	541.0752	31959.8575	32235	-275.1425	
65	4	4	558937	9510130	542.0779	31710.115	32235	-524.885	
66	4	5	558925	9510130	543.415	33289.168	32235	1054.168	

67	4	6	558915	9510130	544,931	33952.41	32235	1717.41	
68	4	7	558909	9510130	545.198	32879.285	32235	644,285	
69	4	8	558900	9510130	546.2009	31804.135	32235	-430.865	
70	4	9	558888	9510130	546.3933	31804.135	32235	-430.865	
71	4	10	558874	9510130	545.66	32708.658	32235	473,658	
72	4	11	558863	9510130	544.2924	33702.4805	32235	1467.4805	
73	4	12	558854	9510130	543.5361	32258.1505	32235	23.1505	
74	4	13	558845	9510130	542.7798	32517.961	32235	282,961	
75	4	14	558835	9510130	541.9396	31123.576	32235	-1111.424	
76	4	15	558826	9510130	541.1834	31087.344	32235	-1147.656	
77	4	16	558817	9510130	540.4273	31945.467	32235	-289,533	
78	4	17	558808	9510130	539.6712	33251.5315	32235	1016.5315	
79	4	18	558795	9510130	537.8715	31991.699	32235	-243.301	
80	4	19	558786	9510130	536.1203	31360.592	32235	-874.408	
81	4	20	558777	9510130	534.3691	30172.6935	32235	-2062.3065	
82	5	1	558755	9510140	528.7119	29814.076	32235	-2420.924	
83	5	2	558764	9510140	530.4669	31642.8165	32235	-592.1835	
84	5	3	558774	9510140	532.4169	32964.7305	32235	729.7305	
85	5	4	558786	9510140	534,757	33871.5315	32235	1636.5315	
86	5	5	558792	9510140	535.9269	35228.703	32235	2993.703	
87	5	6	558801	9510140	537,682	34053.414	32235	1818.414	
88	5	7	558814	9510140	538.8177	34050.3205	32235	1815.3205	
89	5	8	558826	9510140	539.8242	34289.84	32235	2054.84	
90	5	9	558835	9510140	540.5789	32847.4065	32235	612.4065	
91	5	10	558842	9510140	541.166	32623.002	32235	388.002	
92	5	11	558854	9510140	542.1721	32568.7735	32235	333.7735	
93	5	12	558863	9510140	542.9266	33476.8945	32235	1241.8945	
94	5	13	558875	9510140	543.9324	34087.801	32235	1852.801	
95	5	14	558885	9510140	544.7706	33001.496	32235	766.496	
96	5	15	558894	9510140	545.4987	31868.086	32235	-366.914	
97	5	16	558903	9510140	544,538	32356.4005	32235	121.4005	
98	5	17	558915	9510140	543.2569	32745.047	32235	510.047	
99	5	18	558925	9510140	542.5934	31373.043	32235	-861,957	
100	5	19	558937	9510140	540.9084	33336.34	32235	1101.34	
101	5	20	558946	9510140	539.9478	33914.965	32235	1679.965	
102	6	1	558965	9510149	536.8648	31451.746	32235	-783.254	
103	6	2	558956	9510150	537.6533	31621.828	32235	-613.172	
104	6	3	558946	9510150	538.6736	34413.496	32235	2178.496	
105	6	4	558934	9510150	539.8981	31884.955	32235	-350.045	
106	6	5	558928	9510150	540.5104	34456.332	32235	2221.332	
107	6	6	558919	9510150	541.4289	31421.4825	32235	-813.5175	
108	6	7	558906	9510150	542.7557	33183.4845	32235	948.4845	
109	6	8	558897	9510150	543.6741	34078.6915	32235	1843.6915	
110	6	9	558885	9510150	543.3231	32304.5545	32235	69.5545	
111	6	10	558875	9510150	542.8578	32586.0645	32235	351.0645	
112	6	11	558866	9510160	540.5955	33588.996	32235	1353.996	
113	6	12	558857	9510150	541.2062	33536.094	32235	1301.094	
114	6	13	558844	9510150	540.653	32973.8165	32235	738.8165	
115	6	14	558836	9510150	539.9026	32797.617	32235	562.617	
116	6	15	558826	9510150	538.8616	32687.539	32235	452,539	
117	6	16	558814	9510150	538.3298	31795.674	32235	-439,326	
118	6	17	558804	9510150	537.4932	34854.8045	32235	2619.8045	
119	6	18	558795	9510150	535.7431	34269.293	32235	2034.293	

120	6	19	558789	9510150	534,566	35153.047	32235	2918.047	
121	6	20	558777	9510150	532.212	32358.047	32235	123,047	
122	7	1	558755	9510160	527.0803	31097.0315	32235	-1137.9685	
123	7	2	558764	9510160	528.8564	34021.4025	32235	1786.4025	
124	7	3	558777	9510160	531.422	33313.047	32235	1078.047	
125	7	4	558795	9510160	534.9743	32482.162	32235	247.162	
126	7	5	558808	9510160	536.6852	31766.707	32235	-468.293	
127	7	6	558820	9510160	537.4946	32728.082	32235	493.082	
128	7	7	558829	9510160	538.1014	33058.7815	32235	823.7815	
129	7	8	558838	9510160	538.7083	33139.0235	32235	904.0235	
130	7	9	558851	9510160	539.5846	31532.34	32235	-702.66	
131	7	10	558860	9510160	540.1912	34186.8865	32235	1951.8865	
132	7	11	558865	9510150	542.2832	36476.164	32235	4241.164	
133	7	12	558878	9510160	541.4041	33744.0155	32235	1509.0155	
134	7	13	558888	9510160	542.0778	32667.25	32235	432.25	
135	7	14	558897	9510160	542.1697	34849.324	32235	2614.324	
136	7	15	558906	9510160	541.2935	34538.293	32235	2303.293	
137	7	16	558915	9510160	540.4173	34476.4765	32235	2241.4765	
138	7	17	558928	9510160	539.1516	31258.0275	32235	-976.9725	
139	7	18	558937	9510160	538.2755	32455.3885	32235	220.3885	
140	7	19	558946	9510160	537.3994	33831.301	32235	1596.301	
141	7	20	558959	9510160	536.134	32635.4275	32235	400.4275	
142	8	1	558965	9510170	534.3649	31848.4435	32235	-386.5565	
143	8	2	558956	9510170	535.1986	32775.8555	32235	540.8555	
144	8	3	558946	9510170	536.125	34289.0155	32235	2054.0155	
145	8	4	558934	9510170	537.2368	32099.5995	32235	-135.4005	
146	8	5	558922	9510170	538.3487	31783.5685	32235	-451.4315	
147	8	6	558912	9510170	539.2753	31710.115	32235	-524.885	
148	8	7	558900	9510170	540.3873	34273.2265	32235	2038.2265	
149	8	8	558894	9510170	540.9433	33792.2655	32235	1557.2655	
150	8	9	558882	9510170	540,251	33552.926	32235	1317.926	
151	8	10	558872	9510170	539.6594	33441.3865	32235	1206.3865	
152	8	11	558863	9510170	539.1269	34172.199	32235	1937.199	
153	8	12	558851	9510170	538.4167	33848.6055	32235	1613.6055	
154	8	13	558842	9510170	537,884	33564.043	32235	1329.043	
155	8	14	558835	9510170	537.4697	35134.922	32235	2899.922	
156	8	15	558823	9510170	536.7592	32147.049	32235	-87.951	
157	8	16	558814	9510170	536.2262	31878.3595	32235	-356.6405	
158	8	17	558804	9510170	535.6339	32101.508	32235	-133,492	
159	8	18	558792	9510170	533.6099	32553.1055	32235	318.1055	
160	8	19	558784	9510170	532.4864	31522.426	32235	-712.574	
161	8	20	558774	9510170	530.6191	31737.6055	32235	-497.3945	
162	9	1	558755	9510180	525.4487	28035.7345	32235	-4199.2655	
163	9	2	558768	9510180	528.0447	31339.5705	32235	-895.4295	
164	9	3	558774	9510180	529.2429	30962.0195	32235	-1272.9805	
165	9	4	558786	9510180	531.6392	31967.703	32235	-267,297	
166	9	5	558792	9510180	532.8375	30658.2775	32235	-1576.7225	
167	9	6	558804	9510180	534.8525	32242.92	32235	7.92	
168	9	7	558814	9510180	535.3626	31710.664	32235	-524.336	
169	9	8	558826	9510180	535.9746	32401.207	32235	166.207	
170	9	9	558838	9510180	536.5864	32405.674	32235	170,674	
171	9	10	558848	9510180	537.0962	31832.84	32235	-402.16	
172	9	11	558854	9510180	537.402	32624.6975	32235	389.6975	

173	9	12	558866	9510180	538.0134	33814.8085	32235	1579.8085	
174	9	13	558875	9510180	538.5358	32346.5255	32235	111.5255	
175	9	14	558882	9510180	538.8285	32716.8045	32235	481.8045	
176	9	15	558894	9510180	539.4247	31663.535	32235	-571,465	
177	9	16	558906	9510180	538.3691	30689.4335	32235	-1545.5665	
178	9	17	558919	9510180	537.2255	32715.627	32235	480.627	
179	9	18	558925	9510180	536.6977	34626.3475	32235	2391.3475	
180	9	19	558931	9510180	536.1699	33723.203	32235	1488.203	
181	9	20	558943	9510180	535.1144	32106.1775	32235	-128.8225	

Note: X and Y coordinates are expressed in meters in the UTM projection system (Zone 33S). The magnetic anomaly ΔF is calculated relative to the theoretical value of the principal field from the IGRF (International Geomagnetic Reference Field) model.

The 181 stations together form the database used for mapping and interpreting magnetic anomalies. The complete file, including all measurements and observations, is available in the appendix to this report.

5. Map showing the location of magnetic stations

A. Map presentation

The magnetic station location map (Figure 4.1) shows the spatial distribution of the 181 measurement points on the Passager district site. It was created using the UTM coordinates (Zone 33S) of the stations, georeferenced using the Garmin GPSMAP 64CSx GPS receiver. The map includes:

- The measurement points are symbolized by red circles.
- The measurement profiles are oriented west-east, represented by blue lines.
- A graphic scale, an arrow indicating geographic north, and UTM coordinates in the margin.
- A legend specifying the symbols used.

This map allows visualization of the density and distribution of stations on the site, as well as the areas where acquisition was possible or limited.

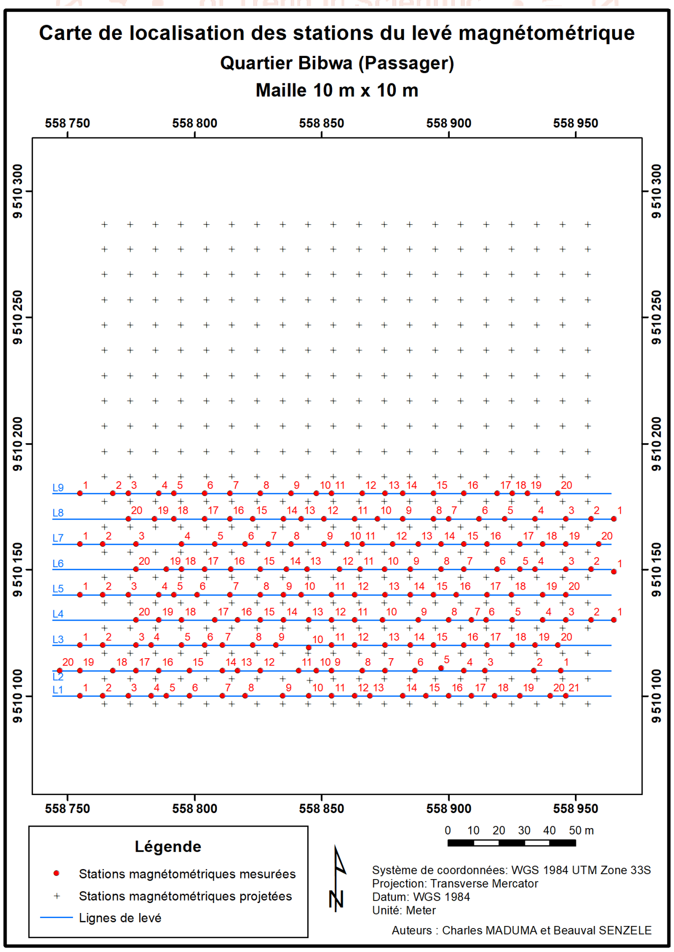


Figure 1: Location map of stations and magnetometer profiles – Passenger District

B. Areas covered and areas not covered (with justification)

The location map clearly distinguishes between two types of zones:

a. Areas covered (181 stations)

The areas covered correspond to the sectors where stations have been successfully installed. They are located primarily in the following part of the site:

- **Southern sector:** Coverage is satisfactory in this area, although some gaps are observed near houses and areas of dense vegetation. Stations are distributed along east-west profiles with regular spacing.

b. Areas not covered (219 stations)

The uncovered areas correspond to sectors where measurements could not be taken at the stations. They are mainly located in:

- **Northern sector:** This part of the site was only partially covered due to the premature interruption of measurements (approaching nightfall). The stations planned for this area did not

6. Statistical analysis of magnetic field intensity data

The statistical analysis was performed using the magnetic prospecting data presented in Table 1. The measurements include the measured magnetic field intensity ($F_{\text{mesuré}}$), the reference field (F_{IGRF}) and the magnetic anomaly (ΔF).

In this work, the statistical and cartographic interpretation focuses mainly on the values of the magnetic anomaly (ΔF), as they allow us to highlight the local variations of the magnetic field after subtraction of the regional reference field.

The magnetic anomaly is given by the following relationship:

$$\Delta F = F_{\text{mesuré}} - F_{\text{IGRF}}$$

In the table, the value of the reference field is constant:

$$F_{\text{IGRF}} = 32235 \text{ nT}$$

In total, 181 measurement stations were analyzed, spread across 9 prospecting lines.

A. Central characteristics of magnetic values

The basic statistical parameters calculated from the data are presented in the following table.

Table 2: Statistical parameters of magnetic data

Setting	(Fmesuré) in nT	ΔF in nT
Number of measurements	181	181
Minimum value	28,035.73	-4,199.27
Maximum value	36,476.16	4,241.16
Arithmetic mean	32,747.02	512.02
Amplitude of variations	8,440.43	8,440.43
Standard deviation	1,224.38	1,224.38
Variance	1,499,104.40	1,499,104.40

The minimum value of the magnetic anomaly is:

$$\Delta F_{\min} = -4199{,}27 \text{ nT}$$

It was observed on line 9, station 1, at the following coordinates:

X = 558755 m, Y = 9510180 m

The maximum value is:

$$\Delta F_{\max} = 4241{,}16 \text{ nT}$$

It was observed on line 7, station 11 at the following coordinates:

$$X = 558865 \text{ m}, \quad Y = 9510150 \text{ m}$$

The average of the magnetic anomalies is positive:

$$\overline{\Delta F} = 512{,}02 \text{ nT}$$

This positive average indicates that, overall, the measured values are slightly higher than the IGRF reference magnetic field. This reflects a general trend towards positive anomalies over a significant portion of the studied site.

Measures of dispersion: standard deviation and magnitude

The magnitude of the variations is calculated by:

$$A = \Delta F_{\max} - \Delta F_{\min}$$

A = 4241.16 - (-4199.27)

$A - 8440{,}43\ nT$

This high amplitude indicates that the magnetic field varies significantly within the studied site. Therefore, the values are not uniform across the entire Passenger Quarter.

The standard deviation obtained is:

$$s = 1224{,}38\ nT$$

This value is also high. It indicates a large dispersion of measurements around the average. In other words, several stations show values very far from the average value, either in the form of negative or positive anomalies.

The wide dispersion may be linked to several factors:

- variations of the subsoil;
- presence of ferruginous materials;
- presence of buried metallic objects;
- soil heterogeneity;
- influence of embankments or previous human activities;
- variations in magnetic susceptibility.

Statistical distribution of magnetic anomalies

To analyze the distribution of values, the magnetic anomalies were grouped into classes. These classes allow for the construction of a frequency histogram and the preparation of thematic mapping of magnetic intensities.

Table 3: Statistical distribution of magnetic anomalies

Class of (ΔF) in nT	Equivalent class of (Fmesuré) in nT	Effective	Frequency (%)	Interpretation
ΔF < -3000	F < 29235	1	0.55%	Very strong negative anomaly
-3000 ≤ ΔF < -2000	29235 to 30235	2	1.10%	Strong negative anomaly
-2000 ≤ ΔF < -1000	30235 to 31235	11	6.08%	Medium to strong negative anomaly
-1000 ≤ ΔF < 0	31235 to 32235	48	26.52%	Weak to moderate negative anomaly
0 ≤ ΔF < 1000	32235 to 33235	57	31.49%	Weak to moderate positive anomaly
1000 ≤ ΔF < 2000	33235 to 34235	41	22.65%	Strong positive anomaly
2000 ≤ ΔF < 3000	34235 to 35235	18	9.94%	Very strong positive anomaly
ΔF ≥ 3000	(F ≥ 35235)	3	1.66%	Exceptional positive anomaly
Total	—	181	100%	—

The histogram obtained from these classes would show a significant concentration of values between:

$$-1000\ nT \leq \Delta F < 2000\ nT$$

Indeed, the classes between -1000 nT and 2000 nT include:

48 + 57 + 41 = 146 measurements

that is approximately:

80.66%

data.

The most represented class is that of weak to moderate positive anomalies:

0 ≤ ΔF < 1000 nT

with 57 stations, representing 31.49% of the measurements. This shows that a large part of the site has values slightly above the reference range.

The negative anomalies represent:

$$62 \text{ stations}$$

either:

$$34.25\%$$

measures.

Positive anomalies represent:

$$119 \text{ stations}$$

either:

$$65.75\%$$

measures.

The distribution is therefore dominated by positive anomalies, although some very marked negative anomalies are observed locally.

Variation of anomalies according to prospecting lines
Line analysis allows us to observe the average spatial variation of the magnetic field over the site.

Table 5: Average magnetic anomalies per line

Line	Number of stations	ΔFmin in nT	ΔFmax in nT	Average ΔF in nT	Amplitude in nT
Line 1	21	-1,625.08	1,669.53	217.65	3,294.61
Line 2	20	-1,930.34	3,430.81	532.28	5,361.16
Line 3	20	-1,099.67	3,163.38	868.48	4,263.05
Line 4	20	-2,062.31	1,717.41	-50.49	3,779.72
Line 5	20	-2,420.92	2,993.70	770.73	5,414.63
Line 6	20	-813.52	2,918.05	835.88	3,731.56
Line 7	20	-1,137.97	4,241.16	977.86	5,379.13
Line 8	20	-712.57	2,899.92	676.31	3,612.50
Line 9	20	-4,199.27	2,391.35	-205.81	6,590.61

Lines 3, 5, 6, 7, and 8 have relatively high positive averages. Line 7 has the highest average:

$$\overline{\Delta F}_{L7} = 977{,}86 \text{ nT}$$

It also contains the maximum value of all prospecting:

$$\Delta F - 4241{,}16\, nT$$

Line 9 has the lowest average:

$$\overline{\Delta F}_{L9} = -205{,}81 \text{ nT}$$

It also contains the most significant negative anomaly:

$$\Delta F = -4199{,}27\, nT$$

This indicates that the most contrasting variations are found particularly on lines 7 and 9.

Measures of dispersion: standard deviation and magnitude of variations
These indicators quantify the dispersion of values around the mean and the total range of variations.

Painting6 Dispersion indicators

Setting	Fmesuré (nT)	ΔF (nT)
Amplitude (Max – Min)	8,440.43	8,440.43
Standard deviation(s)	1,224.38	1,224.38

Interpretation:
The amplitude of 8,440.43 nT reveals a very strong magnetic heterogeneity at the site, with a considerable difference between the lowest (28,035.73 nT) and highest (36,476.16 nT) values. The standard deviation of

1,224.38 nT reflects a very high dispersion of measurements around the mean, indicating the presence of highly contrasting local magnetic sources, potentially associated with lithological variations, magnetized geological structures, or anthropogenic disturbances (infrastructure, embankments).

Main statistics from the table

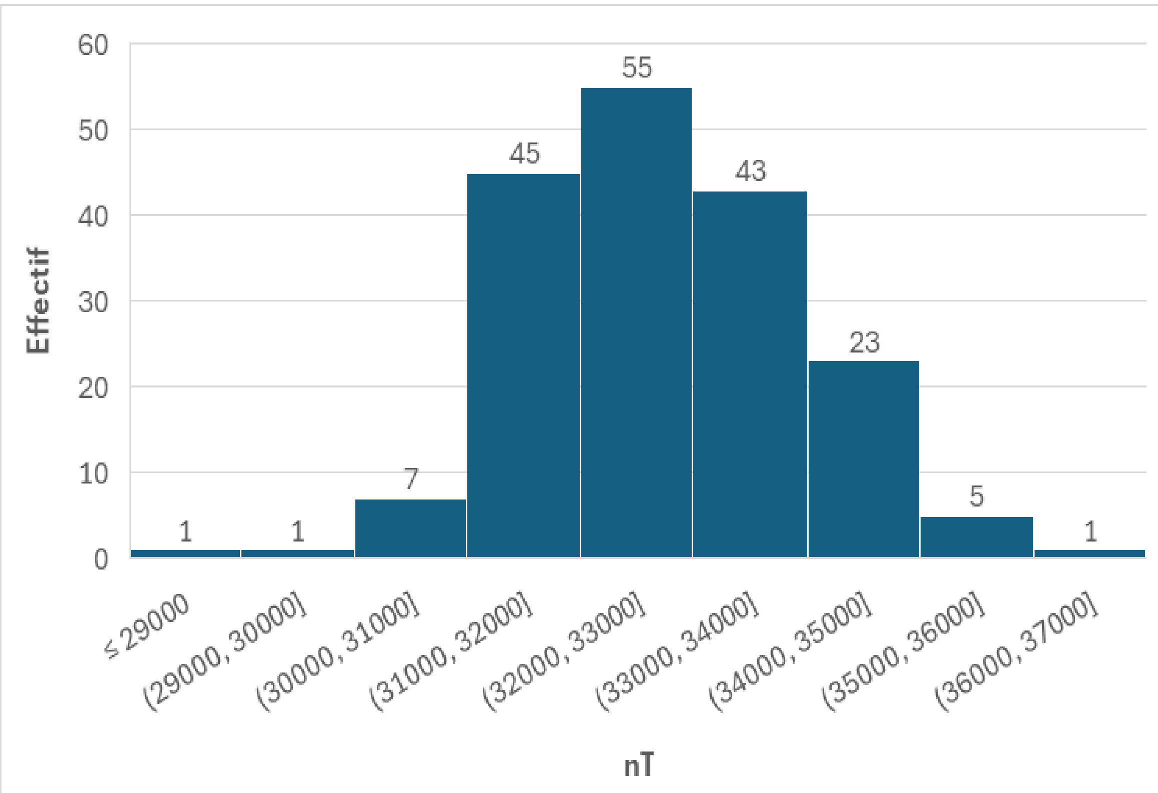
Indicator	Value
Modal class	[32,000 – 33,000 [(55 obs., 30.39%)
Estimated mode	≈ 32,500 nT (midpoint of the modal class)
Estimated average	≈ 32,733 nT (by class centers)
Estimated median	≈ 32,673 nT (91st value → class [32,000 – 33,000[)
F_IGRF	32,235 nT

The estimated average (~32,733 nT) is slightly higher than F_IGRF (32,235 nT), indicating a slight average magnetic excess relative to the theoretical field.

Interpretation

A. Shape of the distribution

The distribution is unimodal and relatively symmetric, centered around the class [32,000 – 33,000[.



B. Data concentration

- 79.01% of the measurements are between 31,000 and 34,000 nT (3 central classes: 45 + 55 + 43 = 143 measurements)
- 60.22% of the measurements are below 33,000 nT
- Only 3.31% of measurements exceed 35,000 nT (values potentially associated with positive magnetic anomalies)
- Only 4.97% of the measurements are below 31,000 nT (values associated with negative magnetic anomalies)

C. Asymmetry

The distribution shows a slight positive skew (tail towards higher values):

- to the left of the modal class: 45 + 7 + 1 + 1 = 54 observations (29.83%)
- To the right of the modal class: 43 + 23 + 5 + 1 = 72 observations (39.78%)

This means that positive magnetic anomalies (excess field) are more frequent and more pronounced than negative anomalies.

D. Geophysical implications

Observation	Possible interpretation
High concentration between 31,000 and 34,000 nT	Relatively homogeneous regional magnetic field
Values > 35,000 nT (positive anomalies)	Presence of magnetized rocks (intrusions, ferromagnetic mineralizations)
Values < 30,000 nT (negative anomalies)	Demagnetization zones, faults, alterations, or low-susceptibility structures
High range (~8,440 nT)	Significant magnetic contrast in the study area
Average slightly > F_IGRF	Positive anomalies predominated throughout the survey.

Conclusion

Statistical analysis reveals marked spatial magnetic heterogeneity at the Passager district site, with high dispersion and contrasting local anomalies. The established classification provides a solid foundation for the next step: mapping the intensity and anomalies of the magnetic field, which will allow for the spatial representation of these variations and the interpretation of their geotechnical and environmental significance.

Analysis of ΔF variations reveals a magnetically contrasting subsoil, dominated by an average excess of +498 nT compared to the IGRF background. While the majority of stations (58%) reflect a homogeneous local background, the extreme anomalies — notably stations 7.11 (+4241 nT) and 9.1 (-4199 nT) — constitute the priority targets for interpretation, to be correlated with the geological and anthropogenic context of the Passager district.

Thus, the spatial distribution of these anomalies will now be examined through the thematic map and magnetic profiles.

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