



Measurement of Magnetic Intensity Using Three Different Sensor Levels and Three Vertical Gradient Determinations to Detect Subsurface Engineering Utilities.

Ahmad S. Al-Banna ^{1*} , Hayder H. Majeed ² , Fitian R. Al- Rawi ¹ , Tariq Safa Aldin ¹ 

geobanna1955@yahoo.com

haidargeo38@gmail.com

drfitian@yahoo.com

triqsaaldan@yahoo.com

¹ Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.

² Directorate General of Education, Diyala, Ministry of Education.

* Correspondence author.

Received: 31 July 2025

Received in revised form: 01 September 2025

Accepted: 16 November 2025

Available online: 01 October 2026

Abstract

Total Magnetic Intensity (TMI) is measured in southern Baghdad at a site located at the University of Baghdad. These measurements are used to investigate the best sensor levels and the suitable vertical gradients to detect subsurface engineering utilities. The measurement is achieved along three E-W parallel profiles. The length of each profile is 28 meters. The spacing distance between stations for the western half (0-14 meters) of the profile is two meters, while it is one meter for the eastern half (14-28 m). The magnetic measurements were carried out using three sensor levels, these are (2.44 m, 1.83 m, and 1.22 m, to determine the best height suitable for investigating shallow subsurface buried objects. Three vertical magnetic gradient values are determined for each station from the three-level magnetic measurements. This study concludes that the sensor height (1.22m) is better than the others in detecting the shallow sources. The three vertical magnetic gradient profiles coincide in detecting the subsurface sources. The vertical gradient results are better than the relatively high sensor-level measurements. The vertical gradient also seems not to be affected by the spacing distance between stations, as the total magnetic intensity measurements.

Keywords:

Magnetic, Vertical gradient, Sensor height, Engineering utilities, Baghdad.

DOI: [10.33899/injes.v26i4.60971](https://doi.org/10.33899/injes.v26i4.60971), ©Authors, 2026, College of Science, University of Mosul.

This is an open-access article under the CC BY 4.0 license (<http://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Since the beginning of geophysical prospecting, the magnetic method has been applied. At first time, it was used in mining prospecting, especially in searching for Iron ores; then it was used in petroleum exploration (Nettleton, 1971). The theory of the magnetic method is described in many references (e.g., Grant and West, 1965; Kaufman et al., 2008; Hinze et al., 2013). The percentage of ferromagnetic minerals, mainly magnetite, within the rocks is the main effective factor in the magnetic method (Dobrin and Saviet, 1988). With the development of aeromagnetic survey at twentieth century, the magnetic method became widely used to

explore the basement rock depth, igneous intrusions, faults, shallow and deep geological features, including mineralization zones (Nettleton, 1971;

Sharma, 2012; Hinze et al., 2013; Al-Banna and Al-Khishef, 2019; Al-Hadithi and Al-Banna, 2022; Abdelrady et al., 2023).

The magnetic method application in shallow surveys includes waste sites, underground storage tanks, drums, buried pipes, archaeology, and groundwater investigation (Breiner, 1973; Tyagi et al., 1983; Emerson et al., 1992; Marco et al., 2002; Burger et al., 2006; Schmidt, 2007;

Canbay et al., 2010; Morsy and Rashed, 2013; Moskowitz et al., 2015; Oni et al., 2020; Alao et al., 2024).

The shallow underground engineering utility includes pipelines, cables, wires, and subsurface concrete engineering utilities. The underground utilities investigation is important to detect the exact location before excavation for additional construction (Lanka et al., 2001). Resistivity, ground-penetrating radar, gravity, and magnetic methods were applied to detect

subsurface utilities (Al-Saady et al., 2022; Al-Mahemmdi et al., 2023).

This study attempts to assess the ability of the three determined vertical magnetic gradients to detect subsurface engineering utilities at a small site at the University of Baghdad. It also attempts to find out the best height of the magnetic sensor to explore shallow engineering targets.

2. Materials and methods

A. Location and description of the studied site

The study site is located on a pedestrian walkway in front of the Geology Department at the University of Baghdad (Jadiriya). The coordinates of the base station are latitude ($33^{\circ} 16' 16''$ N) and longitude ($44^{\circ} 22' 46''$ E) (Fig. 1).

The studied site represents a long, horizontal, and flat concrete pedestrian walkway with a width of 4.3 meters. This concrete walkway covers alluvial sediments, which are part of the sediments of the Tigris River basin. The walkway trends in an east-west direction. Beneath the study site, there are many subsurface engineering utilities, including electrical cables, pipes, and a concrete irrigation canal, which is open to the surface outside the walkway (Fig. 2). The depth of the considered objects is within the upper 2.0 meters from the earth surface.

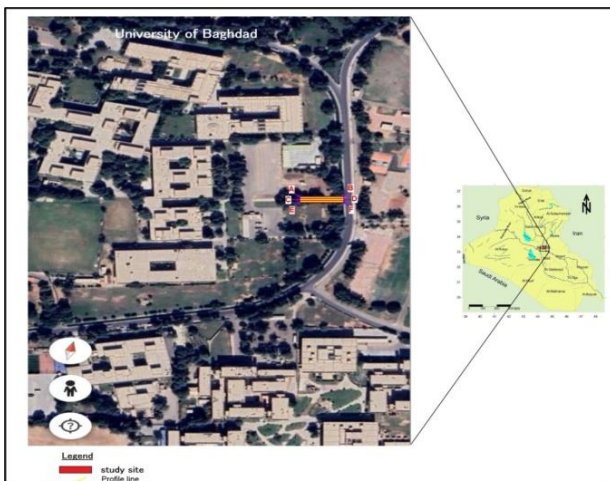


Fig.1: Location of the study site

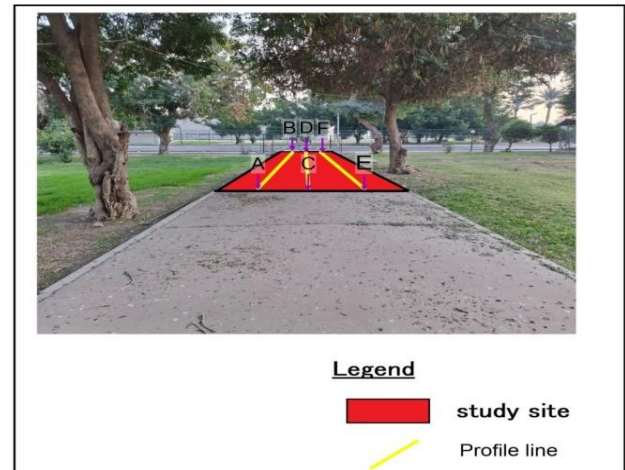


Fig. 2: Engineering utilities including electrical cables, pipes, and concrete irrigation canal under study area; the considered profiles are in yellow color.

B. Data acquisition

Three parallel profiles are established at the end of the pedestrian walkway, on its eastern side near the ring road in Baghdad University campus. The total magnetic intensity measurement is achieved using a portable proton magnetometer G-816 with an accuracy of 1 nT (Breiner, 1973) (Fig. 3). The length of each profile is 28 meters. CD profile passes through the center of the walkway, dividing it into northern and southern parts. Profile AB is one meter apart from the central profile, one meter toward the north. Profile EF is one meter from the central profile toward the south. Each profile includes twenty-two measurement stations. The spacing distance at the western side of the profiles (0-14 meters) is two meters, while at the eastern side (14- 28 meters), the profile spacing is one meter (Fig. 4). Station number eleven in profile CD (central profile) is considered as basestation.

The magnetic measurement is carried out by starting from the base station, then measuring many stations and reoccupying the base station again at an interval of 5 minutes. The magnetic measurements are achieved with three levels: 2.44 m, 1.83 m, and 1.22 meters for each station. The accuracy of measurement is determined using control stations, which is found to be ± 7 nT.



Fig. 3: The proton magnetometer used in the study area

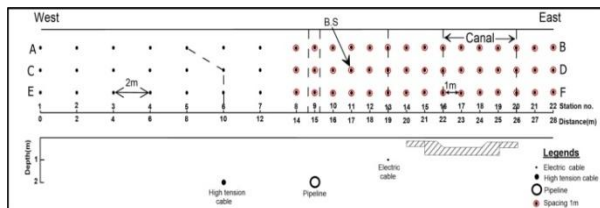


Fig. 4: Sketch of stations' locations in the study site and subsurface engineering utilities.

C. Corrections and magnetic anomaly determination

The correction used in this study is the diurnal correction only. This correction is determined using a drift curve depending on repeating measurements at the base station every 5 minutes. The maximum variation in the magnetic values at the base station in each loop survey did not exceed 25 nT.

The normal magnetic variation correction is neglected due to the short distance of 28 meters profile relative to the global magnetic variation. The elevation correction is also neglected because the variation in elevation between the lowest and highest stations did not exceed 0.10 meters.

After data correction, the magnetic anomaly is measured by subtracting the total magnetic intensity of the base station from the value of each station for all profiles with the three sensor heights. The vertical magnetic gradient is obtained by dividing the difference between magnetic values from every two levels by the vertical distance between sensor levels. The procedures can be simplified by the following equations:

Vertical Magnetic Gradient (VMG) = Δ Magnetic values/ Δ Sensor's level

So, we get three vertical gradients from the three sensor level differences:

VMG1 (nT/m) = Magnetic value (1.22)- Magnetic value (1.83)/ 0.61

VMG2 (nT/m) = Magnetic value (1.22)- Magnetic value (2.44)/1.22

VMG3 (nT/m) = Magnetic value (1.83)- Magnetic value (2.44)/ 0.61

3. Results and Discussion

The magnetic anomaly determined at the three levels (2.44m, 1.83m and 1.22 meters) of profile AB is shown in Figure (5), while the vertical magnetic gradients (VMG1, VMG2, and VMG3) of profile AB are presented in Figure (6). The same procedure is applied to the other profiles. The magnetic anomalies along profile CD for the three considered elevations and the vertical magnetic gradients (VMG1, VMG2, and VMG3) are presented in Figures (7 and 8), respectively. The final results of the magnetic anomalies and the vertical magnetic gradients (VMG1, VMG2, and VMG3) for the three sensor heights of profile EF are shown in Figs. 9 and 10, respectively.

Figs. 4, 6, and 8 show that the low sensor height level is the best level for detecting the shallow sources. At the same time, the vertical magnetic gradients between the three considered levels coincide mostly in locating the subsurface objects (Figs. 6, 8 and 10). The vertical magnetic gradient with a relatively high distance (1.22 meters) is less effective than the low distance (0.61 meters). The variations in spacing distance between the stations along the profiles show the same result in the vertical gradient measurement technique.

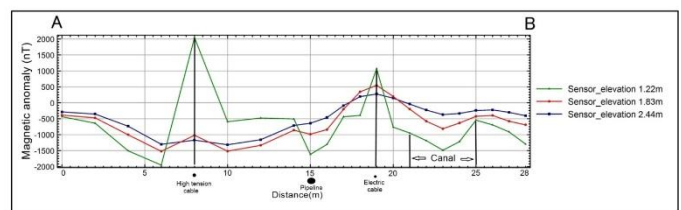


Fig.5: Magnetic profile (AB) using sensor heights (2.44 m, 1.83 m, and 1.22 m), and the detected subsurface sources in the study site

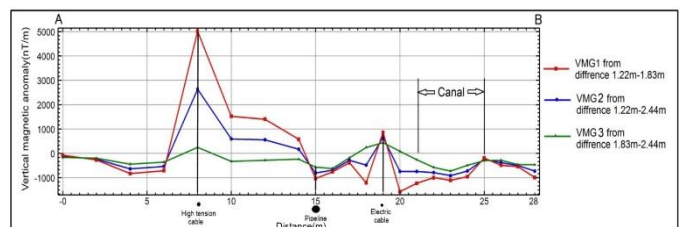


Fig. 6: Three vertical magnetic gradients along profile (AB), and subsurface sources in the study site

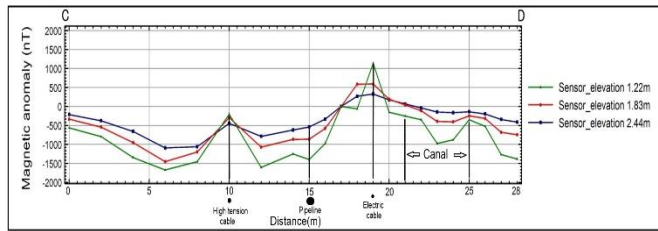


Fig. 7: Magnetic profile (CD) using sensor heights of 2.44 m, 1.83 m, and 1.22 m, and subsurface sources in the study site.

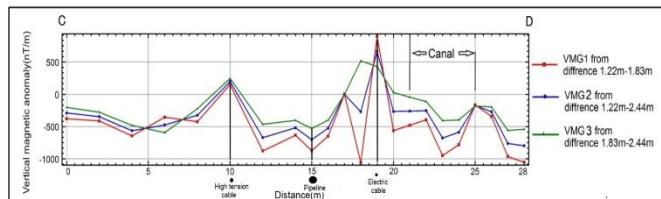


Fig.8: Three vertical magnetic gradients along profile (CD), and subsurface sources in the study site.

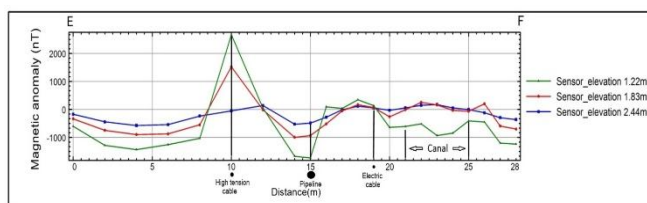


Fig. 9: Magnetic profile (EF) using sensor heights (2.44 m, 1.83 m, and 1.22 m), and the detected subsurface sources in the study site.

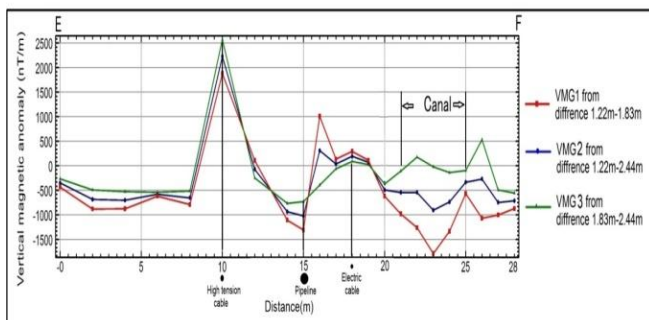


Fig. 10: Three vertical magnetic gradients along profile (EF), and subsurface sources in the study site.

4. Conclusions

The magnetic anomaly with three sensor heights along three parallel profiles is measured to detect shallow engineering sources in the study area. The vertical magnetic gradient is determined between the three considered sensor levels. It is concluded from the results of this study that the lowest sensor level is more suitable than the relatively high sensor levels in detecting shallow subsurface objects. The vertical gradient shows better results than the total magnetic intensity measurements. The determined vertical gradient between low sensor levels is better than at relatively high distances. The vertical gradient seems

not to be affected by the spacing distance between measurement stations, as the total magnetic intensity measurements.

5. Acknowledgments

The authors are grateful to Dr. Jassim M. Thabit for his assistance in the magnetic field measurements.

6. Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

7. Funding Statement

Research received no external funding.

8. References

- Abdelrady, M., Moneim M. A., Alarifi S. S., Abdelrady A., Othman A., Mohammed M. A. A. and Mohamed A. 2023. Geophysical investigation for the identification of subsurface features including mineralization zones, *Journal of King Saud University-Science*, 35: 1-11, DOI: org/10.1016/j.jksus.2023.102809.
- Alao, J.O., Lawal, K.M., Dewu, B.B. and Raimi, J., 2024. The study of magnetic anomalies due to shallow underground targets and the environmental applications, *Results in Earth Science*, 2: 1-9. DOI: org/10.1016/j.rines.2024.100016.
- Al-Banna, A. S. and Al-Khishef, Dh. S., 2019. Evaluation of the tectonic boundaries in Tikrit- Kirkuk area using potential data, north - central Iraq. *Iraqi Journal of Science*, 60 (3): 528-535. DOI:10.24996/IJS.2019.60.3.12.
- Al-Hadithi, S.J. and Al-Banna, A.S. 2022. Using source parameter imaging technique to the aeromagnetic data to estimate the basement depth of Tharthar Lake area and surrounding area in central Iraq, *Iraqi Geological Journal*, 55(1F): 151-159. DOI: 10.46717/igi.55.1F.12Ms-2022-06-27.
- Al-Saady, H. A., Karim, H. H., and Al-Menshed, F. H. 2022. Subsurface investigation of void using ground penetration radar in Basimayah Site southern Baghdad, central Iraq. *Iraqi Geological Journal*, 55(1D):35-46. DOI: <https://10.46717/igi.55.1D.3Ms-2022-04-19>.
- Breiner, S., 1973. Application manual for portable magnetometers, GeoMetrics. Sunnyvale, California, 58 P.
- Burger, H.R., Sheehen, A.F., and Jones, C.H. 2006. Exploration using magnetic method, in *Introduction to Applied Geophysics, exploring the shallow subsurface*, New York. W.W. Norton and Co., 389 P.
- Canbay M.M., Aydin A. and Kurtulus C., 2010. Magnetic susceptibility and heavy- metal contamination in topsoil along the Izmil Gulf coastal area and IZAYTAS (Turkey), *Journal of Applied Geophysics*, 70:46-57. DOI: 10.1016/j.jappgeo.2009.11.002.
- Dobrin M. B. and Saviet C. H., 1988. *Introduction to geophysical prospecting*, 4th Edition, McGraw-Hill, 867 P.
- Emerson D.W., Reid J.E., Clark M.S., Hallet M.S.C. and Manning P.B., 1992. *The geophysical responses of buried*

drums- field tests in Weathered Hawkesbury Sandstone, Sydney Basin, NSW, Exploration Geophysics, 23: pp. 589-617.

Grant F.S. and West G.F., 1965. Interpretation theory in applied geophysics, McGraw- Hill Inc., 584 P.

Hinze W.J., Frese R.R. and Saad A.H., 2013, Gravity and magnetic exploration, principles, practices and applications, Cambridge University Press, 512 P.

Kaufman A.A., Kleinberg R.L. and Hansen R., 2008. Principles of the magnetic method in geophysics. Methods in Geochemistry and Geophysics 42, Elsevier Science, 1st Edition, 320 P.

Lanka M., Butler A., and Sterling R., 2001. Use of approximate reasoning technique for locating underground utilities. Tunneling and Underground Space Technology, ScienceDirect 16(1): 13-31. DOI: [https://org/10.1016/S0886-7798\(01\)00058-x](https://org/10.1016/S0886-7798(01)00058-x).

Marco M., Cafarella L., Di Mauro D., and Zirizzotti A., 2002. Ground magnetometric survey and integrated geophysical methods for soil buried waste detection: A case study, Annals of Geophysics, 45(3/4): 563-573. DOI: <https://10.4401/ag-3519>.

Morsy M. and Rashed M., 2013. Integrated magnetic, gravity, and GPR Survey to locate the probable source of hydrocarbon contamination in Sharm El-Sheikh area, south Sinai, Egypt, Journal of Applied Geophysics, 88: 131-138. DOI: 10.1016/j.jappgeo.2012.11.003

Moskowitz B.M., Jackson M. and Chandler V., 2015. Geophysical properties of the near surface earth: Magnetic properties, in Schubert, G. Treatise on Geophysics, 2nd Edition: Elsevier, 11:139-174.

Nettleton, L.L., 1971. Elementary gravity and magnetics for geologists and seismologists, SEG, Monograph series. 132p.

Oni, A.G., Eniola, P.J., Olorunfemi M.O., Okunubi, M.O., and Osotuyi, G.A., 2020. The magnetic method as a tool in groundwater investigation in a basement complex terrain: Modomo Southwest Nigeria, as a case study, Applied Water Science, 10(8): 1-18. DOI: 10.1007/s13201-020-01279-z.

Schmidt A., 2007. Archaeology, magnetic methods. In D. Gubbins and E. Herrero-Bervera (eds.), Encyclopedia of Geomagnetism and Paleomagnetism: 23-31. Encyclopedia of Earth Science Series, Heidelberg, New York: Springer. DOI: https://10.007/978-1-4020-4423-6_9.

Sharma, P.V., 2012. Magnetic surveying, environmental and engineering geophysics, Cambridge, Cambridge University Press, pp. 65-111, <https://10.1017/CBO9781139171168>.

Tyagi S.A.E., Lord J., and Koerner R.M., 1983. Use of a proton precession magnetometer to detect buried drums in sandy soil, Journal of Hazardous Materials, 8: pp. 11-23.

قياس الشدة المغناطيسية باستخدام ثلاثة مستويات مختلفة للمتحمس وحساب ثلاثة

مستويات للانحدار العمودي للكشف عن المرافق الهندسية تحت سطح الأرض.

أحمد شهاب البناء^{1*} , حيدر حميد مجيد² , فتيان رشيد الراوي¹ , طارق صفاء الدين¹ 

triqsaaldan@yahoo.com

drfitian@yahoo.com

haidargeo38@gmail.com

geobanna1955@yahoo.com

¹ قسم علوم الأرض، كلية العلوم، جامعة بغداد، بغداد، العراق.

² المديرية العامة للتربية دىالى، وزارة التربية والتعليم.

* الباحث المراسل.

تاريخ الاستلام: 31 تموز 2025 تاريخ المراجعة: 01 أيلول 2025 تاريخ القبول: 16 تشرين الثاني 2025

تاريخ النشر الإلكتروني: 01 تشرين الأول 2026

المخلص

تم قياس شدة المغناطيسية الكلية (TMI) في جنوبي بغداد في موقع داخل جامعة بغداد. استخدمت هذه القياسات للتحقق من أفضل ارتفاع للمجس، ومسافات الانحدار العمودي المناسبة للكشف عن المرافق الهندسية تحت سطح الأرض. تم إجراء القياس على طول ثلاثة مقاطع متوازية من الشرق إلى الغرب. يبلغ طول كل مقطع 28 متراً. تبلغ المسافة الفاصلة بين محطات القياس في الجانب الغربي (0-14 متراً) مترين، بينما تبلغ متراً واحداً في الجانب الشرقي (14-28 متراً). أجريت القياسات المغناطيسية باستخدام ثلاثة مستويات للمجس، وهي (2.44 م، 1.83 م، 1.22 م)، لحساب الارتفاع المناسب لكشف الأهداف المدفونة تحت سطح الأرض. تم حساب قيم الانحدار العمودي للمغناطيسية لكل محطة، من قياسات الارتفاعات الثلاثة. خلصت هذه الدراسة إلى أن ارتفاع المجس (1.22 م) هو الأفضل من غيره في اكتشاف المصادر الضحلة. تتطابق مقاطع الانحدار المغناطيسي العمودي الثلاثة في اكتشاف المصادر تحت السطحية. أظهر الانحدار العمودي نتيجة أفضل من قياسات مستويات المجس المرتفعة نسبياً. ويبدو أيضاً أن مسوحات الانحدار العمودي لا تتأثر بمسافة التباعد بين المحطات مثل ما هي في قياسات الشدة المغناطيسية الكلية.

الكلمات المفتاحية:

المغناطيسية، الانحدار العمودي، ارتفاع المجس، المرافق الهندسية، بغداد.

DOI: [10.33899/injes.v26i4.60971](https://doi.org/10.33899/injes.v26i4.60971), ©Authors, 2026, College of Science, University of Mosul.

This is an open-access article under the CC BY 4.0 license (<http://creativecommons.org/licenses/by/4.0/>).

=====