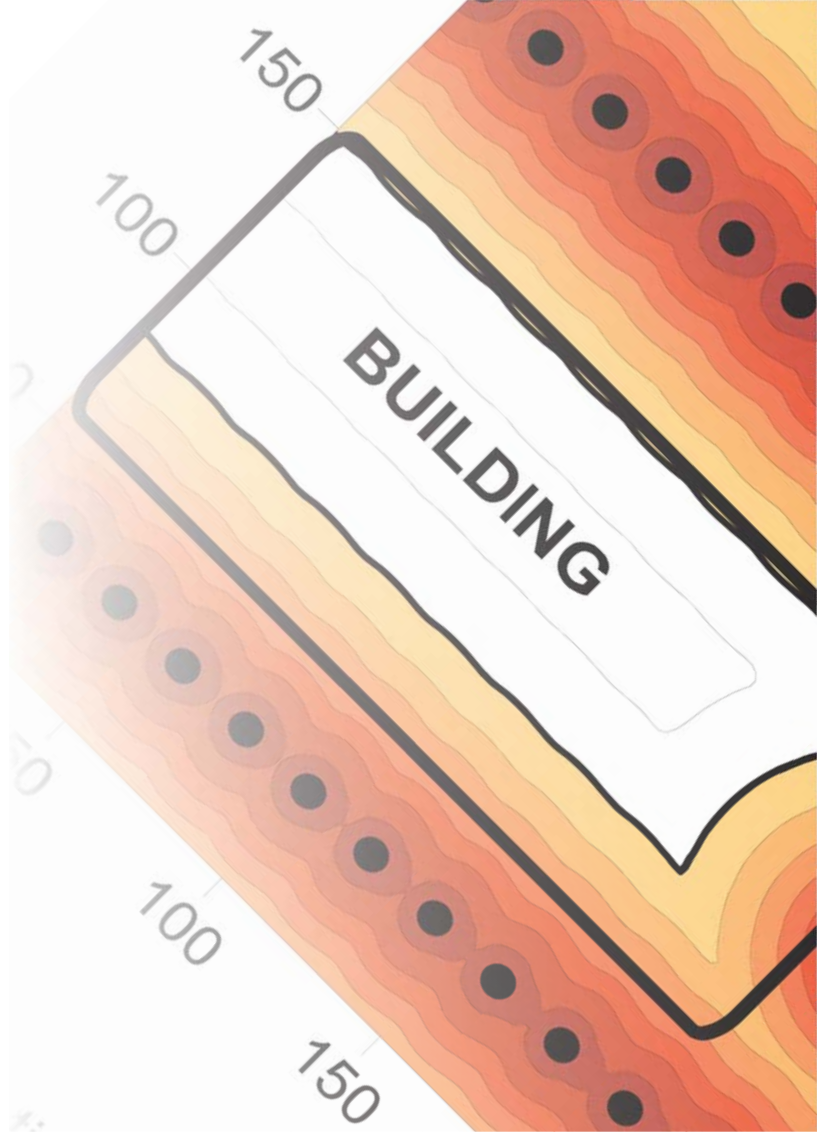
# A SIMPLE APPROACH TO ASSESS THE SPATIAL COVERAGE OF A MICROGRAVITY SURVEY

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When presenting the results of a microgravity survey to an engineering client or other end-user of the data, we are often asked about the spatial coverage of the survey. What percentage of the site is adequately sampled by the survey? How far out do you see from the gravity meter? After explaining that the answers to those questions depend on many factors such as depth of burial, density contrast, target size, target geometry, etc., the client is either confused or asleep. In order to better answer these questions, we present a simple graphical approach in defining the spatial coverage of a microgravity survey. We use microgravity data as an example, but the same approach could be applied to magnetic or other potential field data.

The spatial sampling and survey design for a microgravity survey are generally described in ASTM 6430-99 (ASTM, 2005). Factors such as the expected gravity response to targets of interest and the need for data at a given location are considered when planning a microgravity survey. Optimally, a grid of microgravity stations would equally cover the site with a sampling interval that is adequate to define the shallowest of targets. In reality, project budgets and surface obstructions limit the number of gravity stations and their placement within the site. Therefore, there is a need to assess the spatial coverage of the site, given the limited number of gravity stations and the targets of interest for the survey.

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# TARGET RESPONSE

The gravitational response (or anomaly) to a given target can be modeled using well-known equations developed for three-dimensional shapes that simulate the target (Telford et al., 1976). Typical targets for a microgravity survey include features such as isolated cavities, horizontal karst conduits, and vertically-weathered fracture zones. When appropriate shapes such as spheres, cylinders, and planar sheets are modeled to simulate these features, the anomaly magnitude and width can be calculated for various depths and locations beneath the survey area.

In this example, we examine the response of an air-filled spherical void in rock. The gravity response (vertical component) due to the void depends on its density contrast, size, depth, and the measurement distance from the void as shown in the equation below:

g_z=8.5 (( a^3 ))/(z^2 (1+x^2/z^2 ) ^(3/2) )

Where, $g_z$ is the gravity response in μ Gals, $\sigma$ is the density contrast in g/cm$^3$, α is the radius of the sphere, $z$ is the depth to the center of the sphere and $x$ is the lateral distance from the center of the sphere. Distances are in units of feet.

Figure 1 shows the response of an air-filled spherical void centered at depths of 20, 30, and 40 feet. The void has a density contrast of 2.4 g/cm$^3$ (simulating an air-filled cavity in limestone) and a diameter of 20 feet. Based on this model and our minimum depth of interest, we decide that a 20-foot station spacing will adequately sample the target along our survey lines.

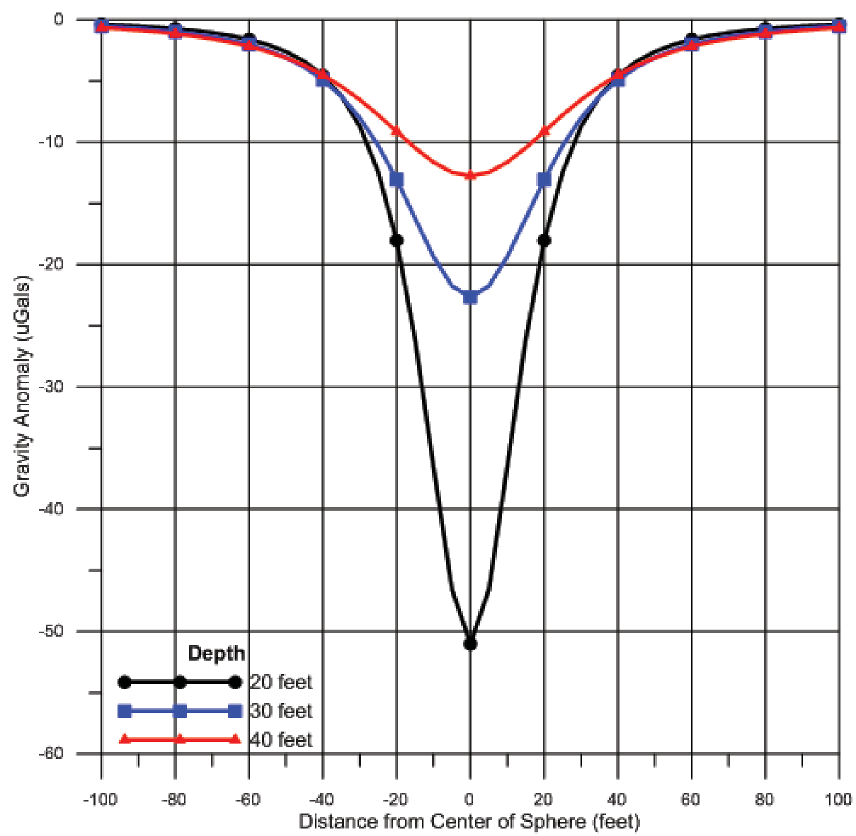


Figure 1. Gravity anomaly due to 20-ft diameter spherical void at various depths.

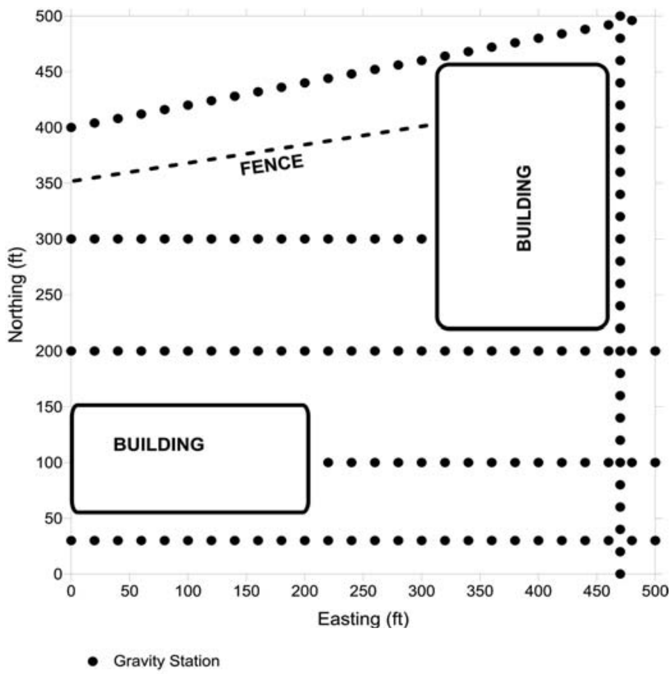


*Figure 2. Microgravity survey line layout.*

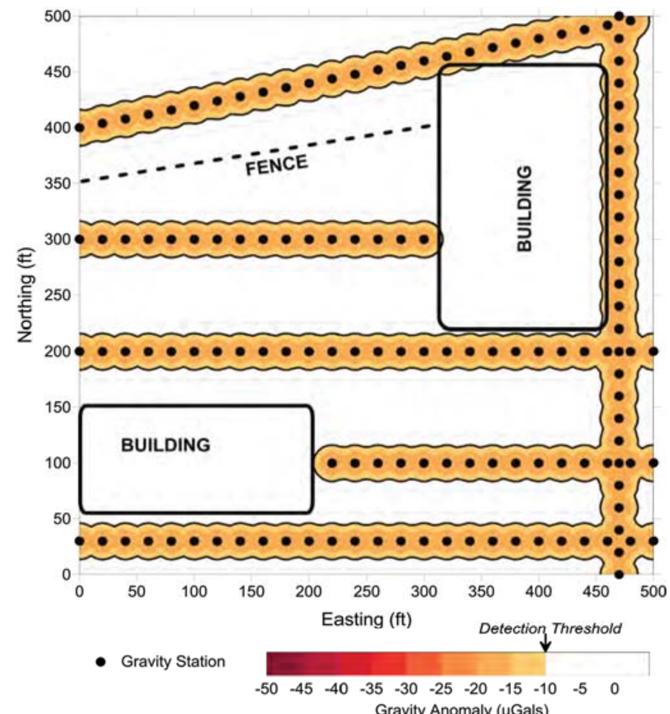


*Figure 3. Maximum gravity anomaly for a 15-foot diameter spherical void at a depth of 20 feet.*

## SPATIAL COVERAGE

Based on the initial modeling, we would like to cover the site with a 20 x 20-foot survey grid for our gravity measurements. However, the site has some surface obstructions that will limit the placement of the survey lines and our budget restricts us to less than 150 stations. Therefore, we position survey lines in accessible areas of the site as shown in Figure 2.

The spatial coverage and detectability of targets within the survey area will be highly biased towards locations directly beneath the survey lines. What if our target lies between the survey lines? What portion of the survey area is adequately sampled for a given target? In order to help visualize the answers to these questions, we calculate the maximum magnitude of the anomaly if a given target is located at any position within the survey area and observed at the gravity stations as shown in Figure 2.

Figure 3 shows the maximum magnitude of a 15-foot diameter spherical void at a depth of 20 feet. The magnitude of the anomaly falls below the detection threshold (conservatively set at 10 QGals) at distances of approximately 17 feet from the gravity stations. Figure 4 shows the maximum magnitude of a larger 30-foot diameter spherical void at a depth of 40 feet. The magnitude of the anomaly falls below the detection threshold at a much greater distance of approximately 50 feet from the gravity stations.

## APPLICATIONS

The plan-view representation of the maximum magnitude anomaly for a given target is a simple graphical means to assess the spatial coverage for the survey. It is a useful method to describe the spatial coverage to end-users of the data without over-complicating the issue. The method can also be used in the pre-planning stages of the survey to aid in survey line placement.

Figure 4 illustrates some important concepts in microgravimetry. Note that the 10-μGal detection threshold area extends significantly away from the survey lines and beneath the buildings. For very good site conditions coupled with very exacting microgravity survey procedures, the detection threshold can sometimes be lowered to 5 μGals, which for this case would extend the detection coverage to most of the areas covered by the buildings. Also, if the interiors of the buildings are accessible, microgravity measurements can easily be made within buildings, where other surface geophysical methods would be limited.

We note that this method is not entirely complete and neglects the spatial wavelength of the anomalies, which would have to be addressed separately as in Figure 1. Similar, but more complex, plan-view maps could be developed for features that extend along one axis such as a cave or tunnel. The method is certainly not a substitute for more complete forward and inverse models of subsurface conditions, but is meant to be a quick way to illustrate the answer to a complex question. Also, the method does not explicitly consider terrain corrections and corrections for manmade surface structures.

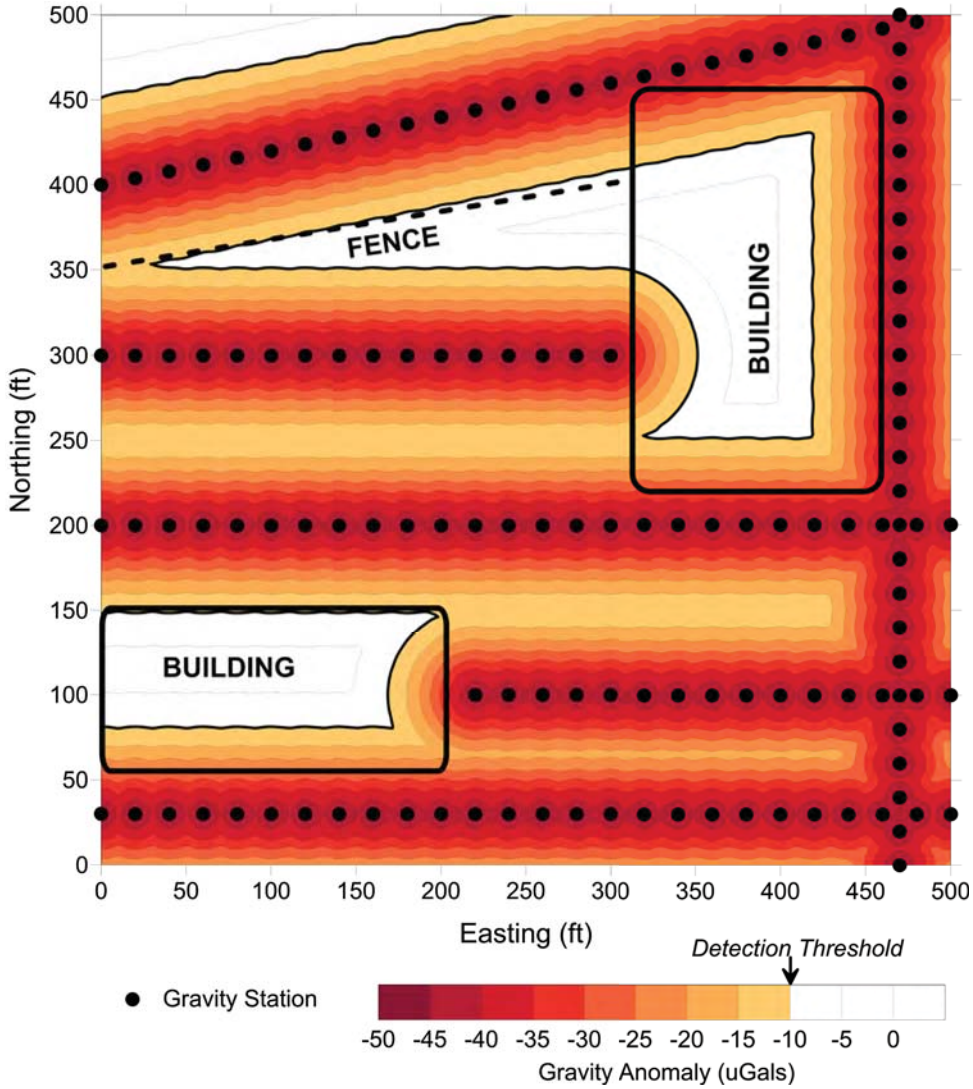


*Figure 4. Maximum gravity anomaly for a 30-foot diameter spherical void at a depth of 40 feet.*

## REFERENCES

ASTM, 2005, Standard guide for using the gravity method for subsurface investigation, No. D6430-99 (Reapproved 2005), ASTM International, West Conshohocken, Pennsylvania, 10p.

Telford, W.M., Geldart, L.P., Sheriff, R.E., Keys, D.A., 1976, Applied Geophysics, Cambridge University Press, 860 p.