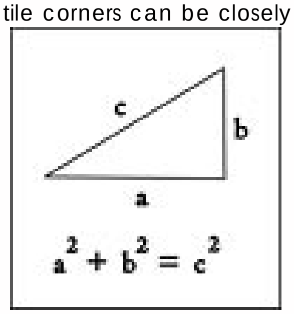
DESIGNING A FIELD STRATEGY

Once it has been determined that a site is a good candidate for geophysical investigation, and appropriate geophysical methods and instruments have been selected, the next step is to plan the survey. Project goals and expectations based on previous investigations often help one develop a sampling strategy to guide the geophysical work. Large continuous areas are almost always more informative than small, discrete patches. Once it has been determined that the available instruments and selected survey strategy are detecting anomalies that appear to be consistent with archaeological features, a ground-truthing strategy should be considered to aid in directing the progress of geophysical survey. In general, it is best to begin geophysical surveys in more promising and better understood areas as a baseline before moving toward the lesser known. When a site is very large, and there are generally no clues as to where subsurface features are most likely to be located, choose a readily accessible portion of the site that is not in need of much preparation work (vegetation removal, etc). After collecting a day's or half-day's worth of data, hopefully the results will help you decide which way to progress. At large sites it is often best to select a few discrete locations for test surveys. If possible, keep them on the same grid system, so that they will eventually be connected if the survey is expanded.

Survey location and size
Setting up a grid
Tile Size
Data Density
Data Density 2
Ground Surface Preparation
Survey Samples

Geophysical surveys can vary greatly in size.
• Ideally, a survey should extend a little beyond the site limits
• ensure that the area surveyed is large enough that features can be recognized based on pattern recognition
• Small features can be detected with small surveys, perhaps 15 x 15 meters or even smaller in special cases. Such small area samples may, however, make it very difficult to interpret distributional patterns.
• Much larger surveys have the benefit of revealing not only individual features and feature clusters, but entire settlements. At this "landscape" scale, the spatial layout of complete sites can be documented, and entire settlements (or, in many cases, settlement palimpsests) can be investigated.

The importance of accurately setting up a grid cannot be stressed enough. If the grid has internal error, or if it cannot be accurately located on the ground in relation to a base map, then the value of the geophysical survey is greatly diminished. Copious notes should also be taken so that the grid can be relocated in the future. (The term "grid" can be confusing sometimes because it is used in many different ways. To avoid confusion we use the word "grid" here in the traditional sense, and describe the individual geophysical survey units in a grid as "tiles.")
There are a variety of ways to set up a grid for geophysical survey. For small areas, tape measures can be used without the help of a transit or similar device. Right-angles for tile corners can be closely approximated using the Pythagorean Theorem.



This method works well for small grids, but as the size of the grid increases, the error gets progressively worse. When relocating a point on the ground to investigate an anomaly, one should tape distances from the corner of that particular tile where survey began. In order to correct error later it is important to record the GPS locations of the tile corners. A dumpy level or an optical square can be used to sight in straight lines and right angles, but taped distances will still be erroneous the farther the grid is extended from the starting point. A much more accurate and precise way to set up a grid is to use a total station or survey-grade GPS.
The orientation of a grid with respect to architectural or other linear features is extremely important. Several problems can occur if data are collected along lines that are parallel to walls or other linear features (e.g., ditches, fences, roads).
• a narrow linear feature could be entirely missed if it falls between collection traverses
• Lines can be easily mistaken for instrument malfunction or interference from outside sources

• anomalies that parallel collection lines will often be removed by a de-striping filter
It is therefore important to choose a grid orientation that is at least 20 degrees offset from the dominant trend in architecture. Where possible it is beneficial to set up the grid close to 45 degrees offset from the architecture (or linear features of interest).

Tile size is often a difficult decision to make, and there are many factors to consider. Using very small tiles (e.g., 10 x 10 m) over a large area will result in a large number of data files. If tiles are too large (40 x 40 or larger), it will take too long to survey each one and the surveyor will probably need to take breaks before a tile is complete. Large tiles have several problems
• most instruments drift over time, small tiles allow for re-calibration
• when survey is resumed after a break, the readings of the new line will not match well with the line of data collected before the break, so an edge-discontinuity is created
• Data collection has to stop at the end of the day or when batteries are drained, so it is best to use a tile size that is both large enough to keep the number of data files manageable, while also small enough that a tile can be finished in under an hour.
• Small tiles are better in oddly shaped or confined spaces
• Managing "walking ropes" or tape measures difficult over large distances
Small tiles are also easier when there are other things going on during the survey that need periodic attention, such as talking to the public, helping with other parts of the field effort, or attending to a GPS unit or battery charger.
Another factor to consider with tile size is uniformity. When using multiple methods at one site it is best to pick one tile size for all instruments. This way, the grid can be set up with markers at every tile corner, and a single set of pre-cut survey ropes can be used for all instruments. A common method in North America is to lay out a grid with markers every 20 meters. The most commonly used software packages for magnetometry and resistivity (Geoplot and ArchaeoSurveyor) also follow this convention and require that all tiles be the same size in order to be displayed and processed together, which simplifies programming. Note that Archaeomapper is designed to process edge discontinuities that occur between and within tile boundaries with ease, and allows tiles of different sizes and data densities in the same survey. We suggest that ropes be laid down along survey lines at all odd meters (1, 3, 5, and so on up to 19 m). Using this technique, there are no locations in the tile that are more than 1 m away from a survey rope, so distances along each transect can be easily estimated for rapid survey.

Ground penetrating radar survey is distinctly different from the other methods. We suggest that larger tiles be used to minimize processing time using 40 x 40-m tiles.
• The edges line up with the typical 20 x 20 m tile boundaries of other surveys, but there are only one quarter as many tiles to process.
• at half-meter line spacing it is likely that a tile can be surveyed in 3-4 hours.
• Two 50-meter measuring tapes are used for baselines and a third one as a "walking tape," which is moved along as lines are surveyed.
• Keep in mind, however, that this method requires at least two and preferably three people, and does not leave much time for breaks during the long surveys.
With EMI, larger tiles are not recommended because, unlike GPR, EMI data (both conductivity and MS) are prone to drift. With a sensor that drifts it is better to tune it frequently, such as before each 20 x 20 m tile.

The ability to detect small or low contrast features depends heavily on the data (or sampling) density of the geophysical survey. The limiting factor for feature detection and image resolution is therefore the distance between lines. The traditional sampling density for most methods is reported to be 1-2 samples per m². We suggest that the traverse interval should be geared to the nature of the site and expected features. Data density should be high enough such that the smallest feature to be detected is recorded at least twice and preferably more for reliable detection. This means that if the target feature is 1 m in diameter the data density should be at least .5 x .5 m so that it is likely to be recorded more than once and thus distinguishable from a data spike.
Unfortunately, the advantages of high data density surveys are accompanied by higher costs. A balance between meeting the survey goals and costs should be found. This sometimes means surveying a smaller area with higher data density rather than a large area at a lower density, or vice versa. Some software packages (including ArchaeoMapper) allow one to remove every other line of data in order to assess the impact on anomaly detection. Where this capability exists, it is wise to begin with a higher density survey, and reduce this if anomalies consistent with features are detected using the lower density.

The term data density can sometimes be confused with image resolution. Data density refers to the number of data values per m² collected in the field. During processing, interpolation procedures are used to cosmetically improve an image by reducing pixel size. Such interpolation is, however, no substitute for an increase in true data density, and it will not aid in the detection of small or low contrast features.
Many instruments are designed to record measurements at regular intervals along each transect. Most magnetometers and EMI instruments emit an audible beep at regular intervals, such as every second, in order to guide the surveyor. The surveyor can then choose how many measurements will be taken between each beep, or can alter the time interval between beeps. This requires that the surveyor is able to proceed at a fairly constant pace. If there are many obstacles, readings can be taken manually by pushing a button, although this is difficult in situations where 8 readings per meter must be recorded. Alternatively, some instruments allow the surveyor to keep track of distance continuously by recording a fiducial-mark every meter or so. The meter marks are then used to interpolate, or "rubbersheet", between markers. This is often done with GPR, but an easier way to record GPR data is to use a survey wheel. The wheel attaches to the antenna and works as an

odometer, taking an equal number of measurements per meter.

While it is ideal for a site to be blanketed in short, smooth grass, most sites are covered in some combination of tall grass, cacti, bushes, and trees. The ideal solution is to remove any vegetation that impedes the movement of geophysical equipment. The method of vegetation removal should be carefully considered. A lawn mower can be used to clear grass, but care should be taken not to do this on days when the ground is soft because shallow tire tracks can be detected by most geophysical methods. If bushes are removed, they should be chopped down to ground level but the root system left in place rather than removed because this would create an anomaly on its own.
As discussed previously, metal debris on and near the surface creates a problem for magnetometry survey, and to some extent conductivity. If metal debris is extensive, then magnetometry survey is not worthwhile until the debris is removed. This adds considerable time and cost to the project, because removing metal entails locating each piece with a metal detector and then usually digging for it with a trowel. This kind of impact might not be acceptable at some (unplowed, cemetery, battlefield) sites. It is a worthwhile effort, however, when magnetometry is the best method for meeting the survey goals.

A variety of field supplies are either required or very helpful for a geophysical survey, particularly for large surveys using multiple instruments. Here we provide a list of basic supplies needed for a survey, but it is not exhaustive.

Tile corner markers. Plastic sections of ½-inch diameter pvc pipe works well to mark tile corners. They can usually be pounded in easily and are readily visible. They can be written on with permanent marker to show the grid coordinates and tile number, or marked with flagging tape that bears this information.

Plastic or wooden stakes. These are best for pinning survey ropes across grid tiles, and can also be used as tile corner markers. Compared to wooden stakes, plastic stakes or ten pegs are easier to work with, last much longer, and are often cheaper.

Flagging tape. This is useful to mark stakes or other tile markers, and other locations.

Plastic Pin flags. Pin flags are useful for marking tile corners, tuning stations, and monitoring stations. Plastic is much preferred over metal for the sake of magnetometry. We advocate that archaeologists never use metal pin flags at sites that may someday be the subject of geophysical survey.

Rubber mallet. A mallet or hammer makes pounding in stakes easier, and one made of rubber is less likely to damage them. Rubber mallets often include some metal, however, so they should be tested before being left within range of a magnetometer.

Tape Measures. Tape measures are needed when laying out a grid unless a total station is available. They can also be used to stretch out along baselines to set up tiles for survey. It is handy to have three tape measures, 30-50 m long each. It is also nice to have one 100-m tape that you can stretch along a series of tiles, or use to measure the hypotenuse when setting-in tiles. If large GPR tiles are being used, tape measures are best for guiding the survey.

Chaining pins. These can be used to secure one end of a tape, allowing one individual to establish a series of tiles. Make sure to remove them prior to magnetometry or EMI surveys!

Survey ropes. Survey ropes are precut sections of rope with meter markers that are highly visible. They are used to lay out a tile for survey. If the typical 20 m tiles are used, then these ropes should be made long enough to lay across the entire 20 m, with some slack at the ends so a loop can be tied. Meter marks can be made visible with brightly colored spray paint, duct tape, or electrical tape. It is also helpful to use different colors to mark increments, such as every five meters, so that distances along the rope can be easily determined. Fiberglass survey tapes, which do not stretch, are available in large rolls from many survey suppliers.

Notebook and pencils. Obviously there is much information to record in the field. Books with grid lines are helpful for sketching the site grid.

Pre-made Forms. For large surveys especially, it is useful to develop a standard form that can be used to record information about each tile. It saves time if the standard-sized tile is already drawn on the form that can be used to sketch in anything on the surface that will affect the interpretation of the data, such as vegetation patterns and the locations of obstacles. If doing resistivity, it is also useful to record the measurements from each tile coner, so that when survey is continued the remote probes can be repositioned to make adjacent tiles match.

Compass. This is especially important for magnetometry, because tuning and set up require that magnetic north be located rather accurately.

Tunings Stands. Fluxgate magnetometers can be tuned standing on the ground as instruction manuals advise, but it is much better to be elevated above the ground. A plastic or some other non-metal stool can be used for this. It is particularly important for dual sensors, because if they are close to the ground they could each find a different zero, resulting in a strong striping pattern in the data. EM instruments, particularly the EM38, also should be elevated high above the ground for tuning. While the instrument can be held this way while standing, it is very tiring and probably not as accurate because it is not held perfectly steady and at the right angle. A collapsible platform can be made out of pvc pipe or some other non-metal material. Use of a bubble level to ensure that the instrument is being held vertically can reduce the time needed to properly tune a Geoscan gradiometer.

Total Station or some other mapping implement. A total station is best, but an optical transit, dumpy level or optical square can be used for small grids.

GPS unit. The geophysical grid should be mapped into real world coordinates if possible, for record keeping and integration with other data in GIS.

Portable Computer. This is necessary to download data, as most instruments do not hold more than a day's worth. It is also important to take a look at data each day to check for errors and see how the methods are working.

Software. The download and processing software for each instrument should be loaded onto the portable computer, but it is also a good idea to have a back-up copy on disk in case the computer fails.

Means to establish a permanent datum. The geophysical data are not worth very much if the grid cannot be relocated on the ground surface in the future. Unless the real-world coordinates of the grid are known (and can be precisely relocated with a GPS), the geophysical grid should be marked with a datum that will last at least long enough to be more accurately documented. A post-hole digger or shovel should be used to dig a hole and fill with cement, with rebar or pvc pipe embedded for visibility. Sometimes the datum should be low to the ground so it will not be removed, damaged, or pose a danger to passing vehicles. Use of rebar is debatable. It is more durable than PVC, and can be relocated with a metal detector, but will cause a large anomaly in future magnetometer surveys. If using rebar, consider temporarily removing it prior to any future magnetometry surveys.

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