SECTION 4

# FIELD PROCEDURE

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## 4-1 Introduction

This section gives practical instructions on how to use the gradiometer in the field. You should read Section 3, which describes in detail initial fluxgate alignment procedures, the operating modes, the keyboard functions, and logging procedures, before reading this section. The order in which the subsections are described below is a good guide to the recommended sequence of field procedures that you should adopt.

## 4-2 Setting up the Gradiometer

### (1) Warm-up time

As soon as you arrive at a site take the gradiometer out into the field and switch on. This will allow the electronics to stabilise and, more importantly, it will allow time for the mechanical support, and hence alignment, of the fluxgate sensors to achieve thermal equilibrium with the field environment. This is especially important if the instrument goes from a warm to a much colder environment, or vice versa.

Allow a stabilisation time of at least 15 minutes before a detailed survey is started and preferably longer. Typically the reading will change by about 1-2nT over the first 3 minutes ( due to the electronics achieving equilibrium ) and then will then settle down. However the fluxgate sensor alignment, being a mechanical arrangement, will not have properly stabilised by this time. Although this will not contribute to reading drift, the sensor alignment will not yet be optimised for minimum tilt errors. Attempts to adjust alignment at this stage are pointless since it will have drifted away from optimum by the time the detailed survey is started.

During this warm-up period preparations can be made for the detailed survey, laying out lines etc. If only scanning is proposed this can be started after 5-10 minutes, since tilt errors at this stage will not generally be large, providing the instrument was correctly set up from the previous survey. It may be prudent to check this however, and adjust accordingly, especially if it is a very quiet site magnetically - see (3) below.

### (2) Precautions

As has already been emphasised in Section 3-5, it is vital that you have no magnetic items in, or on your clothing. Items to avoid and remove before starting are watches, keys, belts, spectacles, zips and studs in trousers, studs in waterproof nylon anoraks, credit cards, studs in boots or even eylets in lace up shoes, etc. Anomalies from these objects can range between 5 and 200 nT, which is very significant compared to the 1 nT survey resolution typically required.

If you must wear spectacles then make sure they have a plastic frame. Footwear can cause particular problems since it will always be moving relative to the gradiometer. In wet weather moulded Wellington Boots are recommended ( make sure there are no metal studs in the sole ) and for dry weather many plimsoles or trainer shoes ( for example Dunlop Green Flash ) are recommended, since the eylets and lace end caps are usually made from aluminium which is non magnetic.

# WARNING

IT CANNOT BE STRESSED TOO STRONGLY THAT MAGNETIC CLOTHING OR OBJECTS SHOULD BE AVOIDED. BEFORE STARTING A SURVEY CHECK, AND THEN CHECK AGAIN FOR MAGNETIC ITEMS AND REMOVE THEM.

If you have absolutely no choice but to wear clothes with a magnetic effect, for example jeans with studs in them, then their effect may be minimised by holding the gradiometer at a constant distance and oriention to your clothes. However this is not really recommended and should only be attempted by experienced operators who know when this is acceptable. Check the clothes suitability by seeing how much movement of the gradiometer is neccessary before the reading changes by more than 1nT - if very little movement is involved then the clothes are too magnetic and you will not obtain sensible survey data.

**(3) Sensor Alignment**

Once the gradiometer has had time to achieve thermal equilibrium with the field environment then the fluxgate sensors should be aligned, following the instructions of Section 3-5. The alignment should need checking only periodically, for example every 3-4 hours, ( ie first thing in the morning, at lunch time and late afternoon ) but depends very much on the weather conditions and the quietness of the site. Steady ambient temperatures of between 10 and 25 degree C with no winds or moderate winds, usually cause little change.

However, temperatures can change fairly rapidly at the beginning and end of the day so it may be prudent to also recheck alignment after the first grid has been surveyed and also after every two grids at the end of the afternoon. Obviously if weather conditions do change markedly during the day check the alignment more often. Also check more frequently if the site is very quiet, ( and/or the 0.1nT range is being used ), say after every two grids, since tilt errors will be more noticable compared to the small magnetic anomalies. On days which represent extremes of temperature, hot or cold, or very windy, check the alignment more frequently. It is also important to minimise tilt errors when doing zig-zag surveys - see Section 4-4 (4) below - so again check alignment more frequently.

## 4-3 Scanning

Scanning is useful, not only for locating areas of interest prior to a detailed survey, but also for indicating typical anomaly strengths and soil noise level. This may be used to decide on the resolution for the detailed survey and whether the averaging mode will be required.

Usually the Analogue Display Mode will be selected though the standard Digital Display Mode may also be used. Assuming the Analogue mode is to be used select the 10nT range for general use, though the 5nT range may be required if the site is magnetically quiet. A larger range may be selected if one is only looking for features which are expected to have a strong anomally, such as a pottery kiln. However, this should not be too high since if wide search strips are being used the feature could be missed since the anomally at the edge will be much smaller. It is probably best to use a lower range and then switch up when neccessary to investigate high strength local anomalies.

Locate a region where there are no localised changes observable ( see Sections 3-5 and 4-7 ) and zero the display, making sure that the gradiometer is pointing in the same direction as the proposed scanning traverses. Although it is possible to align the sensors so that the reading remains the same, no matter which direction the gradiometer is facing, it is much simpler and less time consuming to always point the gradiometer in the same compass direction at all times. The ground can be traversed at walking speed since the reading will be updated nine times every second in the Analogue Display Mode.

## 4-4 Planning a Detailed Survey

**(1) Area or Line survey**

Surveys may consist of either an Area Survey, the most usual choice, or a Line Survey.

In an Area Survey the site is partitioned into a number of grids, typically 20m by 20m, which are in turn subdivided into a mesh of smaller squares, typically 1m by 1m, figure 4-1. An instrument reading is taken at the centre of each small square, giving a detailed and systematic coverage of a site. This approach is useful if it is not known in advance what features to expect, or if indeed known features are intentionally to be investigated more thoroughly.

Sometimes it is not neccessary for all the detail given by an Area Survey. For example it may be that only the course of a major feature such as the ditch of an enclosure, or dyke system is required. In such cases a series of parallel traverses, separated by 2-5m with readings taken at typically 1m intervals and perpendicular to the supposed line of the feature, will generally give the information required, figure 4-1.

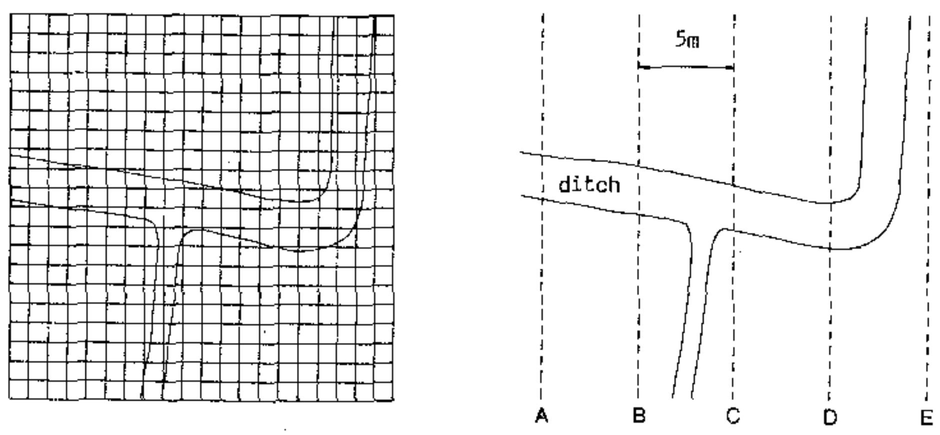


Figure 4-1. Area and Line Surveys over an enclosure ditch.

Note, however, that features running parallel with the traverse lines, such as the 'T' junction in the enclosure ditch, figure 4-1, may well be missed if too wide a line traverse is selected. Also the results may be open to misinterpretation - the apparent petering out of the ditch in traverse E is in fact due to a change in direction and not its disappearance. It may well be prudent, therefore, to also do a series of traverses perpendicular to the original traverse lines so as not to miss such features.

Line surveys may also be used to investigate in detail the response profile over a feature. In this case readings will be logged at 0.25m intervals with an external distance encoder or use made of the analogue output to drive a chart recorder.

It is recommended that an area survey be done wherever possible in preference to a line survey. The detailed information will allow a more reliable interpretion to be made and will highlight tenuous and weak anomalies that would otherwise be missed with a line survey.

**(2) Grid size**

Grid sizes that may be used with the FM18/36 gradiometer are 10m, 20m or 30m square grids. The 20m by 20m grid is a commonly used and relatively efficient size, and can be used with all the features of GEOPLOT (HX20). Whilst grids of 30m by 30m may be more efficient, requiring fewer movements of the survey guidelines over a given area ( see below ), not all GEOPLOT (HX20) features can be used, and in addition 30m by 30m grids can be difficult to fit conveniently into some sites. Grids of 10m by 10m are not recommended since they involve many more grid corner pegs to be set up and much more movement of the survey guidelines. Choice of grid size may also be dictated by the reading interval required and memory capacity of the logger - see following subsection on reading interval.

**(3) Reading Interval**

The choice of reading interval is a compromise between resolution and speed of operation. For many applications a reading interval and line separation of 1m is acceptable, figure 4-2 (a). If more resolution is required then usually a 0.5m reading interval and line separation is adopted, figure 4-2 (b), but at the expense of a quadrupling of survey time. A typical situation where this might arise would be in a search for pits 1m in diameter. A 1m interval survey would only produce one reading directly over the pit. A 0.5m interval survey, on the other hand, would produce four readings over the pit allowing much greater confidence in the interpretation. A 0.25m interval would obviously give even greater resolution but is really only practicable with an external distance encoder, and it must be remembered that survey time will be increased by at least a factor of 16 above that required for a 1m interval.

A compromise between good resolution and fast survey time is to use a line separation of 1m but reading interval of 0.5m, figure 4-2 (c), or even 0.25m, figure 4-2 (d). Line separation could also be reduced to 0.5m, figure 4-2 (e). Clearly this process is orientation sensitive so should be used with care if looking for narrow features. It does however give more information on the magnetic profiles of features that are crossed at right angles. Data can later be selected at a coarser interval, for example every 1m, for presentation with a 1-1 aspect ratio.

A further factor to consider is that it may be desirable to survey an area greater than that occupied by the archaeological structure. This can assist greatly in the interpretation of a site where it is anticipated that complicating factors such as geology, terrain, field drains, ridge and furrow etc. will also produce a response, usually fairly extensive. Indeed, once a survey is started it often becomes apparent that the archaeology also extends further than at first anticipated. Clearly the balance between resolution and time available to survey the larger area must be carefully considered before embarking on too detailed a survey.

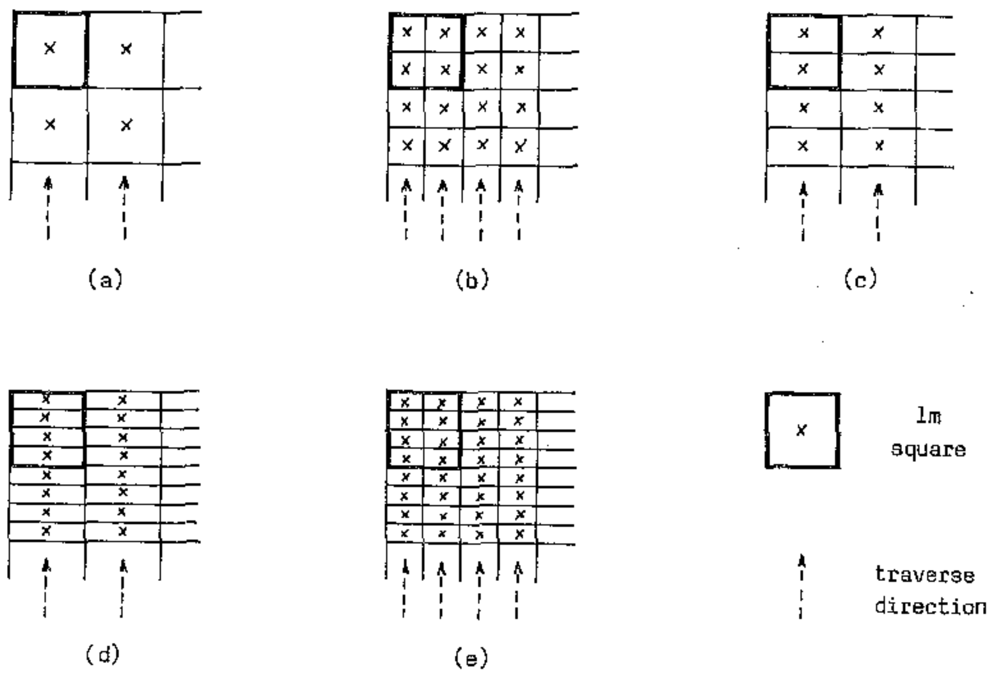


Figure 4-2. Possible data sampling patterns.

**(4) Traverse Pattern**

In an area survey the ground is covered by a sequence of traverses adjacent to one another, ( usually guided by specially marked tapes ). The traverses may be either in the same direction all the time, refered to as Parallel traverses, or may reverse direction for each new traverse - refered to as Zig-Zag traverses, figure 4-3 and 4-4.

Whichever method is chosen the **gradiometer** should always face the same direction, even for zig-zag surveying ( here the operator changes the way he is facing, but rotates the gradiometer in his hand to keep it facing the same way all the time. ) This is because it is difficult and time consuming to align and **MAINTAIN** the gradiometer so that it is truly orientation insensitive, section 3-5, to the degree required. It is much simpler to always keep it facing in the same direction.

The choice of traverse method is a compromise between speed of survey ( zig-zag traverses ) and higher quality data ( parallel traverses ). Since zig-zag traverses eliminate the return walk back to the beginning of the next traverse and are thus more efficient it might be thought that this should be adopted as a matter of course. In practice performance can be slightly degraded compared to parallel traverses. This is due to a combination of three factors.

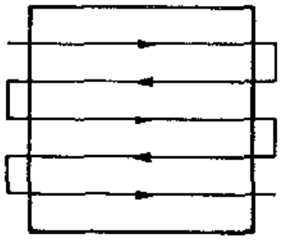

Figure 4-3. Zig-zag traverses

Figure 4-4. Parallel traverses

Firstly, if clothing etc. is slightly magnetic, then the position of the gradiometer sensor tube relative to the body, and hence relative to the clothing, will change for successive traverses causing a shift in reading. This may typically be of the order of 1-2 nT, possibly more, and will cause a stripe effect on the data.

Secondly, alignment or tilt errors building up over a period of time are more apparent for zig-zag traverses. This is because it is virtually impossible to hold the gradiometer **exactly** vertical all the time, and the tilt error will reverse for successive traverses causing a shift in reading. Again this may typically be of the order of 1-2 nT, and will cause a stripe effect on the data.

Thirdly, care must be taken to ensure that the sensor tube is always opposite the tape marker position ( figure 4-7 ) at the instant the data is logged, otherwise the data will be slewed or displaced forwards and then backwards for successive traverses. This occurs because there is a time delay between pressing the LOG key and the reading actually being logged, and the faster the walking pace the greater will be the slewing effect. Depending on the walking pace, slewing can be up to 0.5m ( 0.25m error for each traverse half ), possibly greater. Use of an external distance encoder will alleviate this problem since the delay between the trigger pulse and logging of the reading is much less.

Parallel traverses greatly reduce these potential problems since it is then much easier to maintain a constant, repeatable gradiometer position and tilt angle, and any slew errors are all in the same direction, causing no relative error. Parallel traverses should therefore be adopted whenever possible for the best possible data, especially on quiet sites and always if 0.1 nT resolution is being used. However, if time is critical or the features being surveyed have an anomally strength and width significantly greater than the errors just discussed then zig-zag surveying may be appropriate - with care the total error can be kept to about 1 nT.

**(5) Display Resolution**

For most applications 1 nT display resolution should be used. In the logging mode this will allow a reading to be stored with a resolution of 0.5 nT, which is usually below the "soil noise" on many sites. Soil noise is usually of the order of 1-2 nT but can vary anywhere between 0-10nT, possibly greater, section 6-x. However, if significant anomaly strengths are low, of the order of 1-3 nT, then 0.1 nT resolution with digital averaging should be considered - see section 3-4 - this may be required for example on sandy sites. If anomally strengths are slightly stronger, of the order of 2-5 nT then a resolution of 1 nT may be appropriate, especially if an encoder system is being used that requires a fast settling time, section 3-6, though 0.1 nT resolution should still be considered. A resolution of 10 nT is not normally recommended unless exceptionally high readings consistently above 2000 nT are encountered, as may occur on some industrial sites.

## 4-5 Laying out the Grid

The grid can be aligned in any direction to fit in best with any boundaries or physical constrictions. If there is a choice then align the grid so that its axis are aligned N/S and E/W. This may help in subsequent interpretation of the anomaly signatures.

Mark out the corners of each grid with non magnetic pegs. These may be plastic or aluminium tent pegs, or wooden stakes. Make sure that there are no nails left in the wooden stakes - these are often to be found in stakes from excavations. An as aid to defining a right angle Table 4-1 shows the diagonal dimensions of various grid sizes.

| Survey Grid Dimensions | Diagonal |
|---|---|
| 10 * 10 m | 14.14 m |
| 20 * 20 m | 28.28 m |
| 30 * 30 m | 42.43 m |
| 10 * 20 m | 22.36 m |
| 10 * 30 m | 31.62 m |
| 20 * 30 m | 36.06 m |

Table 4-1. Diagonals of various grid sizes.

## 4-6 Use of Survey Guide Lines

An efficient way of doing an area survey is to use a set of three tapes marked at appropriate intervals - two parallel lines which are fixed and one other which is moved perpendicular to the other two, shown in figure 4-5 for a 10m grid. The central perpendicular line is used as a guide for either zig-zag or parallel traverses. Figure 4-5 shows a zig-zag survey though generally a parallel survey will be used.

In use the first line of readings is made by traversing along one side of the perpendicular line. The gradiometer is held opposite the marks on the central perpendicular tape, at a distance of 0.5m for a 1m mesh or 0.25m for a 0.5m mesh. The second traverse is carried out on the other side of the line, either back down the line back towards the start point ( zig-zag ) or in the same direction as the first traverse ( parallel ). The perpendicular line is then moved on two line intervals, to the 3m mark, for the next two traverses and so on ( 5m, 7m, and 9m marks ) until the whole grid is completed.

This method is assumed in the guide to surveying, described in section 4-8, and is recommended for most surveys.

Do not use standard measuring tapes as guidelines since the winding mechanisms are usually very magnetic - they can have a significant effect at distances up to 2-3m away at 1 nT resolution, and at greater distances with 0.1 nT resolution. It is better to make the survey guide lines from plastic washing lines or nylon rope, marked with bands of coloured adhesive tape - see Appendix F for marking positions. Put loops at each end so that the line may be fixed in position.

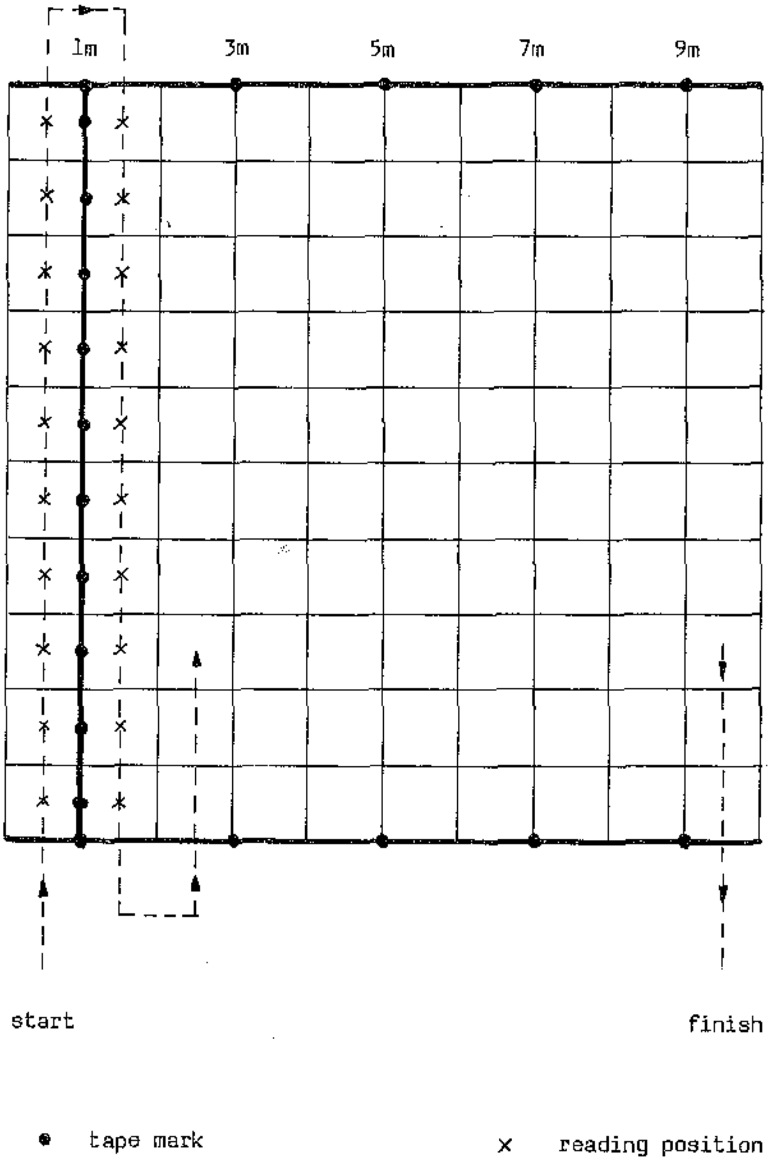


Figure 4-5. Use of Survey Guide Lines.

Experienced operators may be able to do away with the central perpendicular line. Instead sets of tall wooden stakes are placed at all the junctions where the perpendicular line would normally be placed and the traverses are paced out, using the stakes as direction guides. This requires considerable practice to get the pacing correct but can result in faster surveys.

A suggested way of using and moving the survey guide lines is to break the site into a number of strips. Orientate the two outer parallel lines so that they lie along the length of the strip. They can then be 'flipped' over for each successive grid and the perpendicular line moves progressively down the strip one traverse at a time, figure 4-6.

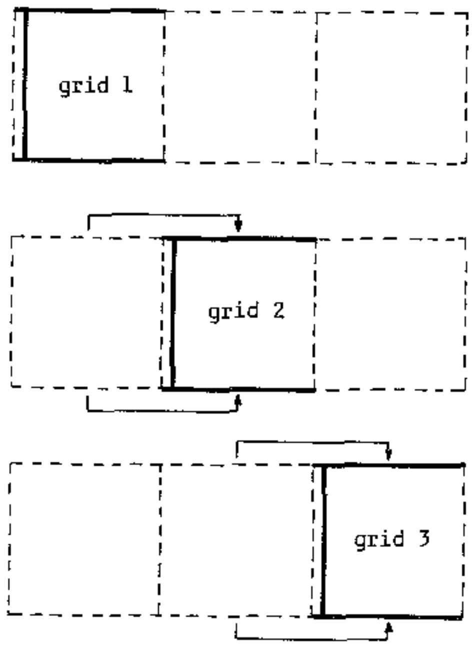


Figure 4-6. Movement of the survey guide lines.

## 4-7 Setting up a Zero Reference Point

To ensure that all grids of data match up with one another a Zero Reference Point is set up. Just before surveying each grid the gradiometer is positioned over the reference point, aligned in the same compass direction as the traverses, and the reading is then zeroed. Readings from different grids are therefore referenced to one another. The zero reference point is also used to monitor and log any drift occuring during the survey of each grid.

The zero reference point must be sited in a region where there are no localised changes observable - see section 3-5 (3) for guidance on selection of a good location. Great care should be taken in selecting the zero reference point since the quality of the data match and monitoring of zero drift depends on it. If there is a localised anomally then, unless the gradiometer is held at **precisely** the same spot each time, which is virtually impossible, grids of data will not match and, perhaps more importantly, the Log Zero Drift facility will lead to faulty correction of the data.

Choose a point within easy reach of all the grids and mark its position with a non-magnetic peg. Mentally note a point or feature some distance away which you can use as a sighting point to make sure you are always aligned with the central survey guide line each time the reference point is used. The fluxgate sensor tube should be positioned directly over the peg, and your body always positioned exactly the same way, each time the zero reference point is used.

# WARNING

IT CANNOT BE OVER-EMPHASISED THAT YOU WILL OBTAIN POOR QUALITY DATA IF CARE IS NOT TAKEN WITH THE USE OF THE ZERO REFERENCE POINT

The zero reference point may need to be relocated on a very large site, though avoid this if at all possible. If the point must be moved then make sure that the sensor alignment is properly adjusted and use 0.1 nT resolution with Digital Averaging Mode to transfer, and check, that the reading is zero at both points. Compare the zero a few times to make absolutely sure the reference points match.

## 4-8 Doing an Area Survey

### (1) Basic procedure

1 Record essential details of the site as listed on the survey sheets of Appendix G. This will be of use when it comes to presenting and interpreting the survey at a later date. In particular record the direction of compass North and draw a plan of the grid pattern with the names of each grid shown. Note the location of obvious physical features and where adjacent ferrous structures are located since they may well have an effect on the readings. However remove where possible any surface iron that is visible.

2 Check the fluxgate sensor alignment at the survey reference point and adjust.

3 Clear the gradiometer data memory. Select display resolution, usually 1 nT, and check the FM18/36 menu settings for log interval, grid size, average period, baud rate, external trigger type. Enable Digital Average Mode and Log Zero Drift if required. It is recommended that the Log Zero Drift mode is used routinely for all surveys.

4 Zero the reading at the zero reference point, taking great care to make sure you are aligned in the same compass direction as the traverse lines.

5 Take the gradiometer to the first survey position. Where one starts on the survey grid depends very much on how the data will be handled by the computer software. For example, GEOPLOT (HX20) requires that the survey starts at the top left hand corner of the survey, with the first traverse going from left to right, figure 4-5. If the correct procedure is not followed then the data will be interpreted by the program as a mirror image.

6 Position the sensor tube over the centre of the first measurement square. This will be opposite the first mark on the central perpendicular survey guide line, figure 4-7. Note that it is the sensor tube and not the gradiometer handle that is positioned centrally. Hold the gradiometer vertically and log the first reading, either in the FM18/36 or DL10 memory, or, if using an FM9 alone, on a gridded survey sheet such as that shown in Appendix G.

7 The gradiometer is moved to each position in turn along the first traverse. Log the reading when the sensor tube is opposite each tape mark. This procedure is followed until the end of the first traverse line. Take care to always hold the gradiometer vertical.

8 The second traverse is carried out on the other side of the line, either back down the line back towards the start point ( zig-zag ) or in the same direction as the first traverse ( parallel ).

9 On completion of the second traverse the line is moved on to its next position, figure 4-5, and traverses three and four completed.

10 When all of the traverses have been completed return to the zero reference point and Log Zero Drift if enabled.

11 At this point the completed grid may be dumped to a computer or the next grid started.

12 If the next grid is to be surveyed zero the reading at the zero reference point and resume surveying as described at point 5 in the sequence.

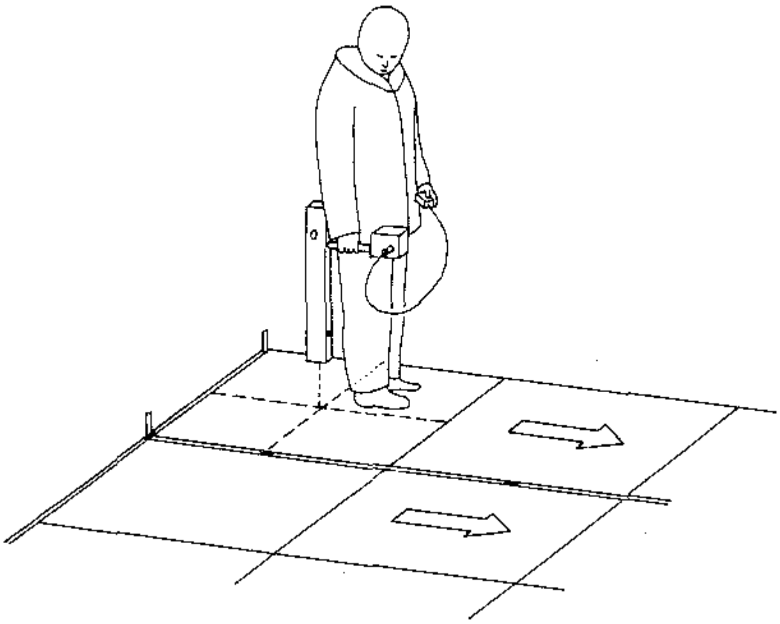

Figure 4-7. Correct positioning of the sensor tube for a reading.

The above procedure is summarised in figure 4-8. It is assumed that Log Zero Drift is enabled. If it is not then simply omit Log Zero Drift.

Align fluxgate sensors

Zero reading at reference point

Survey grid 1 - start top left hand corner

Log Zero Drift of grid 1 at reference point

Zero reading at reference point

Survey grid 2 - start top left hand corner

etc........

Figure 4-8. Flowchart for surveying with Log Zero Drift enabled.

### (2) Dealing with Obstacles at the Grid Edge

The FM18/36 has special provision for dealing with situations where blocks of the survey area cannot be surveyed and which occur at the edge of a grid. Two such areas, Area 1 and Area 2, are shown in figures 4-9 and 4-10.

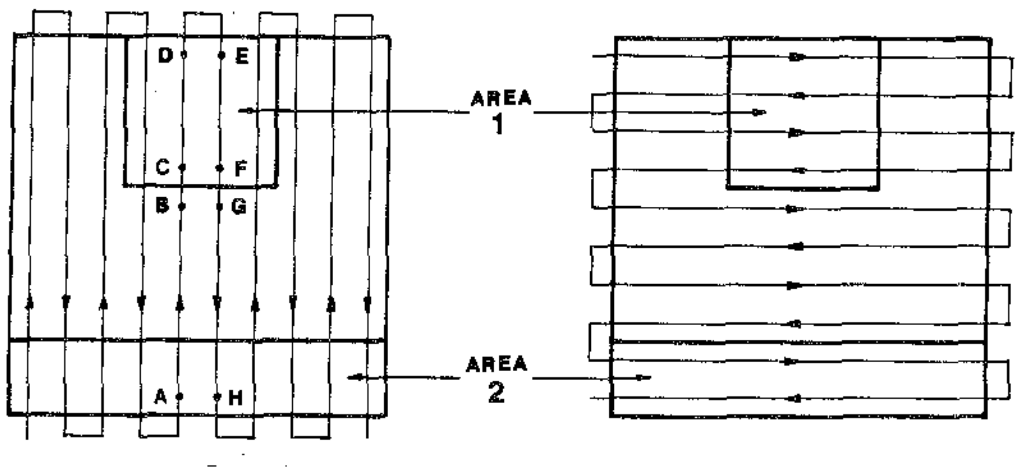


Figure 4-9

Figure 4-10

Consider Area 1 first. If the traverse lines run as shown in figure 4-10 then the obstacle can only be dealt with using the DUMMY LOG key. However, if the survey lines run as shown in figure 4-9 then the following procedure is much quicker to use.

Consider zig-zag surveying first. Proceed with the survey as normal up to the line starting at point A. Continue as normal along the line from point A until point B is reached and the last reading before the obstacle has been logged. Press the FINISH LINE key and this will insert dummy readings from point C up until the end of the line, point D. Next press IMAGE LINE to insert dummy readings from the start of the next line, point E, to point F. Now move the gradiometer to point G and the next reading may be logged. The rest of the line can now be completed normally, and the survey tracking facility will have allowed for the inserted dummy readings.

If the obstacle is first encountered at the start of a line then DUMMY LOGs must be used, though on subsequent lines the procedure just described can be used.

If parallel surveying is being used, then follow the general procedure described above up for the insertion of dummy readings up to point D. In this case, however, next move the gradiometer to point H and survey the next line as though starting affresh until point G is reached and press FINISH LINE to insert dummy readings from point F to E.

Next consider Area 2. If the survey lines run as shown in figure 4-10 then Area 2 may be replaced by dummy readings merely by using FINISH LINE as many times as required to cover the area. If the survey lines run as in figure 4-9 then the general procedure described above using FINISH LINE and IMAGE LINE should be used.

### (3) Quiet sites and use of the Digital Averaging Mode

The Digital Averaging Mode is used on quiet sites where the anomally strength is low - see section 3-4 for further guidance. Select the mode prior to starting, so that it is cycling through each average period, producing a 'click' at the end of each cycle. Move to the reading position, stand still, hold the gradiometer vertically and press the Log key. Keep the gradiometer as still as possible, standing stationary at the reading position until the cycle is completed. On hearing the warble signifying the end of the cycle you can then move to the next reading position.

If the site is very quiet and 'soil noise' is low, much less than 1 nT, it may be worthwhile holding the gradiometer nearer to the ground to enhance weak anomally strengths. Halving the height above ground will give roughly a threefold increase in signal strength, Appendix I. However you should not attempt to do this if 'soil noise' is significant since this will only degrade the superior signal to noise ratio offered by carrying the gradiometer at its normal height, Appendix I.

### (4) Differences with the use of the FM9

Most of the planning and procedures described in this section apply equally well to the FM9. The obvious difference from the FM18/36 is that readings will have to be recorded manually on gridded paper, such as that of Appendix G. Zero drift should also be recorded on the paper and used to manually correct the readings if it is felt neccessary.

If a DL10 is being used with the FM9 then it is most important to keep the DL10 well away from the gradiometer, at least 2m distance. This is because the DL10 will be magnetic and could affect the readings if brought closer. The rate at which readings can be logged by the DL10 is slightly lower than that of the FM18/36 so surveys will take slightly longer - see subsection (5) below.

Program GEOPLOT (HX20) has provision for the FM9/DL10 combination in the 'Logger' menu option. Readings for one or more grids can be stored in the DL10 and the corresponding zero drifts recorded manualy on paper. When the data is input the program asks for zero drifts to be input manually at the same time.

If it is convenient to log and dump one grid at a time ( 10m or 20m squares only ) then, after the grid is completed, zero drift may be logged in the memory at the position which would normally be used for the first reading of the second grid. Configure GEOPLOT to accept data from the FM18/36, not the FM9/DL0 combination, and the zero drift will be input automatically after the data. Note that the range digit stored in the DL10 will always be zero, Section 6 of the DL10 manual, and thus GEOPLOT will reconstruct the data as if a resolution of 0.1 nT was being used, Appendix B. The FM9 can therefore only be used in this fashion with 0.1 nT resolution. No such restriction applies if the FM9/DL10 combinatio is used normally with GEOPLOT.

When in the Digital Averaging Mode the FM9/DL10 combination cannot store the averaged reading, unlike the FM18/FM36. Averaged readings only appear on the FM9 display, not the analogue output, so the DL10 will not store an averaged reading. They will therefore have to be recorded manually.

### (5) Survey Speed

Greatest survey speed will obtained if one operator has charge of the gradiometer and concentrates solely on the traverses and data dumping, whilst one or more assistants are employed to lay out grids, move the survey guide lines etc. Laying out an extra central traverse guide line, in advance of the current traverses, will further increase speed.

When sampling at 1m intervals a 20m traverse can be comfortably walked in 20 seconds. For a 20m grid with 1m line separation (400 readings) the zig-zag surveying time comes to about 7 minutes. The equivalent parallel survey time will be about 14 minutes, allowing for the return walk back to the start position each time. To this must be added the time to move the survey guide lines. Typically this could take from 6-12 seconds per line movement, adding a further 1 to 2 minutes per grid. Moving the lines on to the next grid can add a further 3-4 minutes. The total survey time is therefore 11-13 minutes for zig-zag, or 18-20 minutes for parallel surveys. Three to five 20m grids, at 1m sampling interval, can therefore be surveyed per hour, depending on the method chosen. Recent field trials by experienced operators have shown that areas of 1 hectare may be surveyed at 1m intervals by two people in about 5 hours.

## 4-9 Doing a Line Survey

The basic procedure for a line survey is much the same as described above for an Area Survey. The basic difference lies in the way the survey tracking facility is used. The key to using the tracking facility is to remember that readings are logged sequentially in the gradiometer memory, regardless of grid size, reading interval etc. Thus a grid size of 20m and reading interval of 0.25m simply stores 80 readings per traverse - the readings do not neccesarily have to be 0.25m apart. The possible combinations of grid size and reading interval can give line lengths of 10, 20, 30 40, 60, 80 and 120 units.

Adjacent line traverses may be logged just as though they were traverses in a normal grid, though the line separation will be larger than the 1m normally assumed - see LOG key, p22. Thus by programming the FM18 (FM36) for 20m grids and a reading interval of 1m, 200 (800) adjacent lines may be logged, Table 3-3, by ignoring the grid boundaries.