Section 5: Land Surveying - Detail Survey

Types of Survey.

Although a browse through the library or internet pages will reveal a number of related types of land survey there are perhaps four main branches:

Geodetic Surveys

These are surveys, which are generally carried out on a national basis, providing a framework of precisely located survey stations some distance apart. Account is taken of the curvature of the earth and the accurate measurements used form part of the science of Geodesy in which the size and shape of the earth are examined. Geodetic survey stations are used to control both *Topographic* and *Cadastral* surveys. These days, although rare, provision of framework control at a national level is most likely to be done using GPS.

Topographic Surveys

These are surveys where the physical features of the earth are measured, and maps and plans prepared to show their relative positions both horizontally and vertically. Depending on the extent of the survey these may be either *geodetic* type surveys or *plane* surveys, where no account is taken of the earth's curvature. Ordnance Survey maps are topographic – they show real world features that appear on the ground. Property boundaries will appear if they also coincide with topographic features, they will not appear otherwise (although some inferred boundaries now appear in OS MasterMap).

Cadastral Surveys

These are more a feature of mainland Europe and other overseas countries; it is not something that we have in the UK. Cadastre surveys are usually undertaken to define and record the boundaries of properties, legislative areas and even countries. In many cases cadastral surveys will be almost entirely topographic, with features defining boundaries. The survey tends to be relatively precise with the co-ordinate positions and nature of the boundary defining features recorded as part of the survey. Again geodetic principles may have to be applied in the case of country boundaries, but much of the work consists of plane surveying.

Engineering or Site Surveys

These are surveys undertaken to provide information for construction projects. They are generally large-scale topographic surveys and usually plane surveys except on very large construction projects.

Principles of Survey.

Whatever type of survey is being carried out, it will be governed by several fundamental principles of survey, some of which have already been touched upon in the preceding sections of the reference guide:

Control

The first principle is to establish a framework within which to work ("from the whole to the part"). This is typically a system of control stations, positioned to a high degree of accuracy. Surveys between these control points can then be carried out by less elaborate methods. Any errors, which then arise, are contained within the framework of the control points and can be adjusted to it. Errors will therefore be restricted in magnitude and will not be allowed to accumulate throughout the whole survey. Traditionally, this has generally been achieved by starting with a very rigid framework of primary triangulation, which is broken down by second and third order networks. As previously mentioned, the framework is more likely to be fixed by GPS these days.

Checking

The second principle is that all survey work must be checked. Using good survey procedures will ensure that many operations are self-checking, but when this is not possible independent checks should be applied before the survey is completed.

Economy of Accuracy

Economy of accuracy means that the standards of accuracy should be proportionate to the needs of the task and no higher. For example Great Britain has been divided by Ordnance Survey into urban, rural and mountain/moorland areas, and appropriate accuracy standards have been set for each area. An accuracy greater than that of the control used cannot be achieved. Also, the higher the accuracy, the higher the cost. The 1:1250 scale accuracy appropriate for urban areas would be very expensive to achieve in all areas – but more importantly, it would not be required.

Consistency of Accuracy

The same standards should be maintained for each stage of the task. This applies not only to the accuracy, but also to the quality of the control used and to the density of control or detail points provided. In the case of Ordnance Survey consistency is achieved by having sets of rules and guidelines, a specification for the data, and quality systems for data capture, maintenance, and the creation of the final data products.

Revision

If it is at all possible, any requirements for future revision should be allowed for when planning a survey scheme. When traversing was used by Ordnance Survey as the primary means of providing "minor control" i.e. accurately positioned control stations from which features could be captured, stations had to be sufficiently permanent and well positioned to be useful in the future. With the use of GPS now this principle is still relevant, for example, in timing the survey of large housing estates, to obtain maximum benefit without several repeat visits.

Safeguarding

If permanent stations have been sited, they will be of no use in the future if they cannot be found. The station mark should be as permanent as possible. The mark needs to be found in the future, so some sort of documentation will be required. The station will need a reference number, its exact position recorded and a dimensioned location diagram. Ideally such records will be updated and amended as necessary. This is still relevant today for Ordnance Survey although only for the network of GPS fixed control stations rather than the thousands of minor control stations which once needed to be maintained.

Detail Survey – what to survey?

In discussing land surveying in the context of Ordnance Survey large scale maps we can differentiate between the control surveys required to fix a network of GPS permanent stations, and the capture of real world features on the ground – which is referred to as "detail survey". Detail can generally be subdivided into either:

- Natural or man made features whose extent and shape can be shown on the plan to scale;
- Natural or man made features whose extent cannot be shown on the plan to scale, but which are sufficiently prominent to be of importance. Detail of this type is normally depicted by a standardised symbol.

As seen in the "Ordnance Survey Large Scales Map Data" section of the reference guide this detail can be further classified as either[1]:

- **Definite Detail.** Normally man made features such as buildings, roads, walls and fences whose position can easily be defined and checked both on the ground and on the plan.

[1] See also Ordnance Survey's Land-Line and OS MasterMap user guides for definitions. http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/guides/userguide.html and http://www.ordnancesurvey.co.uk/oswebsite/products/landline/pdf/lluserguide.pdf

- **Indefinite Detail.** Typically, natural features such as areas of vegetation or water, which are incapable of exact definition or are liable to change.
- **Overhead Detail.** Detail which constitutes no obstruction at ground level. (e.g. overhead gantries, power lines etc.)
- **Underground Detail.** Detail located below ground surface level. (E.g. water pipes, sewer pipes etc.)
- **Interior Detail.** Internal features of a building which may or may not determine property boundaries. Normally internal features shown on Ordnance Survey maps are restricted to the divisions between buildings, where they can be seen to extend through the whole building, and to roof level. Surveyors may occasionally be called upon to survey internal floor layouts for land registration cases, particularly when there are overlapping extents at different levels – typically in very old properties.

The type and amount of detail that is surveyed for any particular task varies enormously, and depends primarily upon:

- The scale of the final plan.
- The intended use of the plan.

Detail Survey – how to survey?

Detail survey is a process of completing a map by *ground methods* (i.e. not photogrammetric), within a framework of control. Ordnance Survey surveyors generally use three main ground methods – GPS, graphic survey, and ground surface measurement. As seen in previous sections of the reference guide the methods chosen will be dictated by a number a factors which include economy, the scale of mapping, resources, and health and safety issues.

To differentiate between these main methods this section will consider GPS survey separately, and then combine graphic survey and ground surface measurement under the combined category of *detail survey*.

GPS is typically used by surveyors with a combination of two receivers; one is set up as a base receiver providing the DGPS corrections for the other "roving" receiver. The roll out of a Wide-Area RTK network Infrastructure in 2004 will mean that the 30 or so active GPS stations will be increased to over 130 and it will be possible to use single receivers, in conjunction with the fixed permanent stations, to provide real time detail data capture.

For "infill" of features, either supplementing the GPS survey, or in isolation using existing features as control, detail survey using a combination of graphic survey (lines of sight) and ground surface measurements, with simple survey tools such as an optical prism and a tape measure, is difficult to beat in terms of economy, speed of survey, and accuracy.

- **Graphic Survey –** Map detail is supplied using a combination of lines of sight - shots, rays, intersections, trisections, alignments (straights), and short measured distances. The method is based on the principle that a straight line on the ground is represented by a straight line on the map;

- **Ground Surface Measurement.** Measuring single points, lines or a network of straight lines from accepted control. New map detail can then be fixed by a series of direct measurements taken either at right angles to the measured line, or along a known alignment.

Detail survey must be based on a framework of control. This can take the form of either GPS points and / or existing map detail from previous surveys. By using this framework, the method ensures "local sympathy" and relative accuracy. The density of control needed depends largely on the accuracy requirements which in turn are dictated by the scale of mapping for the area. Ordnance Survey detail survey is normally carried out by a lone surveyor using the following equipment:

- Optical Prism - enables the surveyor to establish alignments and intersections without the necessity of walking to the terminals of the lines. The surveyor looks into the prism and sees two images – each one at 90º to the direction in which he/she is facing. By getting features, for example house corners aligned on top of each other in the prism, the surveyor knows that the prism is exactly on line between those features;

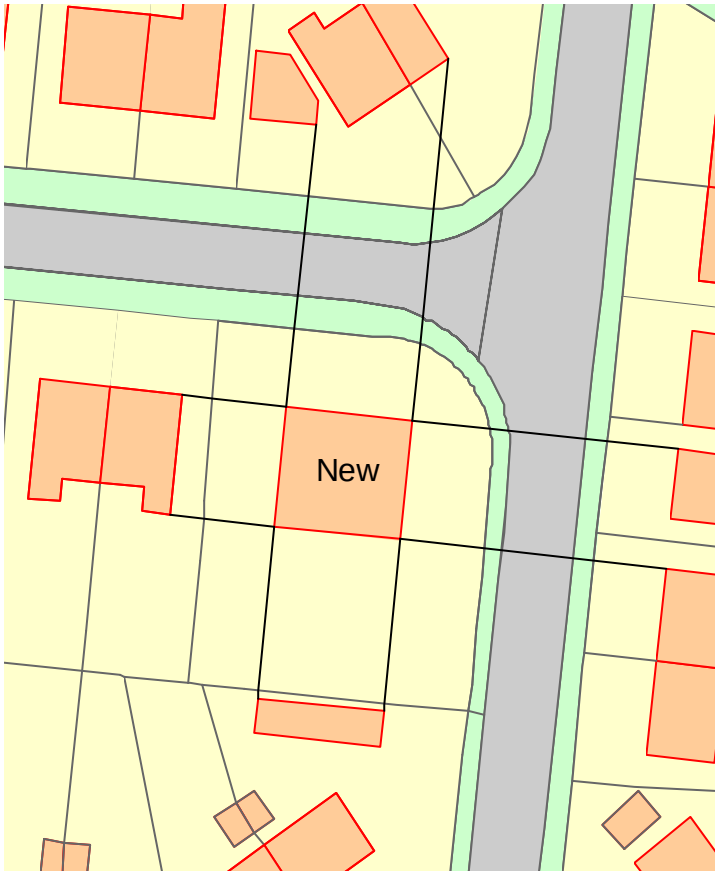
- Tape Measure -usually 20m or 30m, for short measurements. The Ordnance Survey surveyors may alternatively use a DISTO laser distance measurer;
- Tablet PC - with specialist PRISM data capture software;

Until the last decade the surveyor would not have had the PC in the field and would have had to use a “sketching case” to mount the map upon and:

- Scale and pencil. For scaling and plotting measurements;
- Straight Edge. For drawing alignments. (shots, rays etc.)
- Set Square. For field plotting of parallel lines and offsets.
- Small Notebook. For recording measurements prior to plotting.

Graphic Survey - method

Graphic survey is a method used extensively for map revision when there is plenty of existing map detail to which the new features can be related. The existing features are used as "control" – the framework within which the new features are added. New and changed topographic detail is surveyed using a combination of lines of sight, measured straight lines and short reference measurements. It is based on the principle that a straight line on the ground is represented by a straight line on the map – and in the data. The basic concept involves the creation of a framework of control on or around the detail to be supplied (surveyed), using existing detail points. The objective is to minimise ground surface measurements and to correctly locate the new features on the map. Ordnance Survey surveyors will normally use a portable laptop device (PRISM) for recording detail surveyed in this way, although there may be occasions when a Tempory Survey Document (TSD) has to be used. A TSD may be used for example for Land Registration cases when write permission to obtain the data fro PRISM is unobtainable, or in sites where electronic/electrical equipment is forbidden.



This example left shows an ideal situation. The new house in the centre of the map can be surveyed using lines of sight along the edges, or "straights", of the building. The lines of sight, in this case conveniently fall onto existing features – or control. In reality the lines of sight would probably fall close to the points of detail and could be positioned by using short reference measurements.

If the distances to control points are too long to comply with Ordnance Survey rules they can be broken into smaller portions by using graphic techniques such as intersections, or in-direction measurements.

Any tape (or DISTO[2]) measurements should be taken along straight lines, which may be single or part of a network of straight lines – measurements are taken between reliable points of controlling detail or intersecting lines of sight.

Measurements taken over sloping ground must be reduced to the horizontal plane before plotting. The density of controlling detail should be sufficient to ensure that all single measured lines and the measured segments of lines cut by shots/intersections (these terms are described in the following sections) do not exceed the following distances:

Maximum permitted distance (tape/DISTO):

1:1250	Resurvey and subsequent revision	60m
1:2500	Resurvey and subsequent NG-controlled revision	100m
1:2500	Overhall and subsequent NG-controlled revision	100m
1:2500	Overhall and subsequent uncontrolled revision	200m
1:10 000	Resurvey and subsequent revision	500m

There will be exceptional situations where, for example, the proximity of a large building, woodland or topographic feature prevents the cutting of the measured line with a shot. In these instances the measured line can be continued to the selected terminal controlling detail.

An important principle of graphic survey is that all measured lines must “tie out”, that is, the distance scaled from the data must compare with the measured ground distance within stated tolerances (these are listed in the table in the section Ordnance Survey Large Scales Map Data – under Revision controlled by Graphic Survey). Overall precision is maintained by equating the scaled line – i.e. by distributing any small errors evenly throughout the scaled distance, after tying out.

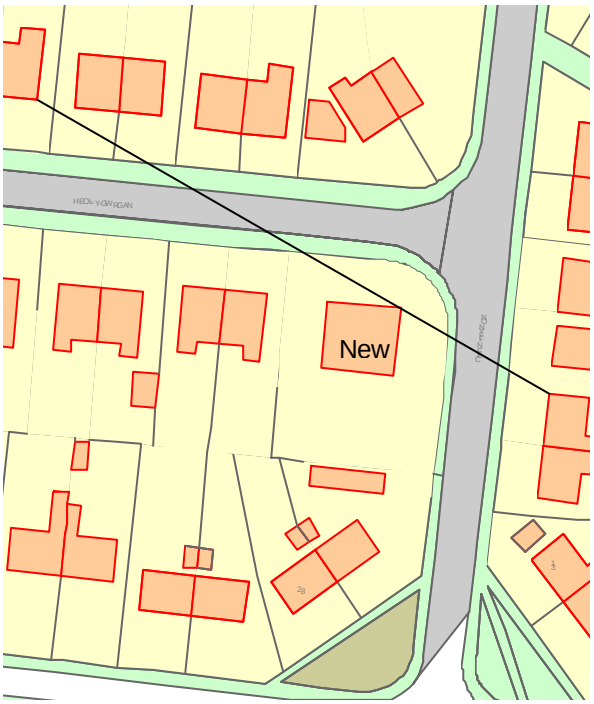
The framework of control may be established by using the following methods:

[2] Hand-held laser distance measurers – see http://www.disto.com/

Ray

A ray is a line of sight between two existing points of map detail. It doesn't have to be along the straight of the building but it should ideally use sharply defined corners or junctions of existing detail.

In the examples on the following pages the features are all in 1:1250 areas of mapping and there is plenty of existing control. In 1:2500 or 1:10,000 areas the amount of existing control can often be sparse and poorly defined.



Shot

A shot is a line of sight from one point, through a second point, to a third point. The terminals are existing map detail and the intermediate point is usually the point to be fixed.

In this example to the left a shot has been placed from one existing building corner to another existing building corner - just grazing the corner of the new building which has to be surveyed.

A shot is often used as a check when a feature has been positioned using a combination of "straights" and measurements.

Intersection

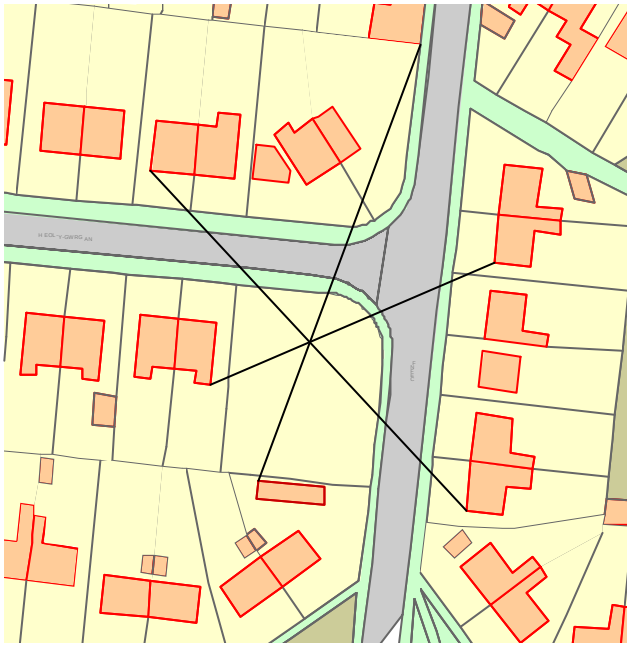
An intersection is the point where two rays, shots or straights cross each other. The exact location being identified on the ground and plotted on the map. The lines forming an intersection should cut at an angle of greater than 30º. An Intersection will not show any error (the two lines will always cut each other) and should be checked by measurement or another line of sight.

This is a useful way of breaking down larger areas in order to minimise the amount of taping required.

Tri-section

A tri-section is the point where three rays, shots or straights cross each other. The exact location being identified on the ground and plotted on the map. This can be achieved, like the intersection, with the aid of the optical prism.

A trisection by its nature is self-checking (the third line cutting the intersection formed by the first two). Ideally the lines should cut each other at angles of about 30º, which in this example they do, but this might not be so easy in 1:2500 or 1:10,000 areas with much less control available.

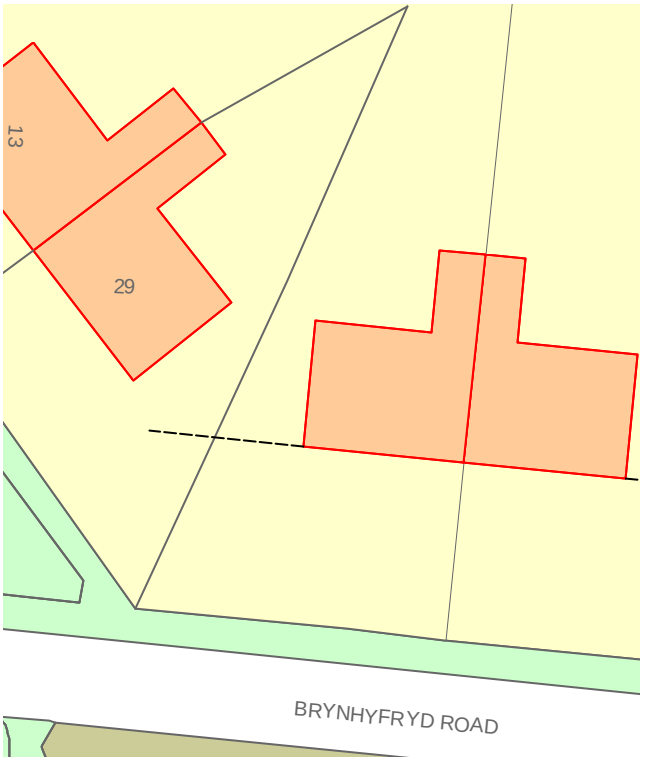


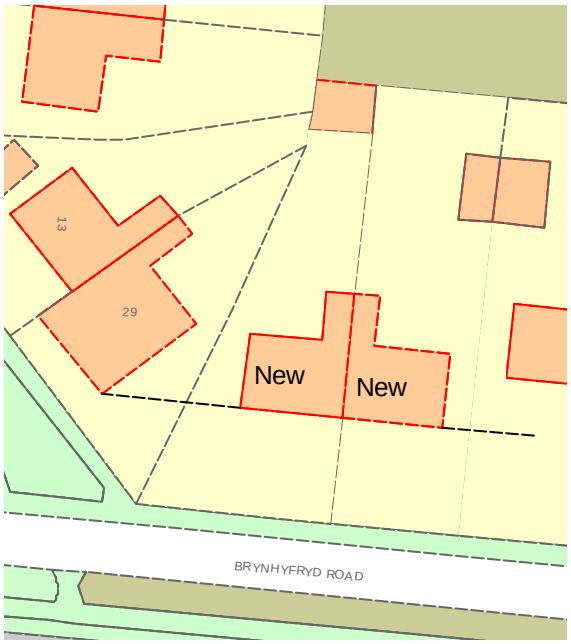
Straight

This refers to the alignment of any straight piece of ground detail e.g. the side of a building, a wall or fence etc.

In this example, to the right, the line of sight is the continuation of the front of the building. By fixing this line at both ends, in relation to existing features, the alignment of one side of the new feature can be positioned.

Using straights is a good method to use for capturing new houses or other new buildings, especially if the straights are long and there is good control surrounding the new feature.





Shooting a Straight

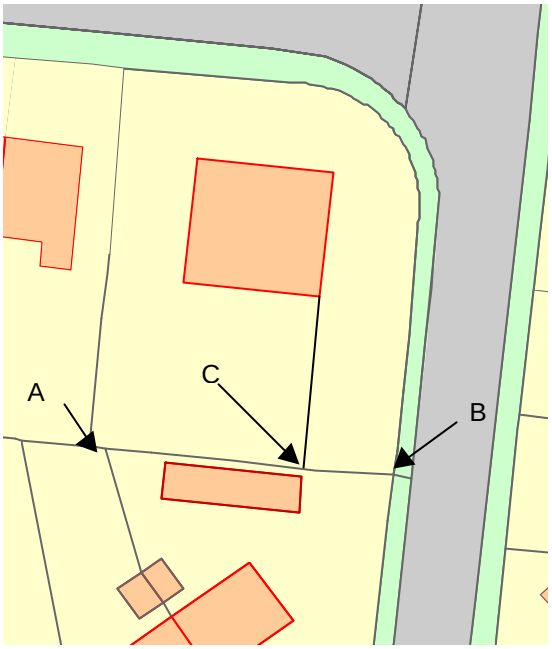
This expression is used to describe the method used to determine a point where the extension of a straight, **away from the observer**, hits a piece of existing detail or other measured line.
In the example to the left the surveyor, to the right of the new buildings, looks along the straight and “shoots” it into the corner of an existing building. Assuming that the near end of the straight can be fixed, this then provides the alignment of one side of the new building. Ideally the longest side(s) should be picked up this way, and then the corners fixed by more lines of sight or by measurement.

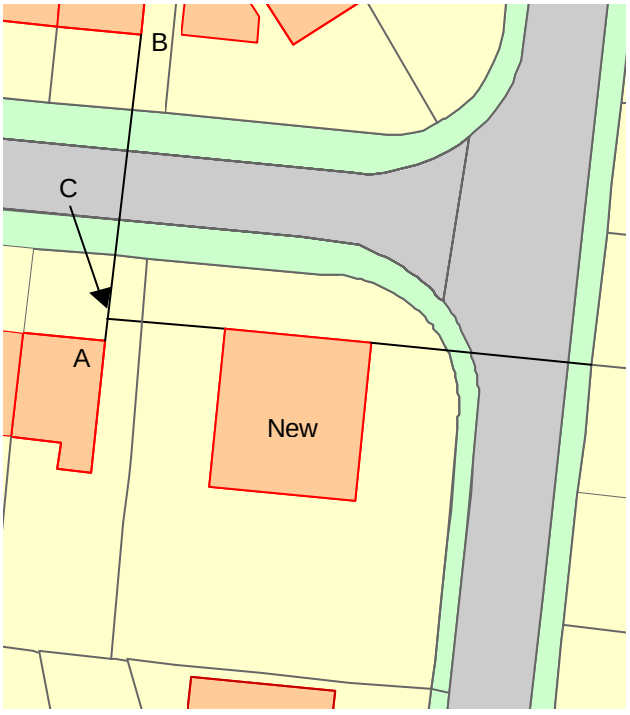
Picking up a Straight

This means determining a point where the extension of a straight, coming **towards the observer**, hits a piece of existing detail or a measured line.

New

In this example to the right, a line is measured from point A through to a tie-out point at B. As the surveyor moves towards B the straight of the new building is “picked up” at C and the measurement recorded. In this particular example the straight also goes through to the corner of the building to the south. Ideally the straight can be picked up at one end and shot through to detail at the other end.



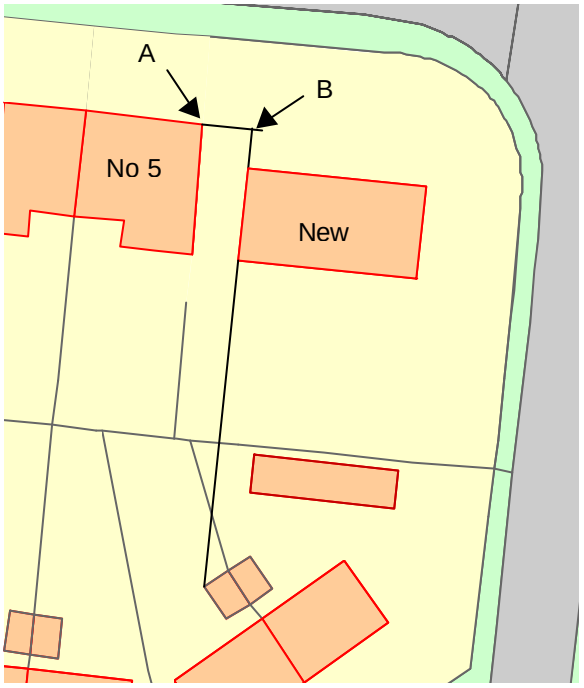


In-direction Measurement

An in-direction measurement is one that is taken from a known point towards another, the line not being measured throughout its length. Over short distances pacing may even be acceptable for the survey of indefinite detail and for surveys at 1:10000 scale.

In the example left, a measurement is taken from A to C in-direction of point B. The distance is only 1.1m and leaves little room for error even though it has not been “tied–out”.

The in-direction measurement is similar to a reference measurement, but not taken along an existing feature.

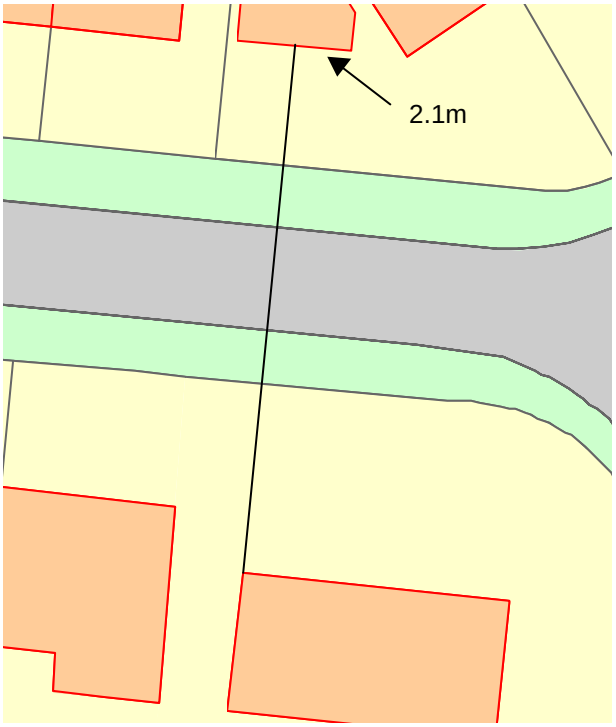


Production

This is the prolongation of a straight line joining two known points in order to supply detail on or from the prolongation.

In the example right, line AB has been created by the "production" of the line of sight along the front of No 5. The side of new building has then been "shot" onto the corner of an existing building to the south.

In using a production the distance AB should never be more than one third of the total distance of the straight used. It is also good practice not to use the new building thus surveyed to control any further survey.



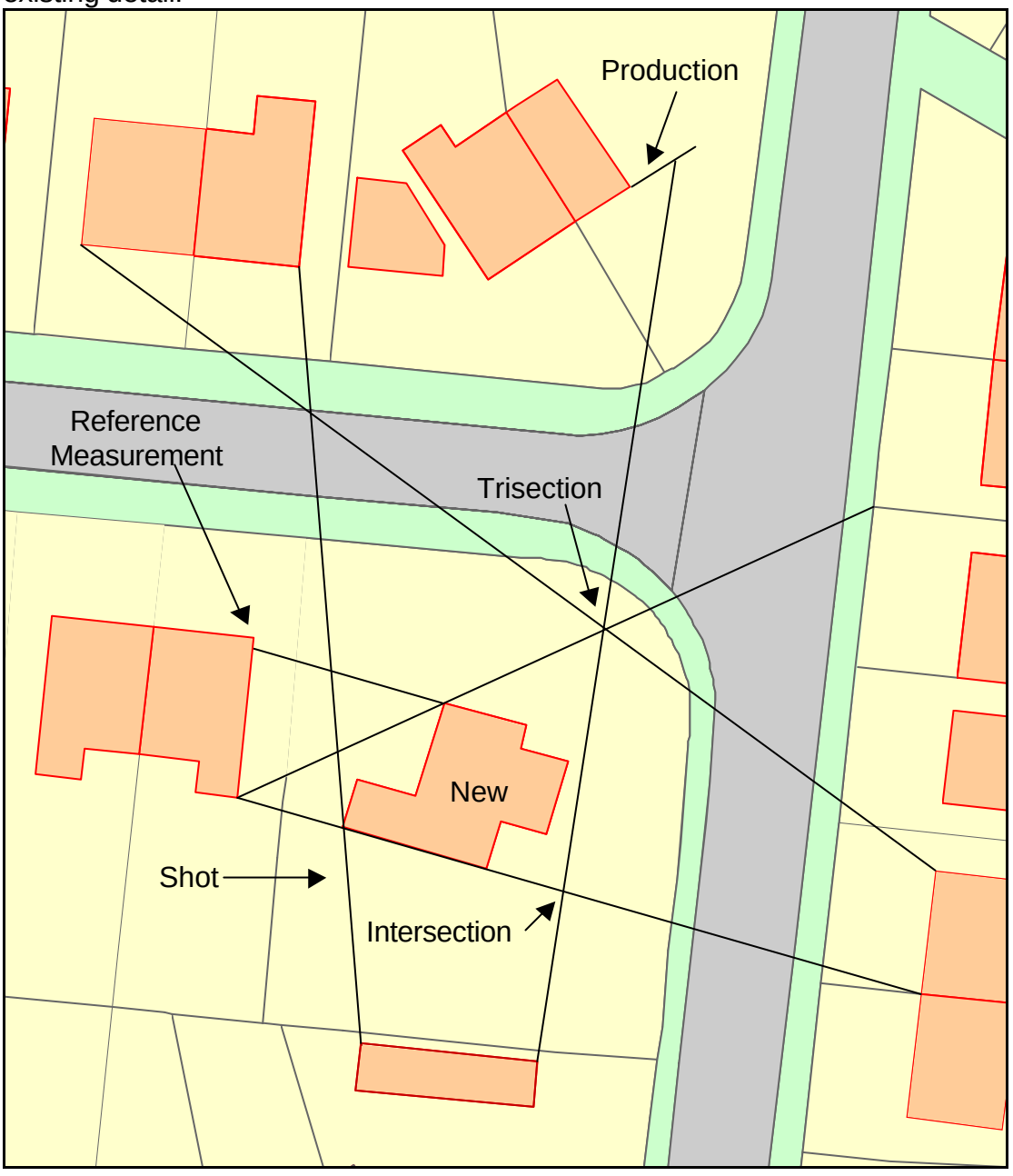
Reference Measurement.

A reference measurement is a short measurement (it should be kept to less than 5m) from a known point on a feature and measured along that feature, the line not being measured throughout its length.

In the example left, the straight from the building opposite has been "picked up" on a building to the north. A short reference measurement from the building corner of 2.1m leaves little room for error, although in this particular case it would be easy to "tie out" the measurement by continuing the measurement across the complete face of the building.

Examples of Methods

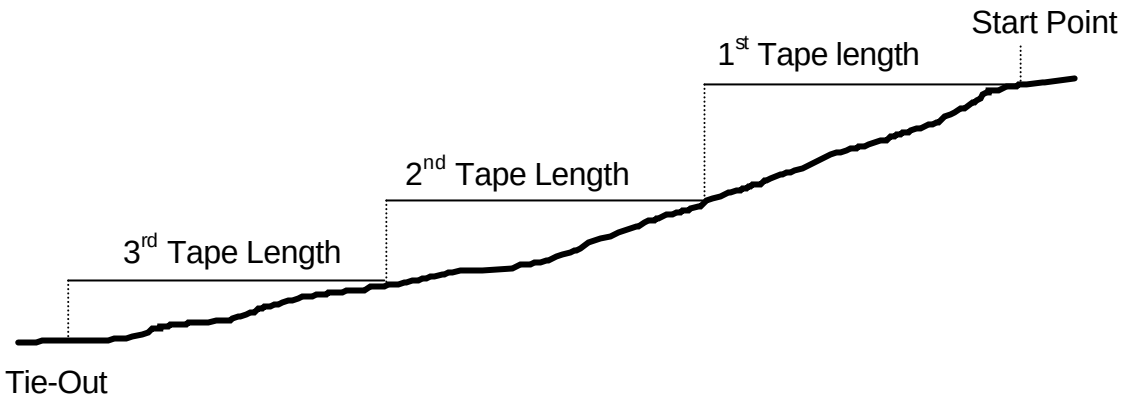
This diagram illustrates some of the many terms used to describe methods of graphic survey. In addition to the ones in the diagram, the lines of sight along the "straights" of the building being surveyed have been "shot" (away from the surveyor) in direction of existing detail or "picked up" (towards the surveyor) with reference to existing detail.



Ground Surface Measurement.

The preceding paragraphs have described how graphic survey techniques can provide a framework of control for the survey of new detail. Some of the examples show very idealistic situations in which all the lines of sight fall onto or near existing detail.

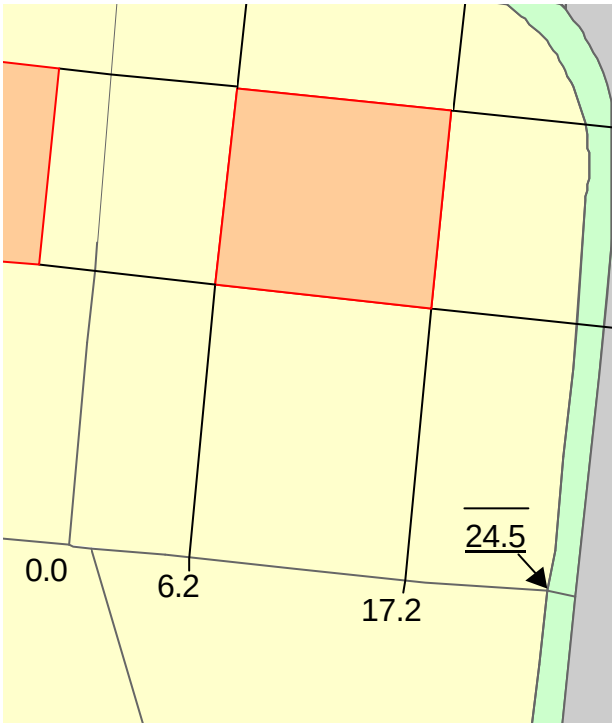
In reality of course, particularly in rural and mountain/moorland areas where there is not the density of detail that exists in urban areas, it will often be necessary to measure lines to supply the required detail. For Ordnance Survey surveyors this will normally be done with a fibron tape measure or DISTO laser measurer. Taped lines should be "tied out' which means that the line will start and finish on identifiable points and a check made to ensure that the taped distance agrees to the scaled distance on the plan (as described already - within acceptable tolerances). It is very important to remember that the distances shown on Ordnance Survey maps are horizontal distances. This is particularly important when comparing deed plans and Ordnance Survey mapping in areas of steep terrain where the differences between horizontal and sloping measurements can be significant. When measuring, the tape should be kept horizontal and on the overall alignment of the line to be measured. Any deviation from the line will result in a longer distance being measured. Taping should be done downhill, keeping each tape length horizontal.



Surveyors will normally mark the end of each tape length using chalk if on concrete or tarmac or using sticks or stones on soft ground. If a mistake has been made in counting the number of tape lengths, marking the ends may save you having to re-measure the entire line. The tape is read to the nearest 0.1m.

To keep the alignment of the taped line straight between the terminals, the line can follow detail or be kept by use of the optical square. The line should always be measured throughout its whole length; a start to finish distance rather than measured in sections.

When supplying detail from taped lines, the two most commonly used methods for capturing new detail are by “picking up straights”’ and taking “offsets”.



Pick Up a Straight.

In the diagram left the surveyor has measured along a feature to the south side of the new house to ‘pick up’ the straights. The surveyor has measured a line between two points to ‘pick up’ the straights and has tied out at 24.5m.

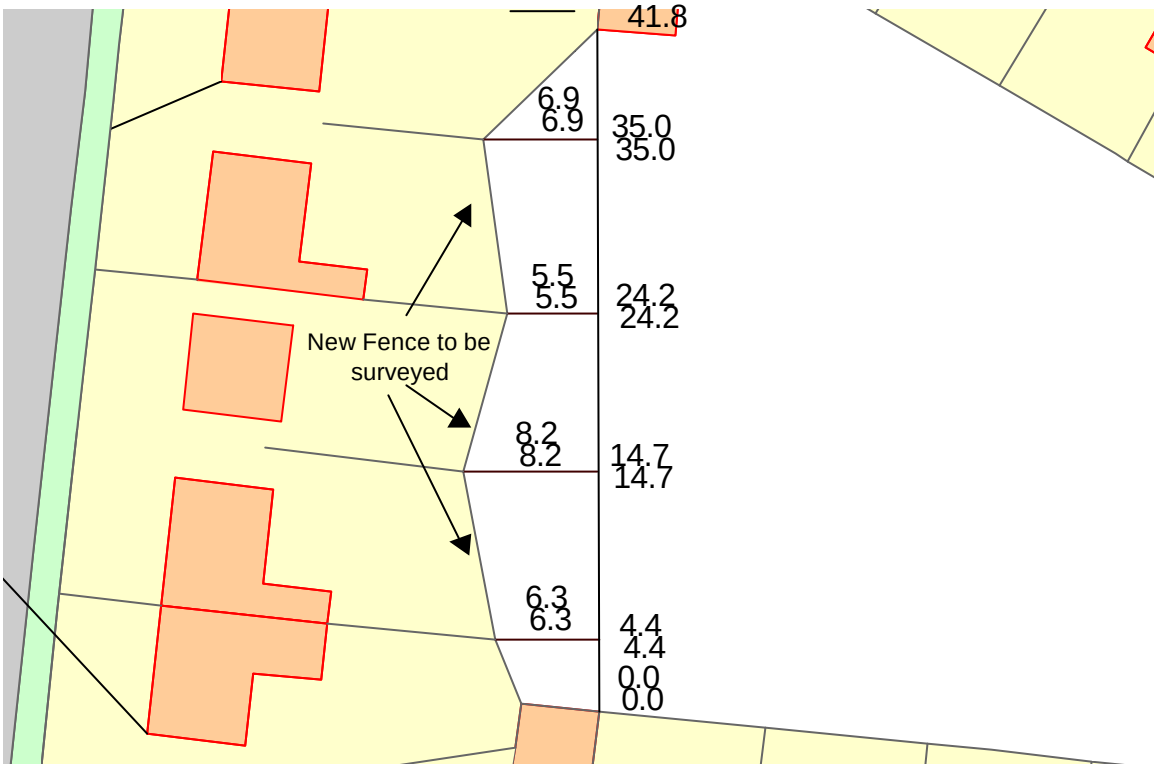
To be able to complete drawing in the alignments they must also be “picked up” or “shot” on the other side of course. Having got both ends of the straights secured the corners can be fixed by further lines of sight or, more commonly, by measuring along the straights that have already been fixed.

Offsets

An offset is a measurement taken at right-angles from a point on a base line. The permitted offset is limited to one third the length of the base line, subject to the following maxima:

	1:1250	1:2500	1:10000
Definite point of hard detail	8.0m	12.0m	30.0m
Other detail	12.0m	16.0m	40.0m

Establishing a right angle from the measured line is usually achieved by using an optical square (popeye). Alternatively, using a second tape measure the surveyor can hold the zero end of the tape on the point of detail and swing the tape through the measured base line. The minimum reading obtained occurs when the tape is perpendicular to the measured line. Offsets can be plotted by using a setsquare to draw the required perpendicular lines.

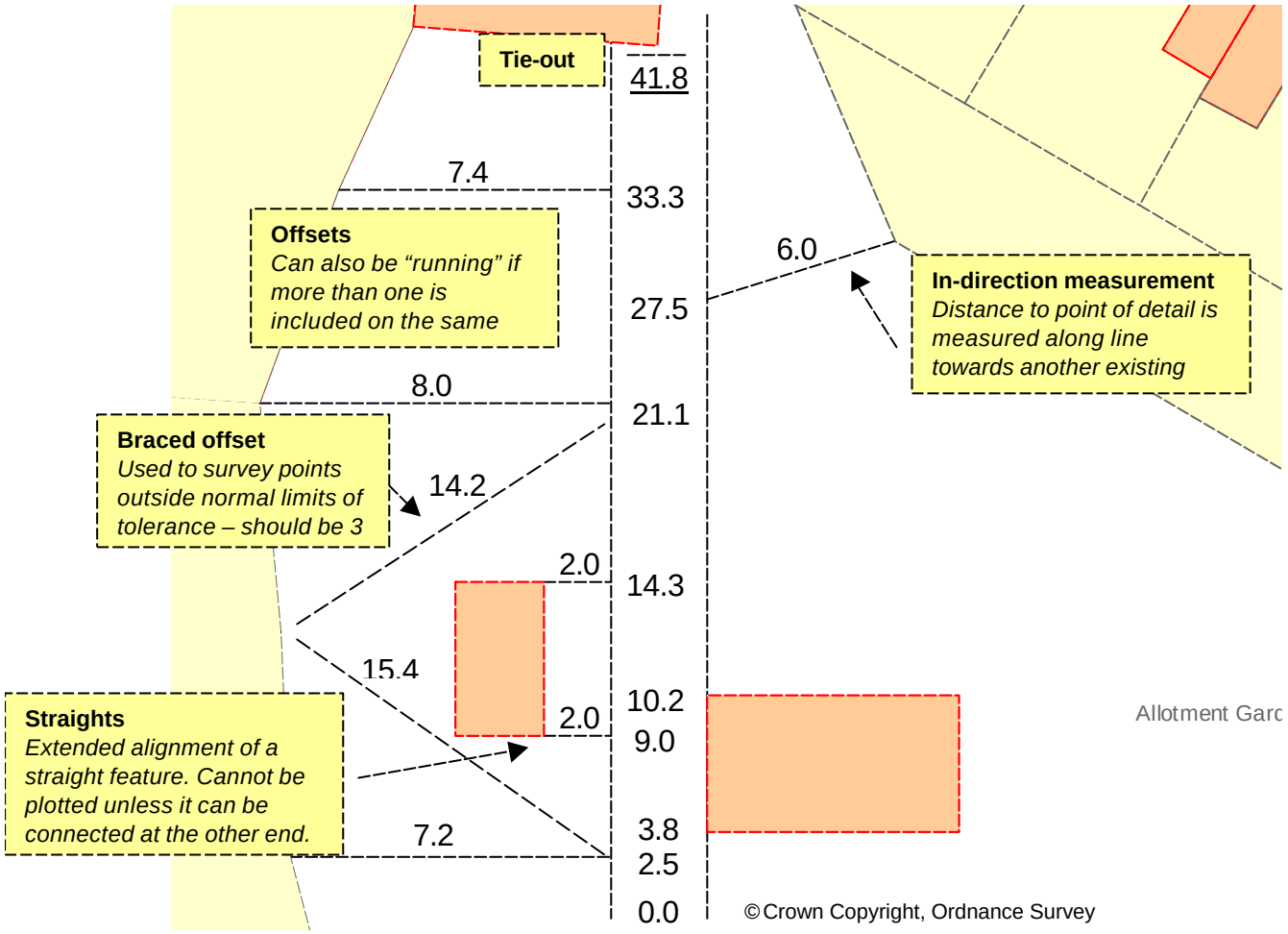


In the diagram above the surveyor has measured a line between two existing buildings, which is close to the new fence feature to be surveyed. The line has been "tied out" at 41.8m. Offsets are raised at right angles to the measured line to each corner on the new feature and to selected points on the curved section. The length of each offset is measured.

Booking

Although today most measurements are keyed directly into PRISM software by Ordnance Survey surveyors, when using non-electronic methods the technique used for booking measurements made during detail survey goes back to that used in the days of chain survey. Most surveyors adhere to basic rules which then enable other surveyors to understand what has been recorded. This is useful as it allows an independent check of the work, or completion of a task by a different surveyor. Clarity and accuracy of booking are obviously essential. Although neatness is desirable, mistakes inevitably occur and should be cancelled and amended in the field. The rewriting of bookings in the office should be avoided wherever possible as this can lead to mistakes, which may go undetected. Traditionally, measurements along a taped line are normally recorded within two parallel lines ruled down the centre of the page. Distances along the line are be entered from the bottom of the

page and proceed sequentially. Detail "picked-up" along the line either as an offset, straight, reference or in-direction measurement etc. should be sketched on the correct side of the parallel line in its approximate position relative to other detail. Distances recorded to this detail should be positioned on the booking sheet to avoid ambiguity. For lines, which have been tied out, the total length of the line is entered at the top of the page and is under and over scored.



Accuracy

As already mentioned detail supplied by direct relationship to existing detail, following the guidelines and permitted tolerances, will be accurate in scale and orientation. The relative accuracy will be good, but of course cannot improve on what already exists. Taped measurements are subject to several sources of error and Ordnance Survey surveyors use the following guidelines for the maximum permitted difference between measured and scaled distances:

1:1250	0.2m for lines up to 60m
	1:1000 for lines over 60m
1:2500 Resurvey	0.5m for lines up to 100m
	1:1000 for lines over 100m
1:2500 Overhaul	0.5m for lines up to 50m
	1:150 for lines between 50 - 200m
	1:850 for lines over 200m

As long as the surveyor's lines measure to within these tolerances, any error is equated to distribute the error proportionately throughout their length.

Checks

A good fundamental rule of survey, along with "work from the whole to the part" is the principle of the independent check. All detail, however supplied, should be checked on completion, preferably using some detail that has not been used to supply it. The first question the surveyor will ask is "does it look right?" but then a graphic check is often done with a shot across the corner(s). The following points are all good principles to bear in mind when performing graphic survey:

- Straight lines on the ground should appear as straight lines on the map – does it look right?
- Even when a measured line is within tolerance, check the terminals before attempting to equate;
- Always attempt to tie lines out – be mindful of maximum limits;
- Intersections must always be checked by measuring (only a trisection should be trusted);
- Detail supplied by shots should be checked by measurements. Detail supplied by measurements should be checked by shots;
- Rays or shots which pass through ground points will pass through the corresponding plan positions when plotted on the map.

Error Solving.

Inevitably, errors arise and lines fail to tie out. Shots drawn on the map may not correspond to those on the ground, check the following:

- Has the tape been misread? *Check the tie out.*
- Has it been booked wrongly? *Check bookings*.

- Are the lines/references plotted accurately? *Check plotting*.
- Have the terminals been identified correctly? *Check terminals*.
- If the tie out uses a shot or a ray, have the

terminals of the shot or ray been misidentified? *Check terminals*.

- Is the survey based on "solid" detail?

If all of the above have been satisfied there could be an existing error in the map detail – they do exist! To locate which end of the line is incorrect (hopefully it won't be both) it is necessary to use the method of cut or extend.

An independent shot is required which will cut through the line which has failed to tie out. This will probably prove one half of the line to be correct and hence isolate the error. Having achieved this, it is important to ensure that the detail immediately adjacent to the tie out point is in sympathy and that the survey is extended until the line ties exactly or is within tolerance. Finally, detail not in sympathy along the plot line must be corrected.

Key points from this section

- Land Surveying is based upon certain fundamental principles – such as working within a framework of control (from the whole to the part), using checks, and being both economic and consistent with methodology;
- Detail survey (and GPS) is used to capture features by ground methods – this comprises graphic survey and ground surface measurement;
- Detail survey is an economic and accurate method using existing detail as control to position new features. It maintains, but cannot improve, existing accuracy;
- Measured distances must be kept within maximum limits, and be horizontal;
- Distances can be kept within maximum limits by using shots, references, intersections etc;
- Measured lines can be used to fix new detail using offsets, in-direction measurements, and by picking up straights;
- Work should always be given an independent check, and any line errors resolved by cut or extend methods.