Chapter 12

CONSTRUCTION SURVEYING

This consists of all forms of setting out as well as the survey of existing buildings, and encompasses a number of the other facets of survey i.e. linear and angular measurements (traversing), tacheometry and levelling. It must be mentioned that it can be very intricate e.g. jacking of a bridge deck in suspension, welding of superstructures for the Moss-Gas Project, tunnelling, setting up monitors for robot controlled motor assembly lines etc., and varied e.g. laying of underground sewers, monitoring of deformations for dams, seismic activity, measuring of bulk materials (earthworks) etc. Some of these are skills which often demand specialists.

Obviously it is well near impossible to go into detail on all aspects of the above mentioned surveys; however for the purposes of this course we will cover some of the more day to day survey activities common to construction survey. Due to the varying nature of construction surveys it is proposed to cover them under specific headings.

Mention must also be made, that most often setting out is done by simple polar and with the advent of total stations, and both horizontal and vertical positions can be controlled three dimensionally. More recently on-board computers allow coordinated data to be stored, so that setting out has become more simplified. Data Logging Programmes are specifically designed for Construction Surveys and have a number of very clever features.

Construction of buildings

Setting out from property beacons and building lines

Most building sites are governed by the extremities of the property on which they are to be built. It is strongly recommended that before any building commences the property beacons of the site in question be exposed and checked by a professional surveyor, especially if you are going to build right up to the boundary line, or if the building lines as stipulated by the local authority have to be adhered to. If the beacons for a particular area have been recently placed and are clearly visible (next to a marker), or the owner of the property has indicated their positions, it is still necessary to conduct the following checks:-

1) Obtain a copy of the survey diagram or general plan; this will give the site dimensions and the beacon descriptions.

2) Measure between the beacons to see whether it corresponds to those on the diagram/ general plan. If you have the use of a total station and you are able to set up over one of the beacons all the better. The measured radial polars should then be carefully compared with the join data for consistency.

3) Also check to see whether the physical features of a beacon in the field correspond to the beacon description indicated on the diagram/ general plan.
4) If there is any discrepancy, or any chance of serious repercussions you are advised to call in a Professional Land Surveyor.

Always check that you use an approved Diagram or General Plan. **Never**, repeat, **never** take the site dimensions off a building plan. Once the beacons have been established (checked), the building lines may be set out either by parallel lines (if the property is rectangular), or if not, by co-ordinates.

### Setting out of building lines

The following sketch indicates typical building lines for a residential site.

![Building Lines Diagram](image)

Alternatively it is often necessary to set out the position of the house as positioned by the architect or plan draughts person. They may very well have skewed the building at an angle to accommodate for the slope of the land or make the front of the house north facing *(orientation)* or to accommodate for a particular view *(aspect)*. It is normally only possible to do this when the property is of a fair size (>1500m²), or slightly smaller (1000m²) if it is a level site. An example can best illustrate this (see sketch below).
Setting out can be done by in number of ways; either by placing a peg at the required distance along AB and then turning of the angle (say 110°); or measuring the distance along the opposite boundary DC so as to create a base line; or if a grid is provided, scaling off the co-ordinates of the corners of the building and then placing them by polars from, say, A.

At all times it is necessary to check the setting out of corner pegs, by check taping between pegs, also diagonals. However if the site needs earthworks it is customary to do these first. It is standard practice to make the site platform bigger than the extent of the building (+/-1,5m all round to allow for the erection of scaffolding etc.) In fact if the site allows an even bigger platform it should be constructed, to allow for more leisure space or later additions.
Bench marks and level control

It is customary that the designer of a building project will have referenced the site relative to a known datum, normally MSL, but sometimes a local datum is used on a building site. Usually, however, all waterborne sewerage connected to municipal manholes is based MSL. In fact most local authorities that even allow septic tanks to be used, will still insist that the site plan is contoured, often, but not always, to approx. MSL. Most plans refer to some point indicated on the site plan as the Bench Mark, which is the level reference to which the builder must base all his/her levels on. It can be a property corner beacon, an existing manhole, or in the case of an existing structure a floor level.

Normally the plan will stipulate levels for proposed floors, sewer and storm water manholes (both cover and inverted) as well as driveway levels. Caution must be taken when reading a plan as sometimes they use a local datum of 100m, while some will indicate levels on all corner beacons, which in fact are the product of guesswork from interpolation of contours. All of these can lead to mistakes if you are not experienced in reading a plan.

Site Levelling for house platforms

At the outset it must be mentioned that as far as site levelling is concerned many builders hire a pay loader for a day, use it to clear the site of vegetation, to cut access and to cut a platform by eye. This hit and miss approach depends to a large extent on the skills and experiences of the pay loader driver, who left unattended, can wreak havoc. Unsupervised machine operators have ripped many a water main/electric cable out.

The approach outlined here is best explained by aid of an example. In the beginning it is advisable to plan the exercise carefully. Firstly it is advisable to check with the local authority as to the locality of services and have them exposed. The site should then be cleared. From the site plan the position and extent of the platform should be scaled off and the corresponding points marked in the field (say four corner pegs). These four pegs should be levelled, and there average height, will in general give the platform level, which will best balance cut and fill. (See sketch below). It is also advisable to take spot heights along the proposed driveway section.

<table>
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At this point it is advisable to draw say three cross sections (see example below) in order to determine the position of the batter pegs. First the natural ground level is plotted, then the platform level is drawn and then the slope (batter) banks are added, normally at 1:2 (1m vertical to 2m horizontal). It is not advisable to make slopes steeper than this as it is likely to slide in heavy rains especially when not grassed. Nowadays many surveyors have earthwork packages on their electronic loggers which do this very quickly.

It is also advisable to prepare a driveway section from the take off point on the road to the garage position on the platform. This should adhere to the layout as designed on the plan which has been approved by the L.A. It is often necessary to do this, as the plan has been prepared on the cheap, with little thought of detail. A typical driveway section has been prepared below. Offset pegs are then calculated.
You are now in a position to place earthwork pegs (batter pegs from the cross-
sections and driveway offset pegs). These pegs are now placed in the field and
batter boards are built (see example). You are now in position to hire the pay loader
or small bulldozer (when the site is rocky). A fatal mistake, which many builders
make, is that they go for the cheapest supplier in town (normally on an hourly rate)
who has tired equipment and inexperienced operators.

Foundations - corner profiles and widths, levels and stepping

The corner pegs are first set out from the corner beacons using a total station. The
corner pegs are then checked (diagonals) with a tape. Offset pegs are now placed,
generally 1m away at right angles to the building, two per corner. (See sketch
below).
DRAINAGE

Sewers and drains

A drain is a line of pipes and fittings, including inspection chambers, traps, gullies, etc., used for drainage of one building and the yards and outhouses of the property. A sewer, on the other hand, is any piped drainage system not included in the above description. As such it may collect the drainage waste from several properties and may be private or public. Private sewers run in private land and must be maintained by the various owners whose drains lead into it. Public sewers, on the other hand, are usually laid in streets or across private land (normally parallel to the boundary line). They are maintained by the local authorities.

In S.A. there is a distinction between waste/foul water (sewerage) and rain/storm water (SWD) drains. The first type "sewers" can be waterborne and therefore connected to a sewerage main network or septic/conservancy tanks depending on the area. Likewise "SWD" can be connected to a storm water drain network or a soak-pit system. Generally in order to allow for septic tanks and soak-pits, the building site has to be fairly big (>1500m) and soil conditions have to be right (soil percolation test required).

Gradients

Drains and sewers are laid to gradients such that the flow of water allows the drain to be self-cleansing. It is beyond this course to give a module on hydraulic engineering. However as a rule of thumb, when laying 100mm Φ pipe sewers the gradient should not be flatter than 1 : 40, and for a 150mm pipe the gradient should not be flatter than 1 : 100, unless a quantity of flow > 0.005m /sec can be maintained.

An understanding of gradients and their determination is vital at the lowest level of drainage works. Gradients can be expressed as a ratio e.g. 1: 40 (grade), which means 1 vertical to 40 horizontal or as a percentage e.g. 2.5% (gradient). This fundamental aspect must not be over-looked, as being too elementary for the learner surveyor.

Setting out of Levels

Sight rails.

These consist of a horizontal timber piece nailed to a single upright or a pair of uprights driven into the ground. The figure below shows several different types of sight rails.
The upper edge of the cross piece is set to a convenient height above the required plane of the structure, usually to the nearest half metre, and should be at a height above the ground to ensure convenient alignment by eye with the upper edge. The level of the top edge of the crosspiece is usually written on the sight rail together with the length the traveller required. Sight rails are usually offset 2 or 3 meters at right angles to construction lines to avoid being damaged as excavation proceeds.

Sight rails are set up to enable excavator operators to cut out earth to an even gradient and to enable the pipe layer to lay his pipes to a given gradient.

Consider a length of sewer being laid from manhole (MH1), which has an invert level of 30.02m, to manhole (MH2), which is 60m away. Note: the invert level of a sewer is the lowest point on the inside surface. The gradient from MH1 to MH2 being 1:100 and falling from MH1 to MH2.

The invert of MH2 = 30.02 - (1/100x60) = 29.42m

The figure shows the proposed sewer, which is generally at a depth of 2 meters below the surface.

If two rails are fixed over station MH1 and MH2 at about 1 meter above ground level and each rail is fixed at the same height above the invert level then by sighting from rail MH1 to rail MH2 one will be sighted down a gradient equal to that of the proposed sewer.
In the example above a convenient height is say 3.20m above the invert, so that a boning rod (traveller) of this length held vertically so that its sight bar just touches the line of sight between the sight rails MH1 - MH2, would give at its lower end a point on the sewer invert line.

To fix these rails for use with a 3.20m boning rod (or traveller as it is often called) two posts are driven in on either side of the two manholes and rails are nailed between these at the required levels.

**Travellers and Boning Rods**

A *traveller* is similar in appearance to a sight rail on a single support and is portable. The length from upper edge to the base should be a convenient dimension to the nearest half metre.

Travellers are used in conjunction with sight rails. The sight rails are set some convenient value above the required plane and the travellers are constructed so that their length is equal to this value. As excavation proceeds, the traveller is sighted in between the sight rails and used to monitor the cutting or filling. Excavation or compaction stops when the tops of the sight rails and the traveller are in line.

The figure below shows a traveller and sight rails in use in the excavation of a trench.
The next figure shows the ways in which travellers and sight rails can be used to monitor cutting and filling in earthwork construction.

There are several different types of travellers. *Freestanding travellers* are also sometimes used to control super elevation on roads, a suitable foot being added to the traveller as shown below.
**Slope Rails or Batter Boards**

These are used for controlling side slopes in embankments and cuttings. They consist of two wooden stakes driven into the ground 1 metre apart and a plank as the sight rail.

For an *embankment*, the slope rails usually define a plane parallel to but offset some perpendicular or vertical distance from the proposed embankment slope and the slope rails are usually offset a distance $x$ to prevent them being covered during filling. Travellers are used to control the slope as shown below.

For a *cutting*, the wooden stakes supporting the slope rail are usually offset some horizontal distance from the edge of the proposed cutting to prevent them being disturbed during excavation. The figure below illustrates this point. A nail is driven into the stake closest to the work-face, a set distance above the ground. This nail position will have a known height relative to the finished road level and the known slope distance will be written on the blank e.g. (SD = 10.38). The sloping sight rail and the slope distance from the nail are used to govern the earthworks.
BOXING

This is a survey operation which takes place once initial road earthworks have been completed. It is dependent on the width of road (hardening and shoulders) i.e. 7m hardening + 2.5m shoulders = 12m wide road. The purpose of boxing is to dig out a box in the road so that road material can be replaced and compacted in layers up to the required levels. Boxing pegs are used to govern the critical levels of the cross-section of the road i.e. cross-fall/ super-elevation etc. The sketch below helps to illustrate their use.

Two pegs/ wooden stakes are placed opposite each other at even chainages at the edge of the road formation (12m apart in the above example). These pegs are levelled (a) and compared to the design level (b) of the road at this point. The diff. is determined and 1m added to design level (c). The diff. between (a) - (c) = height that must be measured up the stake. A 75mm nail is then driven in and colour tape is wound around the stake at this height. A piece of nylon is stretch between the two corresponding nails from a 1m traveller is used to obtain the required level across the section. The subsequent earthwork layers below this nail are marked off accordingly e.g. road hardening 50mm, road metal (crusher run with lime stabilising) 150mm, base course 200mm, sub-base 200mm = 600mm layer works. Different colour tape is used for each layer, while the use of nails assists with the stretched nylon. In this method the same 1m traveller is used throughout the job.

The bulldozer would rip a section 7- 7, 2 m wide and a grader (pay-loader and trucks) would follow removing layers until a box of 600mm deep has been cut. Levels are continually checked until the required box has been shaped. The sub-base layers are brought in, levelled with a grader, compacted with a roller and checked for levels. Then the base course followed by the crusher run. Here a water cart will also be used, both with the grader and roller until the required compaction is obtained until the required level is achieved. This surface is then primed and the wearing course (tarmac) is ready to be laid and compacted to the finished road level.
The geometrics of roads consist of a number components, namely horizontal and vertical alignment and cross sectional elements.

When setting out a road it is necessary to place it on some chosen horizontal alignment, which in most cases is seldom straight. In fact most roads consist of a series of straights connected by horizontal circular curves, the radius of which depends amongst other things on the design speed of the road.

In general the centre line of the road is staked at intervals of 20m (sometimes 10m on the curves). The centre line pegs are then levelled, together with cross-sections every 20m. These are then used together with the vertical alignment and cross-sectional elements to generate batter pegs which are then placed to indicate where the cutting/ filling must take place.

Mention must be made that seldom does a vertical alignment consist of a single straight grade but combines them with vertical curves normally of the parabolic form. The vertical alignment depends to large degree on the nature of the ground (topography) bisected by the horizontal alignment and are therefore interdependent. Likewise the X-sectional elements of the road change as the horizontal and vertical alignments change. For example a road can be cambered, have a cross-fall or have super elevation.

In addition it must be understood that a road, because of it large surface area has to accommodate and control storm water drainage. Clearly this is a tip of an iceberg, which as you can appreciate is a field (road engineering) all on its own. This however does not negate road works from a surveyors repertoire of expertise, as the construction thereof is very much part of the surveyors work.

**Longitudinal sections**

A ground profile along the central longitudinal line of an existing, or proposed, road, pipeline, railway, canal, etc., is termed a **longitudinal section**.

To draw longitudinal sections the elevation of points along the ground line is required, usually at a standard horizontal interval, such as 20 metres etc. as well as at every change of slope along the line or where natural, or artificial features, disturb the ground profile. These points are normally staked out using a total station and levelled using an automatic level. The required levels are then reduced from which the relevant sections can be drawn.

When drawing up a longitudinal section the ratio between the horizontal scale and vertical scale is exaggerated, the vertical scale being 1:5 or 1:10 times that of the horizontal scale.
Cross-Sections

Cross sections would have to have been taken in the field at right angles to the centre-line and radial on curves. It is customary to plot ground profile NGL on graph paper (cross section). In addition to ground profile one would show the section number (e.g. Chainage 140), the Vert. and Hori. Scale, the centre line, the datum and the new formation (road template).

One of the chief functions of cross-sections is to obtain position the batter pegs (where the new form cuts or meets the NGL). These positions are required to be pegged in the field before bulk earth works can commence, details of which have already been discussed under batter boards.

In addition to road works, items like driveways, parking lots and road access are very much part of the on-site adaptation, and a surveyor has to do to make things work.

This often requires that the engineering surveyor does a small detail survey or takes levels and prepares a short long section and grading. This is often done at the site office with consent of the resident engineer.
Setting out SWD, Culverts and Under-passes

Prior to any major road earthworks it is common practice to set out the entire Storm-water crossing under the fill embankments. Culverts are normally positioned at a low point of the valley-line and can be of the Box or Pipe variety. These are normally pre-cast and are laid on a blinding layer of reinforced concrete. In addition they often require head-walls and wing-walls to be constructed out of brickwork. Because of the size of the catchment area the volume of water concentrating at a certain critical crossing may require increased portal size to accommodate maximum flood peak conditions. As a result double and triple box culverts may have to be used. In some instances the SWD (culvert) is cast in situ and requires shuttering and reinforced concrete.

The construction survey of this type of work is dependent on the size of the construction at hand. For small to medium size SWD (300mm - 750mm) pipes, two pegs at inlet and outlet side are all that are required. However for large size (900mm - 1200mm) pipes, six pegs would be required as they are normally laid on a blinding layer as shown in the sketch below.

For anything bigger than this, box-culverts are used and have to be controlled both horizontally and vertically. The sizing of storm-water pipes is beyond the scope of these notes.

Underpasses are used to avoid dangerous crossing of local vehicles (tractors), people and livestock. In design they really just a fairly big box culvert.

Bridges

A bridge is really just an extension of the above topic. Construction and survey thereof depends on the type of bridge being built.
Small bridges are often cast in situ and here initial Y,X position and a bench mark for height is all that would be required. As bridges get bigger (longer and wider) they invariably require tighter control by the surveyor. A lot of these larger bridges make use of pre-stressed beams which are cast off site and set in position by heavy duty cranes. Obviously the bridge piers and their abutments as well as the support columns have to be positioned extremely accurately. Here the shuttering is checked in X,Y & Z before the concrete is cast. The outside control would be conveniently located in a safe position such that the setting out would take place by means of a total station. The positions would be checked from an independent point, downloaded on a computer and using a modelling programme tested for consistency before any concrete is poured. Sub-centimetre accuracy is required here, to ensure that the pieces of the puzzle fit together as designed.

Suspension bridges and bridge jacking are specialized fields, which require even more stringent control by the construction team and will not be discussed any further.

**Pipe-jacking**

Pipe-jacking is done when a pipe is to be laid under a busy main road and particularly under railway lines. For a road one can always build a detour but not so for a railway line.

The survey relating to pipe jacking requires that a launch pad be built on a gradient parallel to the pipe that is proposed to be laid. On this launch pad rails are set up on which the jacking head will run. The first pipe will fit in behind the jacking ring. As the pipe is jacked (pushed) towards the excavation face a mechanical auger bores through the centre of the pipe removing the material to the back of the pipe where it is removed. The whole process is slow and requires constant checking of levels as well as the alignment of the jacking unit. A stumpy staff (0,6m long) is used inside the pipe and sometimes a laser level is also required.

It must be noted that in the case of sewers and water mains the pipe that is jacked acts as a sleeve in which the sewer/ water main (steel pipe) will be sliding through. In the case of SWD the jacked pipe is actually used. Note that with SWDs levels are not as critical as with sewers.

**Outfall Sewers on Critical Grades**

Sewers are intended to be self cleansing and flows are critical for this to be achieved. Water does not flow at gradients of flatter than 1:200. However, gradients of 1: 200 sometimes have to be used on gravity feed mains. For sewers that lead to the sewerage disposal works, the size of the pipe could very well be 1200mm or bigger and here laying and grading the pipes are critical in order that the sewer performs according to design specifications.

The survey involves setting out the route, bend points (MHs) and line pegs. Levels are critical as well and excavation using site rails and boning rods are required. Once rough earthworks are complete, course aggregate stone is laid in the bottom of the trench. Next the surveyor has to transfer the alignment to the bottom of the trench and then place blinding pegs on the required gradient every 5m apart. These
pegs are then concreted in and then the steel mesh with spacer blocks attached is laid in the trench. The concrete is then poured to the level of the blinding pegs. This blinding layer is floated to give a smooth surface.

The surveyor is again called in to transfer the alignment back into the trench and to set out the benching of the saddles for the pipes. Normally on a section between manholes, only the first and last saddle are laid and checked by the surveyor, all the rest are boned in by the drain layer using stretched nylon, although he would still mark the position of each saddle using a permanent marker pen. The pipes are then laid by a crane onto the saddles. Final alignment is checked by a laser level (see sketch below) along the bottom (invert) of the pipe before grouting the joints takes place.

![Sketch of surveying equipment](image)

**Piling**

Most major structures require piles to support the foundations and the bearing loads of the structure. Two kinds of piles are used either the pre-cast types or the cast in situ types. The former requires a hydraulic hammer and the latter a bore-hole machine/ auger.

Positions of the piles have to be calculated from the foundation plan of the structural engineer. Great care has to be taken in computing the position, as the principle of breaking down from the “whole to the part” applies, i.e. site dimensions and building lines are the key to this, as most often the building is at offset distance and parallel to these boundary lines. The piles for the perimeter are computed first and then the internal piles are computed in between using polars/ intersections/ running lines /data traverses etc.
Sometimes they are placed on a grid formation which makes setting out easier i.e. terminals are placed and lines are run in between to obtain the grid formation. A system of checking would need to be applied to make sure that the pegs are in their correct positions e.g. checking diagonal distances. However, there are many times when piles do not conform to a set grid and here each peg has to be set out by polar and checked from an independent point (double polar).

In most cases the building platform would have been cut prior to setting out the pile positions. It is also important to number the piles when computing and using the same numbers in the field. The numbering can use alpha numbering down the one side and numeric numbering on the perpendicular side especially on a grid system. (See sketch below)

It is important to have checked that the computed pile position is correct and according to the foundation plan. Here a plot of the pile positions is made and super-imposed on the foundation plan (plotted to the same scale, normally 1:100), to check for consistency. This can also be checked by E-mailing the co-ordinate data in DXF to the structural engineer, who would be able to import the data into his/her CAD package on which s/he did the design.

**Setting out Reservoirs and Water Towers**

With regards to reservoirs, it depends on the shape of the structure being constructed as they can either be rectangular or circular. Not all reservoirs have Water Towers. Water Towers are used to increase the hydraulic head (pressure in the pipes) to an area serviced by the reservoir, as water supply in general is by gravity feed.
Setting out of the reservoir begins with initial earthworks i.e. levelling the site and stock-pilling the surplus material. It is common that most reservoirs are partly submerged. For the purpose of this explanation a rectangular reservoir (40 x 60m) will be discussed.

As the surveyor will be called on at various stages during its construction s/he would first put in control X, Y & Z. From here s/he would set out the four corners of the reservoir on the levelled platform. In addition s/he would calculate and set out eight offset pegs, say 10m at right angles to each corner. Hopefully these will be in a safe place and preserved in concrete with a metal fence standard next to it. These pegs will be co-ordinated and used as a constant form of reference (see sketch).

The foundations of the reservoir are cast in alternate sections with extensive shuttering and steelwork. Once the perimeter has been cast, the internal floor slab is cast in squares much like a chessboard i.e. “black” squares first followed by “white” squares later. The uncompleted slabs use the completed squares as their shuttering. Note this method allows for expansion joints which are later sealed with bitumen. Some of these square slabs also include the starter columns (footings) for the internal columns.

Once the floor slab has been cast the side panels are cast in alternate sections and here alignment is critical. The steel shuttering has to be plumbed (aligned) by means of a total station. This is a tricky process and involves loosening and tightening of the supporting jacks. The total station is set up at an offset distance (say 150mm) from the outside face of the shuttering and a parallel alignment is established. A short staff or ruler is held at the top of the shuttering perpendicular to its face and at right angles to the total station. Obviously the bottom of the shuttering is fixed to the footing already cast in the deck. If the alignment at the top does not conform to the pre-set distance (150mm) then the shuttering must be adjusted until it
does. Once the alignment is within 5mm tolerance all jacks are tighten equally. Obviously the reinforced steel and spacer blocks would already be in the shuttering and it would now be ready for concreting. Once all the alternate sections are cast the intermediate sections use the cast section for their shuttering alignment.

The internal columns will also need to be aligned (plumbed) by means of a total station (in fact two total stations at right angles to each other). Note the height of these columns/ side-panels would be in the order of 8 - 10m high i.e. not safe to use a builders level. Side panels would not be built until all the decking was complete.

**Existing plans and services**

Existing plans are only obtainable from the local authority with the owners consent. In some cases the architect will need to give his authorization as well.

With regards to services such as existing Sewer and SWD manholes, the local authority should have records showing positions, invert and cover levels. It is generally unreliable to work off cover levels unless the plans are stamped with "AS BUILT" on them. Care must be taken when using these records as sometimes they are old and have imperial measure (feet and inches), in which case a conversion factor has to be applied (1 English ft = 0.3047972654metres).

**CONSTRUCTION SURVEYING CALCULATIONS**

**EXAMPLE 1**

See Survey Diagram of Portion 2 of Erf 213 Forest Hills.

Calculate setting out data for a rectangular building 30m x 15 m which is to be erected on this site. The 30m side of the building will be parallel to boundary DE, and the 15 side will be parallel to boundary EF. The building line for both boundaries is 5 metres. All four of the building corners must be marked with pegs at 2 metre offsets. Calculate coordinates for all eight offset pegs. HINT: Start by calculating the coordinates of the corner of the building near point E, where the boundary forms a 90º angle.
ENSV2SE H1

SURVEYING ENGINEERING

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Description of Beacons
A, D, F, G : 20mm IRON PIPE
B : 25mm IRON PIPE
C : 37mm IRON PIPE NEXT TO WOODEN POST
E : 20mm IRON PIPE NEXT TO FENCE POST

Scale 1:2000

The figure A B c middle of stream d E F G A represents 4199 square metres of land being
PORTION 2 OF ERF 213 FOREST HILLS TOWNSHIP
Situate in the Borough of Kloof Administrative District
and Province of KwaZulu-Natal
Surveyed in July 1996
by me
A N OTHER
Professional Land Surveyor

This diagram relates to No.
Registrar of Deeds

The original diagram is
S.G. No. 1190/1949
Transfer 7739/1955

File No.
S.R. No.
Comp.

Degree Sheet 59

221
SOLUTION

Dir DE = 200.20.30 (from diagram)
Dir EF = 290.20.30 (from diagram)
Coordinates from Diagram:

\[
\begin{align*}
D & \quad +15\ 401,02 \quad +2\ 851,52 \\
E & \quad +15\ 370,41 \quad +2\ 768,94 \\
F & \quad +15\ 340,21 \quad +2\ 780,41 \\
\end{align*}
\]

Polars:

\[
\begin{align*}
E - X1 & \quad +15\ 365,722 \quad +2\ 770,678 \\
X1 - C1 & \quad +15\ 367,460 \quad +2\ 775,366 \\
E - X2 & \quad +15\ 372,148 \quad +2\ 773,628 \\
X2 - C1 & \quad +15\ 367,460 \quad +2\ 775,366 \\
C1A & \quad +15\ 366,765 \quad +2\ 773,491 \\
C1B & \quad +15\ 369,335 \quad +2\ 774,671 \\
C2 & \quad +15\ 353,395 \quad +2\ 780,581 \\
C2A & \quad +15\ 352,700 \quad +2\ 778,705 \\
C2B & \quad +15\ 351,520 \quad +2\ 781,276 \\
C3 & \quad +15\ 363,824 \quad +2\ 808,710 \\
C3A & \quad +15\ 364,519 \quad +2\ 810,585 \\
C3B & \quad +15\ 361,949 \quad +2\ 809,405 \\
C4 & \quad +15\ 377,888 \quad +2\ 803,495 \\
C4A & \quad +15\ 378,584 \quad +2\ 805,371 \\
C4B & \quad +15\ 379,764 \quad +2\ 802,800 \\
C1 & \quad +15\ 367,460 \quad +2\ 775,366 \\
\end{align*}
\]
EXAMPLE 2

You are to build a graded concrete channel at the base of embankment of a sports field. The existing catch pit has an inlet level of 54.39m and the grade on the channel is to be 1:80, sloping towards the catch pit. Calculate the levels of all the pegs to be placed every 10m along the entire length of 100m.

SOLUTION

<table>
<thead>
<tr>
<th>Distance from catch pit</th>
<th>Ht diff</th>
<th>Invert level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catch pit</td>
<td>0</td>
<td>54.39m</td>
</tr>
<tr>
<td>10</td>
<td>0.125</td>
<td>54.515</td>
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<tr>
<td>20</td>
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<td>54.640</td>
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<tr>
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<td>0.375</td>
<td>54.765</td>
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<tr>
<td>50</td>
<td>0.625</td>
<td>55.015</td>
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<tr>
<td>60</td>
<td>0.750</td>
<td>55.140</td>
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<tr>
<td>70</td>
<td>0.875</td>
<td>55.265</td>
</tr>
<tr>
<td>80</td>
<td>1.000</td>
<td>55.390</td>
</tr>
<tr>
<td>90</td>
<td>1.125</td>
<td>55.515</td>
</tr>
<tr>
<td>100</td>
<td>1.250</td>
<td>55.640</td>
</tr>
</tbody>
</table>