TVET CERTIFICATE III IN CROP PRODUCTION

Module: TOPOGRAPHICAL DATA COLLECTION

CRPTD302

Collect topographic data

Competence

Learning hours

60

Credits: 6

Sector: Agriculture and Food Processing

Sub-sector: Crop Production

Module Note Issue date: November, 2020

Purpose statement

This module describes the skills, knowledge and attitude required to collect topographic data. It is designed for learners who have successfully completed 9 years basic education or its equivalent and pursuing TVET certificate IV in Crop Production or other related qualifications. At the end of this module, learners will be able to prepare for topographic data collection operations, perform surveying and display survey results.

Table of Contents

Learning Unit 1 – Prepare for topographic data collection operations

LO 1.1 – INTERPRET INSTRUCTIONS PROVIDED BY SUPERVISOR

- Content/Topic 1: Instructions on topographic data collection

These instructions are based on tools, materials and equipment to be used, their conditions and precautions, selection availability and activities calendar

- Content/Topic 2:Site environment condition

These are instructions related to the Slope, temperature, rainfall, altitude, humidity and wind effects or analysis, based on topographic activities.

- Content /Topic3: Site operation

These instructions are based on site or land clearing, delimitation, design or layout and establish topographic data collection measures.

- Content /Topic4:Maintenance of tools and equipment

Maintenance of tools and equipment instructions are related to the good maintenance of topographic tools and equipment before, during and after topographical data collection activities or work.

LO 1.2 – Assess occupational, health, safety (OHS) hazards and risks to the supervisor

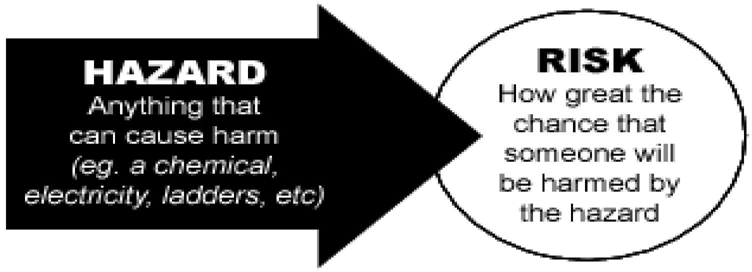
- Content/Topic 1: Definition

A **hazard** is something that can cause harm

E.g. electricity, chemicals, working up a ladder, noise, a keyboard, a bully at work, stress, etc

A **risk** is the chance, high or low, that any hazard will actually cause somebody harm.

For example, working alone away from your office can be a hazard. The risk of personal danger may be high.



- Content/Topic 2: Types of hazards associated with topographic data collection

The types of hazards are:

- Chemical hazards
- Physical hazards
- Biological hazards

- Content /Topic3: Types of hazards risks

CHEMICAL HAZARD: is a type of occupational hazard caused by exposure to chemicals in the workplace. These hazards can cause physical and/or health risks. Depending on chemical, the hazards involved may be varied, thus it is important to know and apply the PPE especially during the lab.

Chemical hazards can take various forms such as:

- ✓ **Liquids** such as acids, solvents especially if they do not have a label
- ✓ **Vapors and fumes**
- ✓ **Flammable materials**

Chemicals can change their physical state depending on temperature or pressure. Thus it is important to identify the health risks as these states can determine the potential route the chemical will take. For example, gas state chemicals will be inhaled or liquid state chemicals can be absorbed by the skin.

PHYSICAL HAZARD: is an agent, factor or circumstance that can cause harm with or without contact. They can be classified as type of occupational hazard or environmental hazard.

The physical hazards are:

Falls: are a common cause of occupational injuries and fatalities.

Confined spaces: also present a work hazard. Spaces of this kind can include storage tanks, ship compartments, sewers, and pipelines. Confined spaces can pose a hazard not just to workers, but also to people who try to rescue them.

Noise**:** also presents a fairly common workplace hazard: occupational hearing loss is the most common work-related injury.

Temperature: can cause a danger to workers.

Cold Stress**:** Overexposure to freezing conditions or extreme cold can result in a risk to many workers.

***Heat* stress:** Outdoor workers such as farmers and mining workers are more vulnerable to exposure to extreme heat.

Electricity**:** poses a danger to many workers.

Sunlight: is the most commonly known physical hazard which affects the people who work outside. Outdoor workers get highest sunlight exposure during high-intensity hours and during the summertime.

Vibration**:** has long been recognized as a serious occupational hazard. Continuously repeated exposure to high levels of vibration results in injuries or illnesses

Other hazards**:** Lighting and air pressure (high or low) can also cause work-related illness and injury. Asphyxiation is another potential work hazard in certain situations and can also be a potent hazard.

BIOLOGICAL HAZARDS: refer to organisms or organic matters produced by these organisms that are harmful to human health. These include parasites, viruses, bacteria, fungi and protein.

In general, there are three major of routes of **entry** for these micro-organisms into our body, i.e. through the **respiratory system, transmission through contact with body fluids of the infected or contact with contaminated objects**. The harmful effects posed to human health by these biological hazards are mainly of three types: **infections, allergy and poisoning**.

It is also known as **biohazards** and as explained above refer to biological substances that pose a threat to the health of living organisms, primarily that of humans. This can include samples of microorganism, virus or toxin (from a biological source) that can affect human health. It can also include substances harmful to other animals.

Elimination of the source of contamination is fundamental to the prevention and control of biological hazards. Engineering controls such as improvement of ventilation, partial isolation of the contamination source can help contain the spread of contaminants. If the contact with biological hazards cannot be prevented, the employees must use personal protective equipment and adhere strictly to the practice of personal hygiene. The personal protective equipment includes masks, gloves, protective clothing, eye shields, face shields and shoe covers.

- Content /Topic 4: Assessment of hazard and risks

Topographical data collection technicians must assess their workplaces to find out if there are hazards that require using PPE. If there are such hazards, employers must select the right type of PPE and make sure it fits the employee correctly. In most cases, the employer is required to supply PPE to their workers at no charge; however there may be exceptions if you wear your PPE off the job site. Employers must train workers who have to use PPE on how to use it correctly. This includes the following: Knowing when PPE is needed; how to use PPE correctly; knowing what kind of PPE to use; understanding what PPE can and cannot do to protect workers; how to put on, adjust, wear, and take off PPE and how to maintain PPE.

LO 1.3 – Select PPE according to the desired operation

- Content/Topic 1:Importance of PPE

Personal protective equipment (PPE) is designed to protect you from hazards found on or off the job.

- <u>Content/Topic 2: Categories of PPE used in agriculture</u>

- Head protection equipment
- Hand protection equipment
- Face protection equipment
- Body protection equipment
- Ear protection equipment

Hand protection equipment

• Gloves protect the hands from hazards

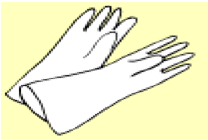


Figure: Gloves

• Most gloves are disposable after use;

• Standard gloves should be chosen

• Check whether the material used for the gloves is resistant to chemicals. Ask for details from the gloves suppliers;

• Gloves should fit the hands snugly but they should not hamper movement or affect sensibility;

• Keep the nails short to avoid piercing the gloves;

• Two pairs of gloves might be worn in handling highly hazardous substances;

• Wash hands thoroughly before and after use;

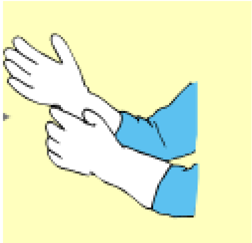


Figure: A technician with gloves

• Check if there is any puncture before use

• Contaminated gloves should be disposed of in special rubbish bag marked with “hazard" warning and label. Fasten the bag and place it in a designated location for special disposal

Face protection equipment

• Safety goggles/glasses and face shields can protect the eyes from contacting hazards.

• Standard goggles should be chosen (for example, EU EN 166; U.S. ANSI Z87.1-1989);

• Glasses without side shields can only protect the front, for example from liquid splash ;

• Goggles fit the face snugly and therefore are better than glasses in eye protection;

• If necessary, face shield should be used to protect the whole face;

• Both face shields and goggles/glasses should be cleaned with liquid soap regularly and place them in plastic bags after wiping dry and store them in their proper storage place;

•Check them regularly. Replace them if out of shape, cracked, scratched or fogged;

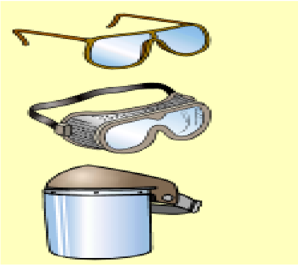


Figure: Glasses; goggles and face shield respectively

Figure: A technician with goggles

Body protection equipment

• Protective clothing includes protective coverall

• In some cases, protective clothing should be waterproof or impervious to liquids to protect the body from contamination byfluids;

• Protective clothing is disposable in most cases though some are reused;

• Standard protective clothing should be chosen;

• Protective clothing should fit the wearer and should not hamper movement;

• Protective clothing should be checked before use and replaced if damaged;

Figure: example of a technician with protective clothing

Ear protection equipment

-Ear-plugs: An ear-plug is a device that is inserted into an individual's ear canal to protect them from exposure to loud noises. Ear-plugs come in wide variety of forms, mostly manufactured from soft plastic, PVC, silicone and Polyurethane. They provide good sound attenuation when fitted correctly. The type of ear-plug chosen will depend on each individual's needs and personal preference.

Figure: different forms of ear-plugs

-***Ear-muffs***: Ear-muffs, also known as ear defenders, are hard plastic cups that fit over and surround the individual's ears and are sealed to the head by cushion seals. These are usually manufactured from plastic materials with a metal or plastic head band and foam or liquid ear cushion. Depending on the material used, the ear-muffs can irritate skin around the ears, particularly in warm weather.

Figure: Ear-muffs

Canal caps/semi-insert earplugs: Canal caps have rounded heads that cover the entrance to the ear canal, while semi-insert plugs generally have conical tips that are pushed into the ear canal. Both types are convenient for situations where the hearing protection has to be taken on and off frequently. Firm pressure from the head band is required to maintain an effective seal, which can be uncomfortable over longer use. These are normally recommended for use in areas of intermittent noise.

Respiratory protection

Using the appropriate respiratory protective equipment is important for the securing and adequate protection from hazards.

Common protective equipment includes:

• **masks** – mask generally consists of three layers of non-woven fabrics. It provides a barrier protection against large respiratory droplets;

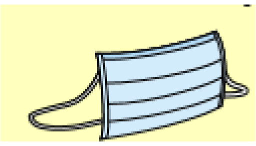


Figure: Mask respirator

• **N95 or higher level respirators** – This type of respirator filters out particulates and liquid droplets in small particle size, therefore providing protection from inhaling aerosols and microorganisms that are airborne.

Figure: Higher level respirators

Figure: A technician with respirator

The selection of particulate respirators should also consider whether the work environment contains oil mists

Particulate respirators with replaceable filters

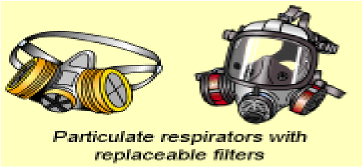


Figure: Particulate respirators with replaceable filters

There are different forms of respiratory protective equipment; the type hazard, the nature of work and the work environment will determine the choice of respiratory protective equipment to be used. Some adequate training is required for using some respirators to ensure their correct and safe use. It is also necessary to follow the manufacturer's recommendations in the use of these respirators. It is extremely important that the respirator should fit the wearer for a good face seal and the user must perform the seal check to ensure that the respirator is worn correctly for the required protection.

Boots and Shoe covers

• Boot and boot covers offer a high protection. Cover the boots with the trousers of protective clothing to prevent contaminants from getting into the boots;

• Boots and Shoe covers should be water resistant and skid proof;

• The size should fit so as not to hamper movement.

• Shoe covers are usually disposable after use and mostly recommended for biological hazards.

To ensure their protectiveness, all personal protective equipment requires correct selection and use, as well as proper maintenance and storage. Re-useable protective equipment should be cleaned before they are used again. Damaged items should be replaced immediately.

a)  b) 

Figure: a) Boots and shoe covers to protect biological hazard and b) surveyor boots

- Content /Topic3: Maintenance of PPE

Regularly Cleaning of reusable personal protection equipment is strongly advisable.

Personal Protection Equipment should be kept in appropriated location and environment and sometimes as indicated by manufacturer for sophisticated ones.

Some Biological and chemical hazards protection equipment may require sterilization (the process using ultra heat or high pressure to eliminate bacteria, or using biocide to eliminate microorganisms, including spores in bacteria.)

Note: Chemical; Physical and Biological hazards can kill. Or they may cause discomfort and affect the health and performance of employees at the very least. We have to be vigilant in preventing and controlling Chemical; Physical and Biological hazards to make the work environment a safer and healthier place.

Learning Unit 2 – Perform surveying

LO 2.1 – IDENTIFY TOPOGRAPHIC DATA ACCORDING TO THE PURPOSE

- Content/Topic 1: Definition of topography

Topography is the study of the shape and features of land surfaces. The topography of an area could refer to the surface shapes and features themselves, or a description (especially their depiction in maps).

Topography is a field of geoscience and planetary science and is concerned with local detail in general, including not only relief but also natural and artificial features, and even local history and culture.

Topography in a narrow sense involves the recording of relief or terrain, the three-dimensional quality of the surface, and the identification of specific landforms.

- Content/Topic 2: Main objective of topography

Main objective of topography is to determine the position of any feature or more generally any point in terms of both a horizontal coordinate system such as latitude, longitude, and altitude. Identifying (naming) features and recognizing typical landform patterns are also part of the field.

- Content/Topic 3: Topographic data

Topographic data are:

- ✓ Altitude
- ✓ Latitude
- ✓ Longitude
- ✓ Slope
- ✓ Horizontal distance
- ✓ Height difference
- ✓ Horizontal angle
- ✓ Vertical angle
- ✓ Area

Altitude

Altitude refers to the height of a place from mean sea level. Altitude modifies the climate considerably (solar radiation; temperature; rainfall; wind and soil) reason why an agronomist has to identify this factor.

Altitude or height (sometimes known as depth) is defined based on context in which is used (geographical survey; geometry; sport and many areas or more).

As general definition "*altitude*" is a distance measurement, usually in the vertical or up direction, between a reference datum and a point or object.

Latitude

Latitude is a geographic coordinate that specifies the north-south position of point on the earth's surface. It is an angle which range from zero degree at the Equator to 90 degrees (North or South) at the Poles. In other words, the value of equator is 0° and the latitude of the poles is 90°N and 90°S.

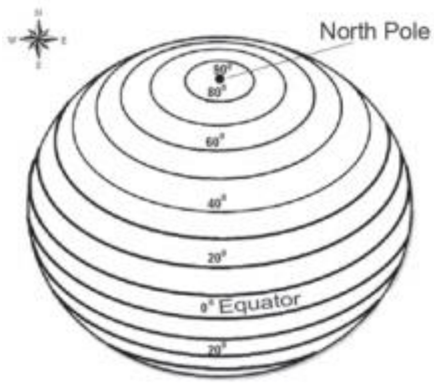


Figure: Parallels of latitude

Lines of constant latitude or parallels run east-west as circles parallel to the equator. Latitude is used together with longitude to specify the precise location of features on the surface of the earth.

Longitude

Longitude is a geographic coordinate that specifies the east- west position of a point on the earth's surface.Meridians (lines running from the North Pole to Sought Pole) Connect points with the same longitude.

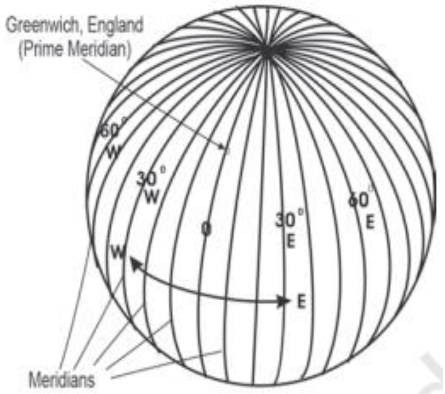


Figure: Meridians of Longitude

By convention, one of these, the Prime Meridian, which passes through the Royal observatory, **Greenwich** England, was allocated the position of zero degrees longitude. The longitude of other places is measurable as angle East or West from the prime meridian to $+180^o$ Eastward and -180^o Westward.

Note: With the help of altitude; latitude and longitude named geographic coordinates, location, distance and direction of various points can be easily determined.

Slope

A slope is the rise or fall of the land surface.

It may also be defined as:

The change in vertical distance or elevation over a given horizontal distance, or the change in horizontal distance over a given vertical distance; the vertical angle made by the sloping line and a horizontal line.

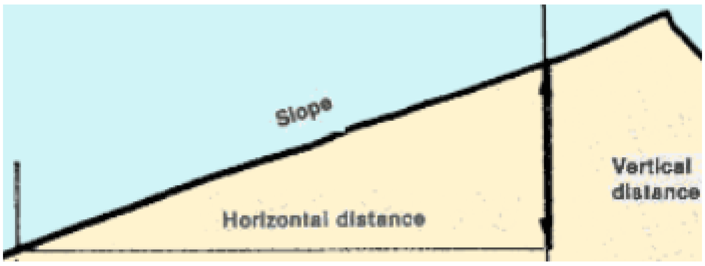


Figure: Land slope; horizontal distance and vertical distance

Flat areas are never strictly horizontal; there are gentle slopes in a seemingly flat area, but they are often hardly noticeable to the naked eye. An accurate survey of the land is necessary to identify these so called "flat slopes".

The slope of field is expressed as a ratio. It is the vertical distance or difference in height between two points in a field divided by horizontal distance between these two points.The formula is:

$$The\ slope = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)}$$

The slope can also be expressed as in percent,

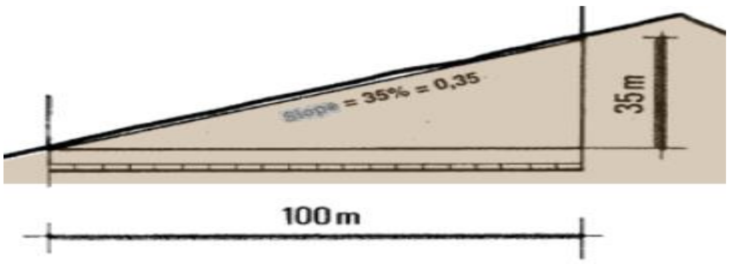


Figure: slope Percent

The formula used is then:

$$Theslope\% = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 100$$

The slope can be expressed per 1000, the formula used then:

$$Theslope\ {}^{o}/_{oo} = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 1000$$

Note: Slope in $^{O}/_{OO}$=Slope in % * 10

The slope can also be expressed in degrees, as the measurement of the vertical angle made by the slope and the horizontal plane.

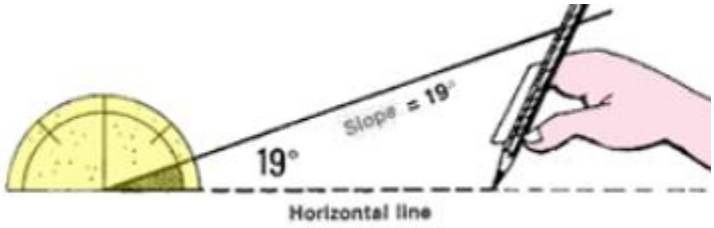


Figure: A slope expressed in degrees

The slope angle expressed in degrees is found by taking the arctangent of the ratio between rise and run.

Slope in degrees= arc tan ($\frac{rise\ (m)}{run\ (m)}$**)**

A slope is always measured between 0° (horizontal) and 90° (vertical)

There are several good ways to measure slopes. The method you use will depend on several factors such as how accurate a result you need; the equipment you have available and the type of terrain on which you are measuring.

Horizontal distance

Horizontal distance is the measured distance on the ground following the ground horizontal level.

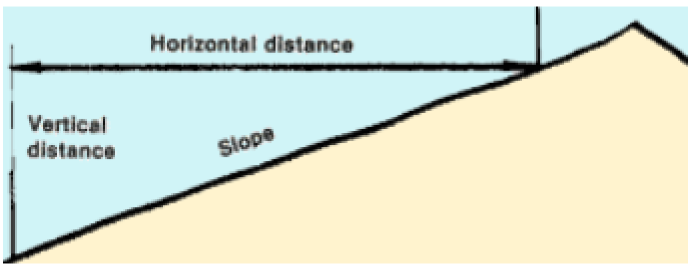


Figure: Horizontal distance; Vertical distance and slope

It can be calculated by multiplying the inclined distance by the reduction factor.

Reduction factor (RF): $RF = \frac{100}{\sqrt{100^2+s^2}}$

Where: RF= Reduction factor

S= Land slope

Or, it can be calculated by dividing the rise by the tangent of slope angle expressed in degrees

Horizontal distance= $\frac{rise\ (m)}{\tan \text{slope (degrees)}}$

Height difference

If point A is chosen as a reference point or datum, the elevation of any other point in the field can be defined as the vertical distance between this point and A.

For example, if a point A is at the top of a concrete bridge(see the following figure). Any other point in the surrounding area is higher or lower than A, and the vertical distance between the two can be determined.

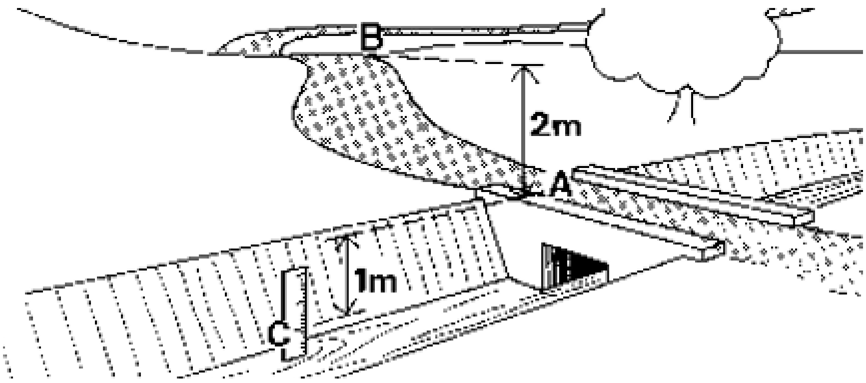


Figure: Vertical distance or height difference from reference point or datum “A”

“Datum” is any convenient level surface coincident or parallel with mean sea level to which elevations of a particular area are referred.

The "***leveling***" is the process of directly or indirectly measuring vertical distances to determine the elevation of points or their difference in elevation and "***difference in Elevation*** "is the vertical distance between the two level surfaces in which the points lie.

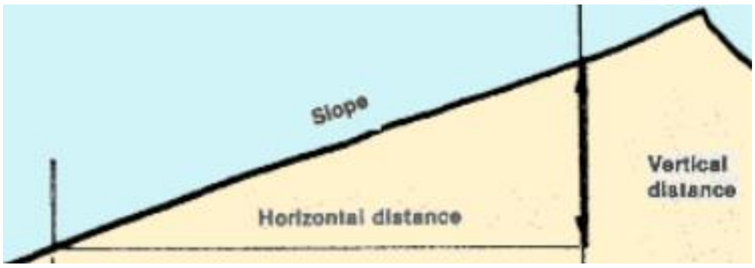


Figure: Vertical distance; horizontal distance and slope

The steepness of the slope depends on the difference in height between its points.

Horizontal angle

In topography, the angle made by two ground lines is measured horizontally, and is called a horizontal angle. These lines of sight are directed from your eyes, which form the summit A of the angle BAC, towards permanent landmarks such as a rock, a tree, a termite mound, a telephone pole or the corner of a building.

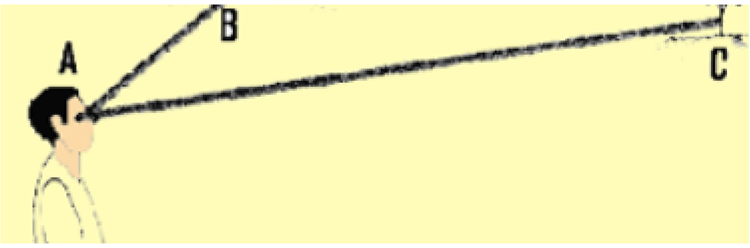


Figure: The lines of sight in angle BAC

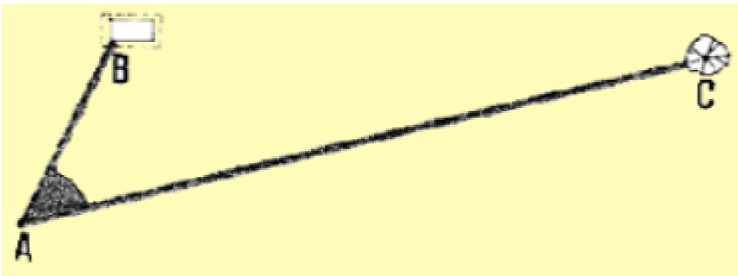


Figure: Horizontal angle BAC

Horizontal angles are usually expressed in degrees. There are different ways to measure horizontal angles in the field. The method you use will depend on how accurate a result you need, and on the equipment available.

Vertical angle

A vertical angle is an angle formed by two connected lines in the vertical plane, that is, between a low point and two higher points. Since these angles are in the vertical plane, the lines that form them will usually be lines of sight. Let us use the following figure:

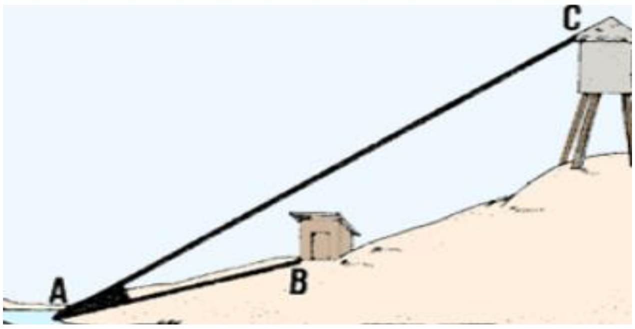
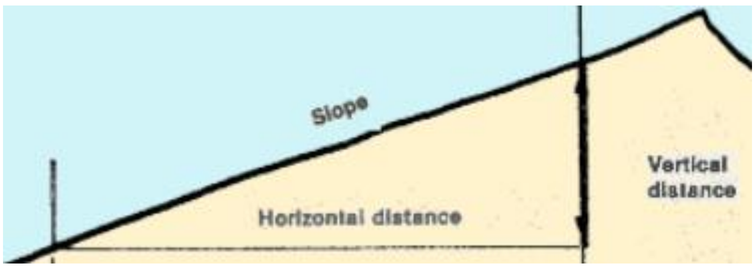


Figure: Vertical angle BAC

A vertical angle BAC can be formed, for example, by the line of sight AB from station A on a river bank to a higher water-pump installation, and the line of sight AC from station A to a much higher water-storage tank. Whenever a line is not horizontal, it has a slope.



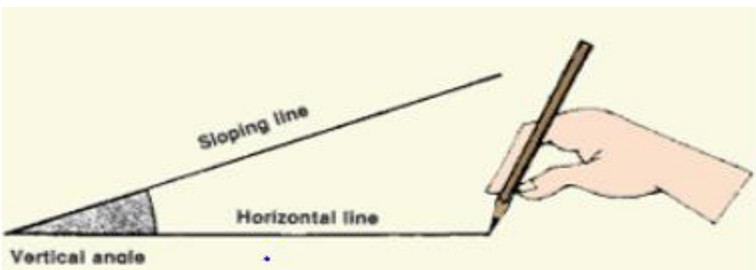


Figure: Vertical angle; vertical distance; horizontal distance and land slope

Area

The fields are often irregular which makes direct calculation of their areas difficult. In such case, fields are divided into a number of regular areas (triangles, rectangles, etc.), of which the surfaces can be calculated with simple formulas. All areas are calculated separately and the sum of these areas gives the total area of the field.

The following is example of a field with irregular shape and its area has to be calculated

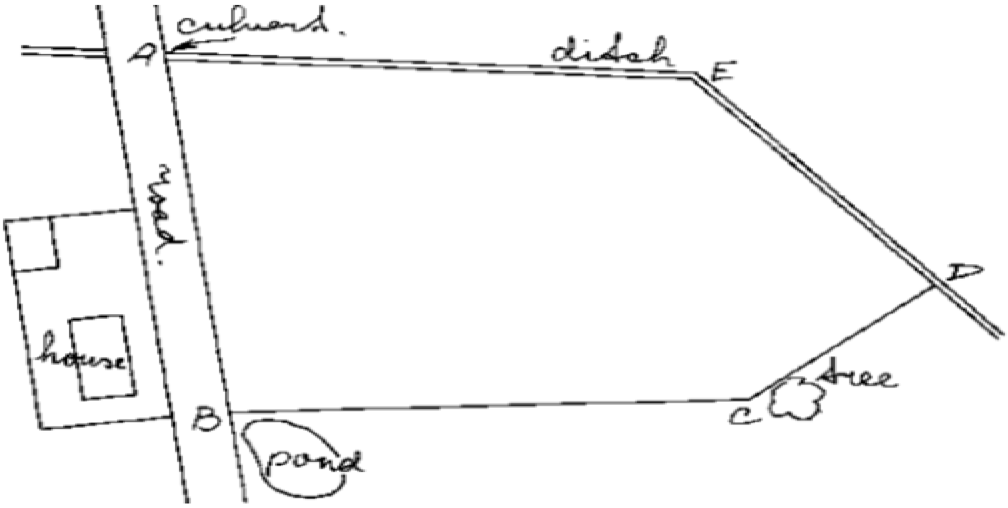


Figure: A field with an irregular shape of which the surface area must be determined.

The procedure to follow is:

Step 1: Make a rough sketch of the field indicating the corners of the field (A, B, C, D and E) and the field borders (straight lines). In addition, some major landmarks are indicated (roads, ditches, houses, trees, etc.) that may help to locate the field.

Step 2: Divide the field, as indicated on the sketch, into areas with regular shapes. In this example, the field can be divided into 3 triangles ABC (base AC and height BB,), AEC (base AC and height EE1) and CDE (base EC and height DD1).

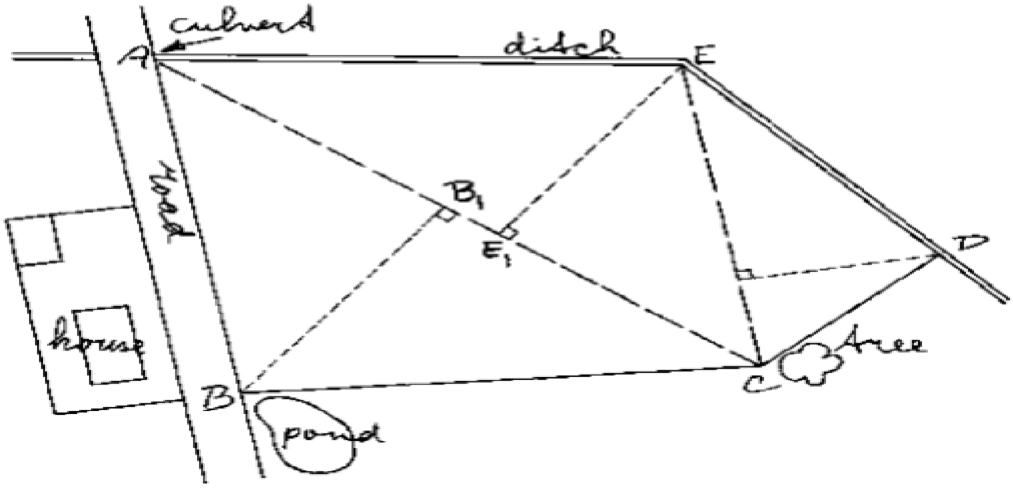


Figure: Irregular field divided into regular shapes

Step 3: Mark, on the field, the corners A, B, C, D and E with pegs.

Step 4: Set out ranging poles on lines AC (base of triangles ABC and AEC) and EC (base of triangle EDC) and measure the distances of AC and EC.

Step 5: Set out line BB_1 (height of triangle ABC) perpendicular to the base line AC (see Fig. 29d). Measure the distance BB_1,

Step 6: In the same way, the height EE_1, of triangle AEC and the height DD_1, of triangle CDE are set out and measured.

Step 7: The base and the height of the three triangles have been measured. Now, the final calculation can be done.

Note: This process is used when Digital equipment are not available as they can determine the area calculation for any field shape. Digital equipment can be used to automatically measure, store, and compute area, and are capable of achieving the results with higher accuracies.

- Content /Topic4: Purpose of topographic data

Topographic data are applied to all technicians having responsibility for the planning, engineering and design, operation, maintenance, construction, and related real estate and regulatory functions of construction, civil works, and environmental restoration projects.

It is intended for use by hired-labor personnel, construction contractors, Architect-Engineer contractors and Agriculture engineers.

In agriculture topographic data are mostly used for soil erosion control; canals construction; structures construction; land grading; land levelling and Irrigation system design

It is also applicable to surveys performed or procured by local interest groups under various cooperative or cost-sharing agreements.

LO 2.2 – Select tools, material and equipment based on required topographic data

- Content/Topic 1: Categories of tools and equipment

The main categories of topographic data correction tools and equipment are **non-optical tools**, **optical equipment** and **digital equipment**.

Non-Optical tools:

- **Tape measure**

Description

Measuring tapes are made of steel, coated linen, or synthetic material. They are available in lengths of 20, 30 and 50 m. Centimeters, decimeters and meters are usually indicated on the tape. Tape measures are sometimes with handle.

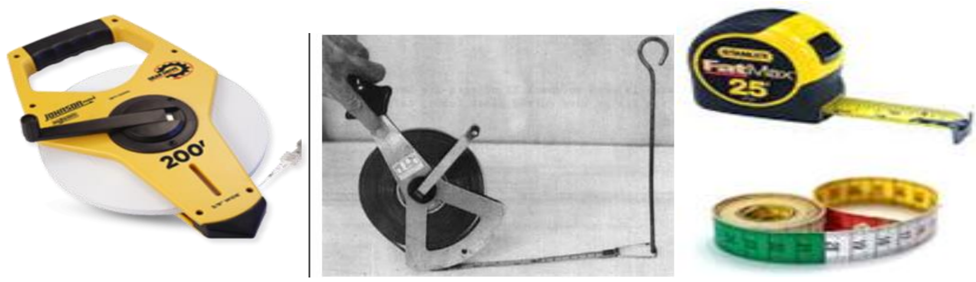


Figure: Different forms of tape measures

Function

Measuring tapes are used to measure distances on the field.

A-frame level

Description

The A-Frame is a tool which can be made at home from local resources. It is called an A-Frame because it looks like the English letter "A".

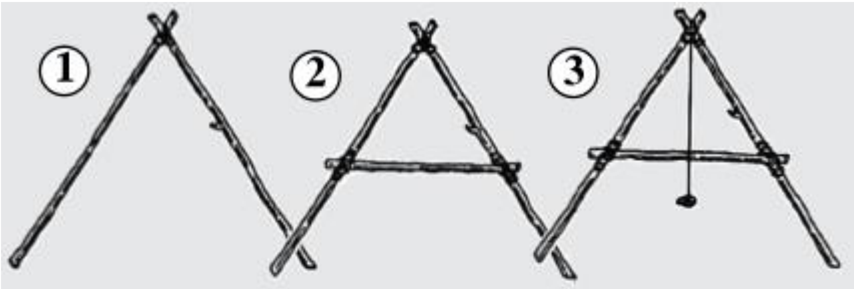


Figure: These pictures show how the A-Frame is put together.

The A-Frame is constructed by joining the legs, level stick and string as in drawings 1, 2 and 3 above.

Function

The A-Frame is used for marking out horizontal lines, or contours, across a slope.

N-frame level

Description

This instrument consists of a wooden or steel frame. On the main lath, a carpenter level is firmly fixed (e.g. with metal strips).

Before fixing the carpenter level to the frame, the instrument must be tested to make sure that it is in the correct position.

The frame is placed on two points which have the same elevation (for example on a horizontal table or on a floor that has been checked previously with the carpenter level). If the bubble of the level tube is not exactly in between the marks, the carpenter level must be adjusted by putting a spacer under one end of the level.

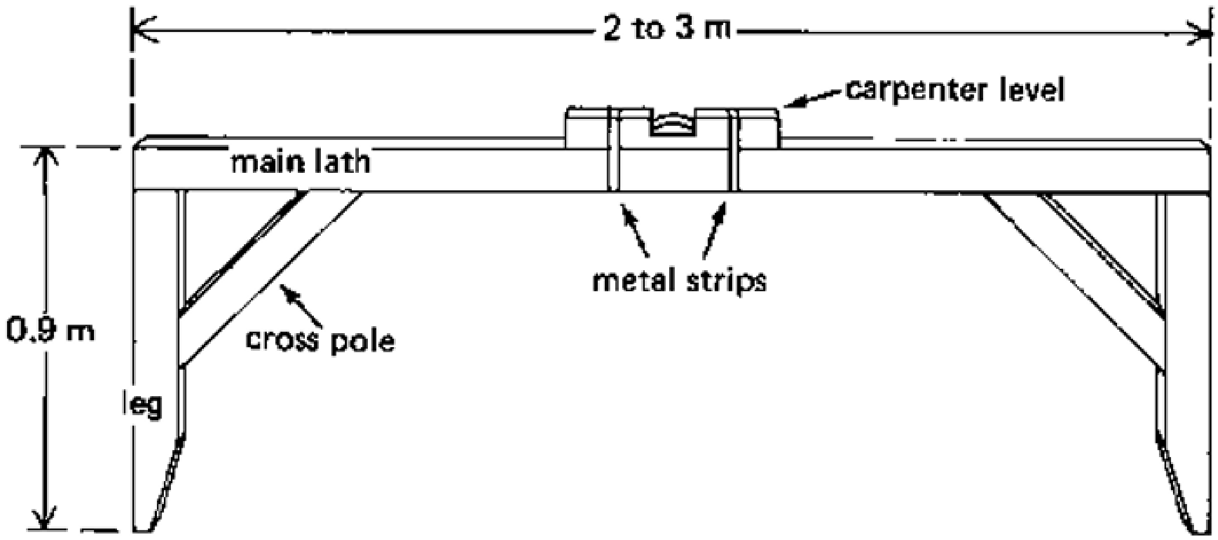


Figure: N frame level

Use of the N-frame level

Setting out contour lines

Starting from peg (A), a contour line has to be set out. The procedure to follow is:

Step 1: One leg of the instrument is placed close to peg (A). By turning the frame around this leg, a position of the frame is found such that the second leg is on the ground and the bubble of the carpenter level is in between the marks. This means that the spot thus found by the second leg of the frame is at the same elevation as the starting point. Both points belong to the same contour line. A new peg (peg B) is driven in close to the second leg to mark the place.

Step 2: The N-frame is moved to the newly-placed peg and the procedure is repeated until the end of the field is reached. All the pegs, thus driven in the ground, form a contour line

Step 3: When the first contour line has been pegged out it might be necessary to make minor adjustments by moving some of the pegs to the left or to the right to find a smooth line. Most of the pegs will remain in the same place. The smooth line thus formed by the pegs represents the first contour line.

Step 4: The next step is to determine the second contour line. A choice has to be made on how many centimeters lower (or higher) the next contour line should be. This choice should be based on **the required accuracy** (a little difference in height means it is more accurate), the **general slope of the area** and the **regularity of the general slope of the area**. In practice, the height difference will vary between 10 and 50 cm

Setting out slopes

In addition to the determination of contour lines, the N-frame level can be used to set out lines with a uniform slope, which is useful, e.g. for setting out furrows or ditches.

Step 1: The shortest leg of the N-frame is placed close to the starting peg (A). By turning the N-frame around this leg, a position is found such that the second leg is on the ground and the bubble of the carpenter level is in between the marks. The spot thus found is 2 cm lower than the starting point and is marked with a new peg.

Step 2: The N-frame is moved and the short leg is placed near peg (B). The procedure is repeated until the end of the field is reached. The succession of pegs thus placed form a line with a slope of 1%.

- **Carpenter level**

Description

Within a carpenter level, there are one or more curved glass tubes, called level tube. Each tube is sealed and partially filled with a liquid (water, oil or paraffin). The remaining space is air, visible as a bubble. On the glass tube, there are two marks. Only when the carpenter level is horizontal (or vertical) is the air bubble exactly between these two marks.

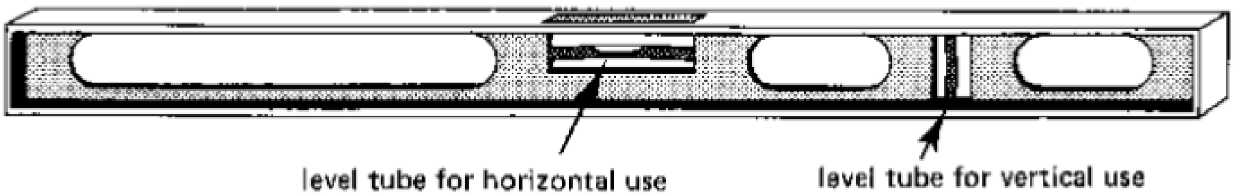


Figure: A carpenter levels

Function

A carpenter level is used to check if objects are horizontal or vertical.

- **Chain**

Description

A chain is made up of connected steel segments, or links, which each measure 20 cm. Sometimes a special joint or a tally marker is attached every 5 meters. Usually, a chain has a total length of 20 meters, including one handle at each end.

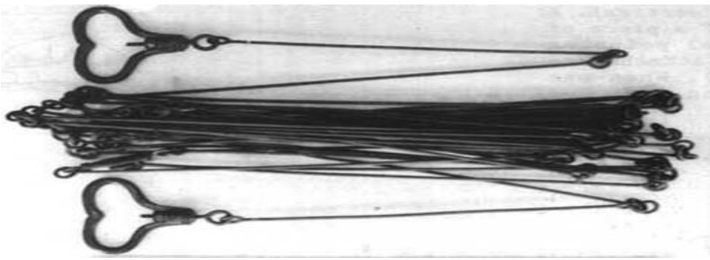


Figure: A chain

Function

A chain is used to measure the distance on the field.

- **Arrows**

Description

Very often, the distance to be measured is longer than the length of the chain or the tape. The front man is then provided with "*short metal pins*", called "arrows". The arrows are held together by a carrying ring.

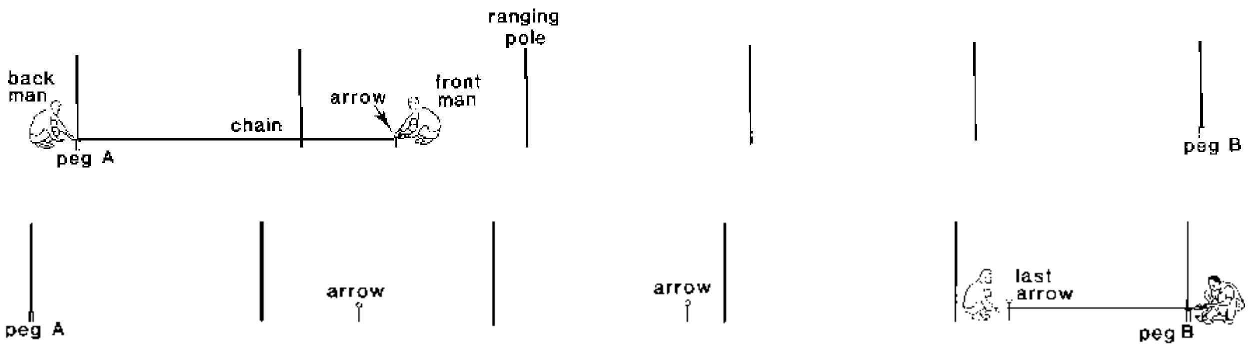


Figure: Arrows used in long distance measurement

Function

These arrows are used to mark the position of the end of the chain (or tape) each time it is laid down.

- **Ranging poles**

Description

Ranging poles are straight round stalks, 3 to 4 cm thick and about 2 m long. They are made of wood or metal. Ranging poles can also be home made from strong straight bamboo or tree branches.

Ranging poles may never be curved.

Ranging poles are usually painted with alternate red-white or black-white bands. If possible, wooden ranging poles are reinforced at the bottom end by metal points

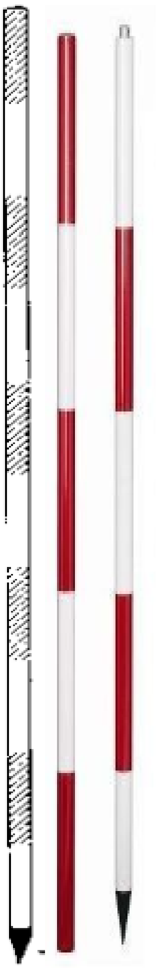


Figure: Ranging poles

The correct way to hold a ranging pole is to keep it loosely between thumb and index finger, about 10 cm above the soil.

When the observer indicates that the ranging pole is in the right position, the assistant loosens the pole. The sharp bottom point of the ranging pole leaves a mark on the soil exactly where the pole has to be placed. Once in place, it should be checked if the ranging pole is vertical, e.g. with a plumb bob, or a carpenter level.

Function

Ranging poles are used to mark areas and to set out straight lines on the field. They are also used to mark points which must be seen from a distance, in which case a flag may be attached to improve the visibility.

- **Plumb bob**

Description

A plumb bob consists of a piece of metal (called a bob) pointing downwards, which is attached to a cord.

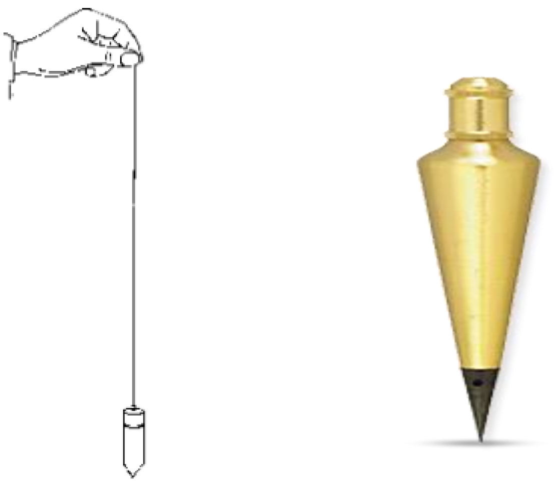


Figure: A plumb bob

Function

A plumb bob is used to check if objects are vertical. When the plumb bob is hanging free and not moving, the cord is vertical.

Compass

Description

The compass is an optical instrument using the property of a magnetic needle that moves freely always in magnetic north direction.

There are two types of compass such as **fixed scale** and **mobile scale compass**.

Fixed scale compasses: are the oldest compasses. The fixed scale compass is composed by a dial in which a needle rests on a pivot and indicates the magnetic direction through the ending point of the needle. The fixed scale is engraved on the housing of that compass. The angle measured by that kind of compass is always magnetic azimuth.

Mobile scale compasses: are the most common compasses. There are a large range of models and marks. The scale sometimes called pink is immersed within an oil bath. The magnetic needle is part of scale. The scale is a device that ensures a rapid breaking of the oscillations which facilitates a rapid sighting and reading. The angles measured using such compass is always a Magnetic bearing.

Types of mobile compass.

a) Suunto Compass.

Suunto compass is in the form of aluminum housing, having 7cm long, 5cm wide and 1.5cm thick. The foresters prefer to use that kind of compass because of its simplicity and robustness. The accuracy of sight with Suunto compass is about 0.5degree or 0.5 grades

Sighting principle:

- Held the compass by hand, at the eye level while horizontal
- Sight with both eyes open, one eye sights on the sighting point, (on the compass) the other eye sights on the target object (often the rod).

-For an optical effect, we see the graduations of the compass and the target direction overlap. Read the result.

If the target point is on the top of steep slope or down, it will be better to align a point that is enough closer to the compass in order to continue to sight with the compass while holding it in its horizontal position.

b) Meridian compasses

The meridian compasses are also optical instruments popular with the foresters. They are delicate but accurate when used with a tripod or rack instrument (supporting device). There are two types of meridian compasses such as: **Graphometer (cylindrical meridian compass) and flat meridian compass**

Graphometer

The Graphometer has a cylinder form with a height of 10cm and 5cm diameter. The true compass is located on the bottom side of the compass.

A small magnifying glass is attached on the cylinder side for easy reading. A slot of sight (cross hair) is facing the magnifying glass that helps to sight the wanted point.

Due to the great length of this slot, one can carry out the sights on the steep slopes. A ring attached to the top side of the cylinder allows the use of the compass either suspended from a finger or suspended from a rod through a supporting device.

The graphometer can be also mounted on the tripod with a screw located on the bottom side of cylinder. On the top side of cylinder, there is a circular bubble that allows fixing the instrument perfectly horizontal.

Major types of magnetic compass are: **prismatic compass**; **surveyor's compass** and **level compass**

Figure: prismatic compass

Function

The compass is used to measure horizontal angle.

- **Pegs**

Description

Pegs are generally made of wood; sometimes pieces of tree-branches, properly sharpened, are good enough. The size of the pegs (40 to 60 cm) depends on the type of survey work they are used for and the type of soil they have to be driven in. The pegs should be driven vertically into the soil and the top should be clearly visible.

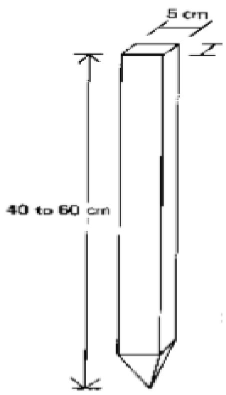


Figure: The pegs

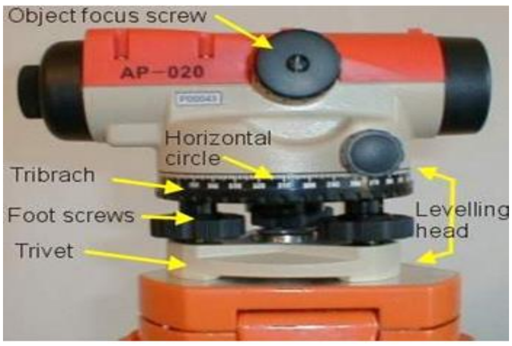
Function

Pegs are used when certain points on the field require more permanent marking.

OPTICAL EQUIPMENT:

- **Automatic level**

Description



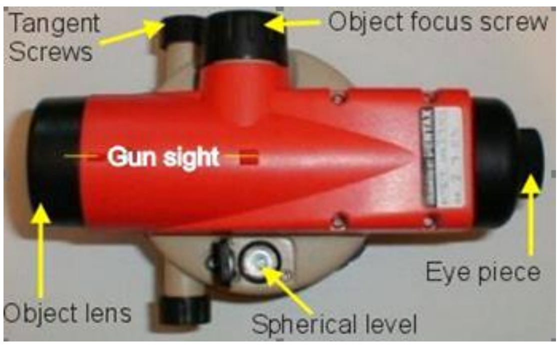


Figure: Main parts of a dumpy level (right side)Figure:Main parts of a dumpy level(top view)

Figure: Example 1 of Automatic level

Figure: Example 2 of Automatic level

Function

An automatic level is an optical instrument used to establish or verify points in the same horizontal plane in a process known as leveling, and is used in conjunction with a leveling staff to establish the relative heights levels of objects or marks. It is used in surveying to measure height differences and to transfer, measure, and set heights of known objects or marks.

- **Leveling staff**

Description

Many types of staff are used with varying lengths and different markings. The E-type face is commonly used in the UK and Ireland. This can be read directly to 0.01m and by estimation to the nearest mm.

There are many types of staffs, with names that identify the form of the graduations and other characteristics. Staffs can be one piece, but most of them are sectional and adjust the length by telescoping..

The metric staff has major numbered graduations in meters and tenths of meters (there is a tiny decimal point between the numbers).

When viewed through an instrument's telescope, the observer can easily visually interpolate a 10 mm mark to a quarter of its height, giving a reading accuracy of 2.5 mm. On one side of the rod, the colours of the markings alternate between red and black with each meter of length.

Figure: A reading staff and tripod

Function

A levelling staff is needed to measure vertical distances and an instrument known as a level is required to define the horizontal plane.

- **Theodolite**

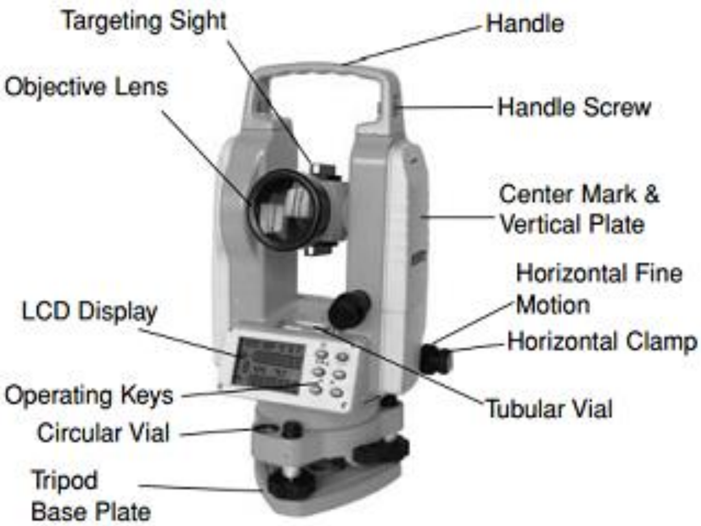
Description

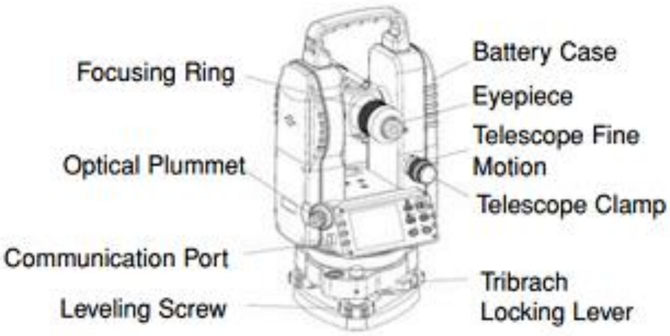
There are two different kinds of theodolites: **digital** and **non-digital**. Non digital theodolites are rarely used anymore. Digital theodolites consist of a telescope that is mounted on a base, as well as an electronic readout screen that is used to display horizontal and vertical angles. Digital theodolites are convenient because the digital readouts take the place of traditional graduated circles and this creates more accurate readings.

Theodolite also can be classified as **transit** and **Vernier theodolite**.It is called a **transit** theodolite when its telescope can be transited means revolved through a complete revolution about its horizontal axis in the vertical plane, whereas in a **Non-Transit** type, the telescope cannot be transited. They are inferior in utility. For reading the graduated circle if verniers are used, the theodolite is called as a **Vernier**, theodolite. Whereas, if a micrometer is provided to read the graduated circle the same is called as a **Micrometer** Theodolite. Vernier type theodolites are commonly used.

Parts of a Theodolite

Like other leveling instruments, a theodolite consists of a telescope mounted on a base. The telescope has a sight on the top of it that is used to align the target. The instrument has a focusing knob that is used to make the object clear. The telescope contains an eyepiece that the user looks through to find the target being sighted. An objective lens is also located on the telescope, but is on the opposite end as the eyepiece. The objective lens is used to sight the object, and with the help of the mirrors inside the telescope, allows the object to be magnified. The theodolite's base is threaded for easy mounting on a tripod.





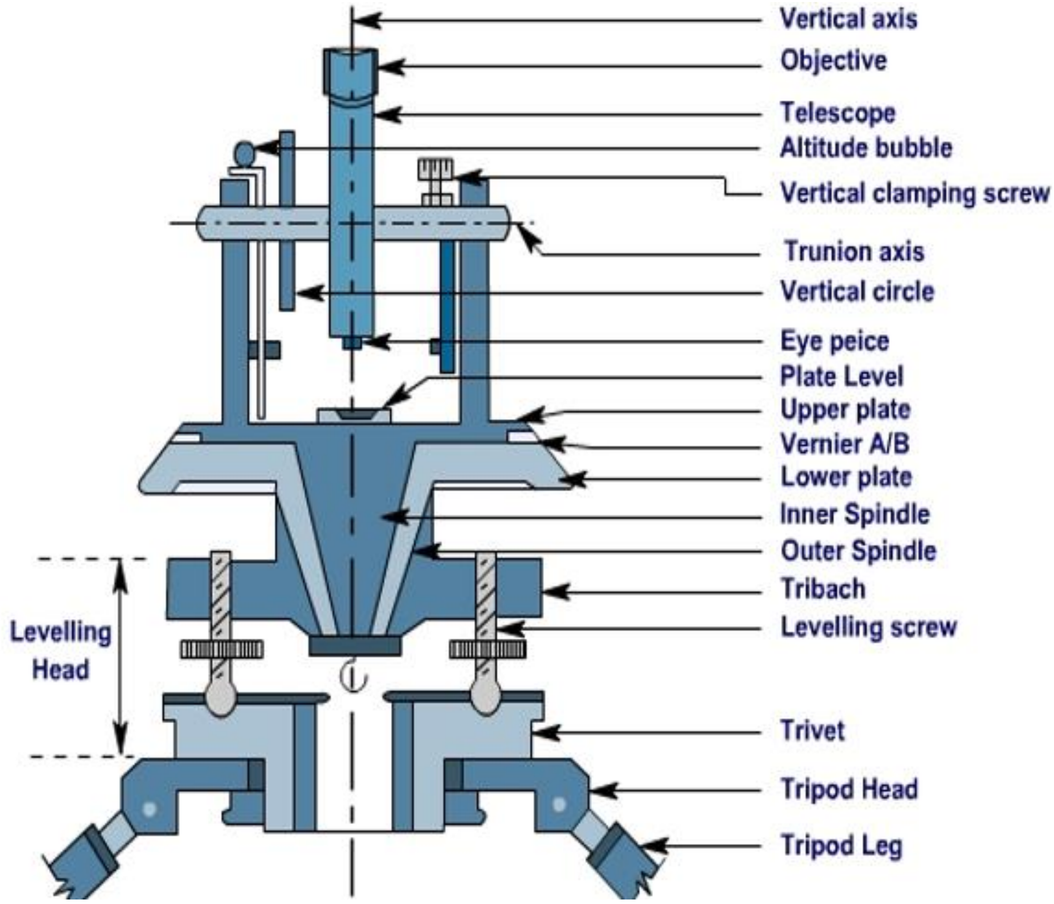


Figure: Main parts of a Theodolite

Figure: Theodolite

A theodolite works by combining optical plummets (or plumb bobs), a spirit (bubble level), and graduated circles to find vertical and horizontal angles in surveying. An optical plummet ensures the theodolite is placed as close to exactly vertical above the survey point. The internal spirit level makes sure the device is level to the horizon. The graduated circles, one vertical and one horizontal, allow the user to actually survey for angles.

How to Use a Theodolite

1. Mark the point at which the theodolite will be set up with a surveyor's nail or a stake. This point is the basis for measuring angles and distances.
2. Set up the tripod. Make sure the height of the tripod allows the instrument (the theodolite) to be eye-level. The centered hole of the mounting plate should be over the nail or stake.
3. Drive the tripod legs into the ground using the brackets on the sides of each leg.
4. Mount the theodolite by placing it atop the tripod, and screw it in place with the mounting knob.
5. Measure the height between the ground and the instrument. This will be used as reference to other stations.
6. Level the theodolite by adjusting the tripod legs and using the bulls-eye level. You can make slight tunings with the leveling knobs to get it just right.
7. Adjust the small sight (the vertical plummet) found on the bottom of the theodolite. The vertical plummet allows you to do ensure the instrument remains over the nail or stake. Adjust the plummet using the knobs on the bottom.
8. Aim the crosshairs in the main scope at the point to be measured. Use the locking knobs on the side of the theodolite to keep it aimed on the point. Record the horizontal and vertical angles using the viewing scope found on the theodolite's side.

Function

A theodolite is a precision instrument used for measuring angles both horizontally and vertically.

Both theodolites and transits (a" *transit* "is a surveying instrument that also takes accurate angular measurements) can be used for similar projects, but there are slight differences between the two instruments.

Transits use vernier scales and external graduated metal circles for angular readings. **Theodolites** use enclosed graduated circles and angular readings are taken using an internal magnifying optical system. Theodolites tend to have a more precise reading and provide greater accuracy in measuring angles than transits do.

Theodolites are mainly used for surveying, but they are also useful in others applications like meteorology and measuring and laying out angles and straight lines.

Advantages of Using a Theodolite

Theodolites have many advantages when compared to other leveling instruments:

- Greater accuracy.
- Internal magnifying optical system.
- Electronic readings.
- Horizontal circles can be instantly zeroed or set to any other value.
- Horizontal circle readings can be taken either to the left or right of zero.
- Repeat readings are unnecessary.

Theodolites have an internal optical device that makes reading circles much more accurate than other instruments. Also, because the theodolite allows you to take fewer repeat readings, these measurements can be made much more quickly. Theodolites with optical instruments have advantages over other layout tools. They have more precise measurements, they are unaffected by wind or other weather factors, and they can be used on both flat ground and sloped ground.

Digital equipment:

- **GPS**

Description

GPS (NAVSTAR" Navigation Satellite Timing And Ranging") is a satellite based navigation system. There are often more than 24 operational satellites as new ones are launched to replace older satellites.

The GPS system is free for everyone to use, all that is needed is a GPS receiver (Which require cost).

The GPS receiver of user is composed of processors and antennas that allow receiving the broadcast. The receivers convert space signals into position, velocity and time. A total of 4 satellites are required to compute these calculations. In order to make this simple calculation, then, the GPS receiver has to know two things: The location of at least three satellites above you and the distance between you and each of those satellites.

Most modern receivers are parallel multi-channel design. Parallel channels are quick to lock on to satellites when first turned on and they are able to receive the satellite signals even in difficult conditions such as dense foliage or urban settings. If you want to have continuous real-time position measurements, then the receiver has to have at least four channels. If it does, then it can devote one channel to each of the four satellites at the same time.

The satellite orbits repeat almost the same ground track (as the earth turns beneath them) once each day. These satellites travel at speeds of about14,000kilometers per hour with a 12hr period(precisely 11hr 58 min).

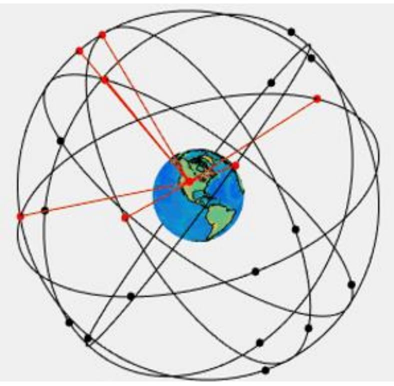


Figure : GPS orbit

Figure :GPS satellite

Figure: 2 GPS receivers

Function

GPS was designed for military use for US Department of Defence to give positioning information at any weather conditions and anywhere on the surface portion of earth. Later it was made available for civilians use also. Initially most of civilian applications were in marine navigation and surveying. But in modern era, different applications become very popular.

- **Theodolite**

Precision digital theodolite for professional angle survey measurement is a modern engineering instrument for measuring both horizontal and vertical angles. It is a key tool in surveying and engineering work. The theodolite consists of a telescope movable within two perpendicular axes- the horizontal axis, and the vertical axis. When the telescope is pointed at a desired object, the angle of each of these axes can be measured with great precision (see optical equipment).

Digital theodolite is provided with1X Rechargeable Ni-MH Batteries & an extra AA battery pack to ensure that the unit can be used continuously at work site without having to stop & recharge. It has capacity of Water & Dust Proof; all significant parts are protected by tight rubber rings. With Waterproof Grade IP54, you are free to operate your job no matter in rain or desert.

Figure: A digital theodolite

LO 2.3 – Delimitate site according to the guidelines

- Content/Topic 1: Landmarks

A landmark is an object or feature of a landscape or town that is easily seen and recognized from a distance, especially one that enables someone to establish their location.

Landmark can also be defined as the position of a prominent or well-known object in a particular landscape. It can also be a mark showing the boundary of a piece of land.

In topographic data collection, the landmarks mostly are roads, trees, canal, river, lake, houses and pastures or other selected depending on considerations.

- <u>Content/Topic 2: Shape of site</u>

It is important to be able to know and respect the site shape during site delimitation. It might be necessary used for other related topographic surveying activities.

The most common surface sites: the square, the triangle, the rectangle, the trapezium and the irregular shape.

- **Square shape site**

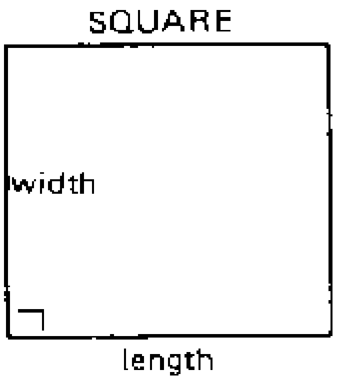


Figure: Square shape

- **Triangle shape site**

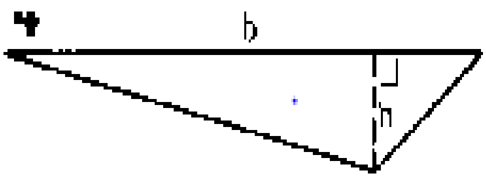


Figure: Trianlge shape

Rectangular shape site

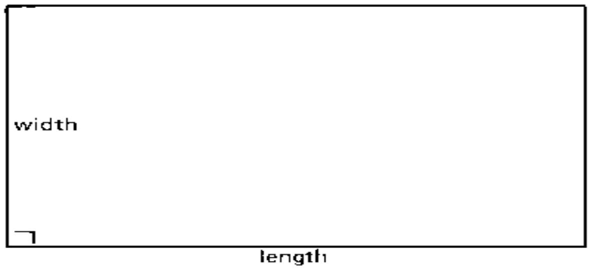


Figure: rectangle shape

Trapezium shape site

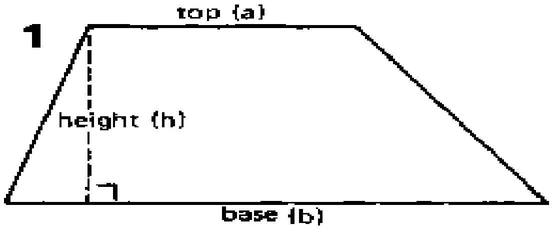


Figure :Trapezium shape

Irregular shape

The fields are often irregular shape. In such case fields are divided into a number of regular shapes (triangles, rectangles, etc.), of which the calculation can be done with simple formulas (for example area calculation).

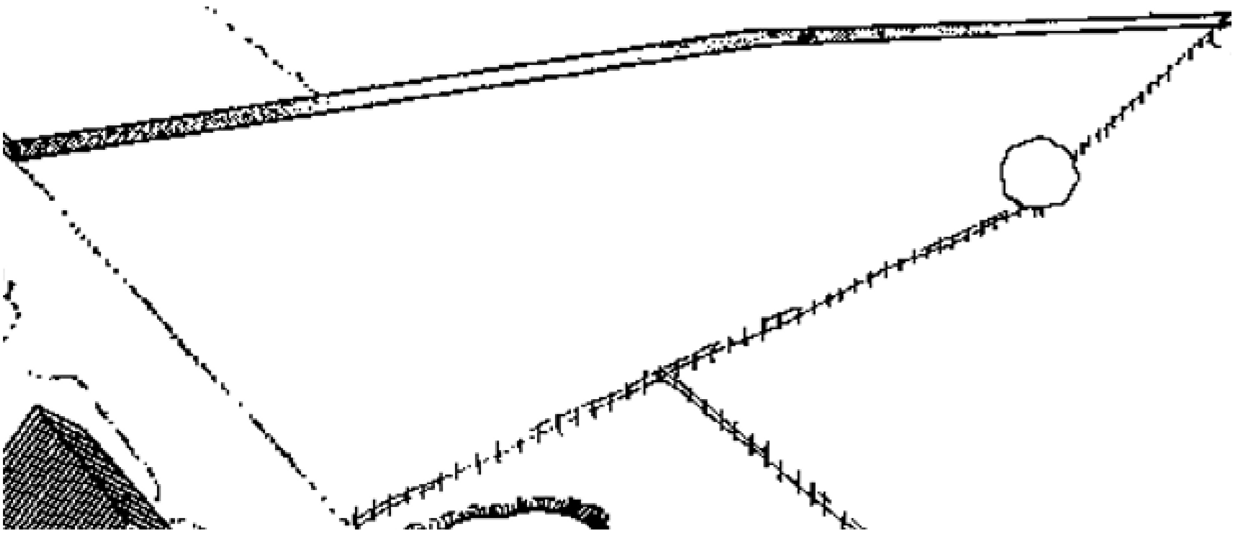


Figure: Site of irregular shape

- Content/Topic 3: Site delimitation

The site delimitation consists of setting out or establishing the limits or boundaries of site where the topographic data collection will be carried out. The required tools and equipment for this task are: Machete, Rope, Tape measure, Ranging rods, Pegs, Clinometers, Compass, Dumpy level or Theodolite.

The limits of the site may be determined by lines such as straight line, broken line and curved line. Each line will be marked (picketed) according to its form.

- **Marking of a straight line.**

For marking a straight line, the rods or pegs are fixed (planted) on the starting and ending points. If the line is very long, the intermediate rods or pegs are introduced between starting and ending points, maintaining the line straightness.

- **Marking of a broken line.**

For marking a broken line, the rods or pegs are fixed (planted) on the points where the straight line changes its direction.

- **Marking of a curved line.**

Concerning the curved (bent) line, one places/fixes many rods on this bent line, what produces a broken line, so that they transform it into a broken line without changing significantly the initial curve shape.

Note: If you need to find the exact point where the rod was planted for making other measures or control measures, one fixes a peg at the exact point where the rod was. One takes care to fix it straight and deeply. If necessary, one can also make the comment on this peg, for example numbering.

LO 2.4 – Position of tools and equipment referring to the operation manual

- Content /Topic 1:Non optical equipment adjustment

i) Testing the N-frame level

Before fixing the carpenter level to the frame, the instrument must be tested to make sure that the carpenter level is in the correct position.

The frame is placed on two points which have the same elevation (for example on a horizontal table or on a floor that has been checked previously with the carpenter level). If the bubble of the level tube is not exactly in between the marks, the carpenter level must be adjusted by putting a spacer (e.g. thin piece of board) under one end of the level.

N- Frame also can be adjusted for measuring slope by reducing the height of one leg according to the slope needed. For example a slope of 1.5% would require one Leg to be 3 cm (1.5% of 2 m) shorter; a slope of 2% would require a 4 cm (2% of 2 m) shorter leg (see figure).

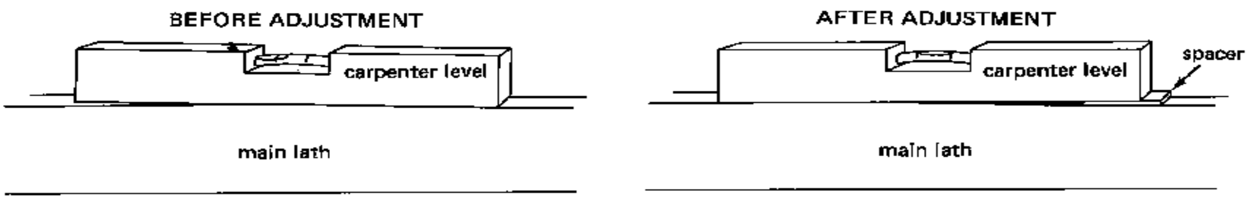


Figure: N- frame level adjustment (top view)

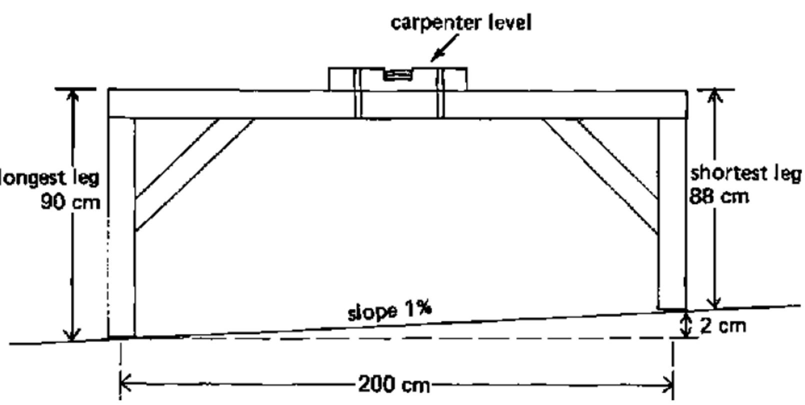


Figure: N frame level adjustment by reducing the leg height for measuring slope

ii) Placing of Ranging Poles

The correct way to hold a ranging pole is to keep it loosely between thumb and index finger, about 10 cm above the soil.

When the observer indicates that the ranging pole is in the right position, the assistant loosens the pole. The sharp bottom point of the ranging pole leaves a mark on the soil exactly where the pole has to be placed. Once in place, it should be checked if the ranging pole is vertical, e.g. with a plumb bob, or a carpenter.

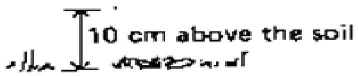


Figure: Placing a ranging pole

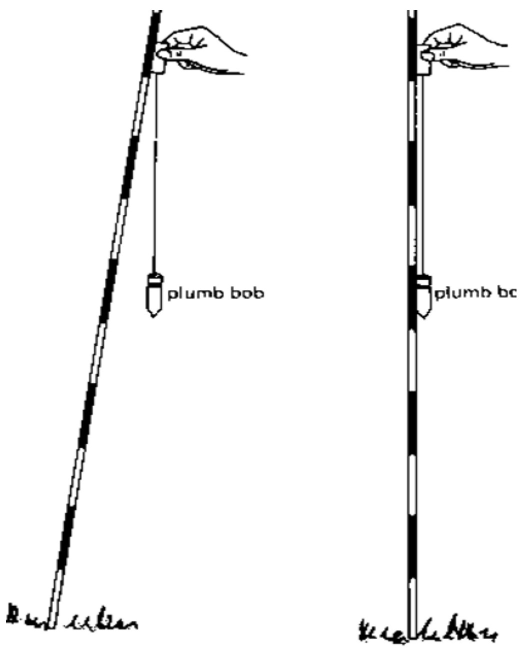


Figure: Wrong and Right placing a ranging pole

- <u>Content /Topic 2: Optical equipment positioning</u>

i) Automatic level positioning

Setting up the Level

Step1: Find a benchmark location near the spot you want to measure. A benchmark location is a spot that you already know the height of thanks to previous land surveys. In order to get the most accurate data out of your dumpy level, you'll need to search online and find a benchmark location located close to the spot you want to measure.

If you can't find a benchmark location, you can measure from a distinct land feature, such as a large tree or building, instead**.**

Step 2: Set your tripod up near the spot you want to measure**.** Place your tripod on a patch of flat, clear ground that sits between your benchmark location and the spot you want to measure. Then, undo the latches on your tripod's legs and extend each leg out. Adjust the legs until your tripod is completely level, then close each latch.

- Almost all tripods come with a built-in bubble level. You can use this to assess whether or not the tripod is level.
- To measure the area properly, make sure you set up in a spot that's slightly higher than your benchmark location.

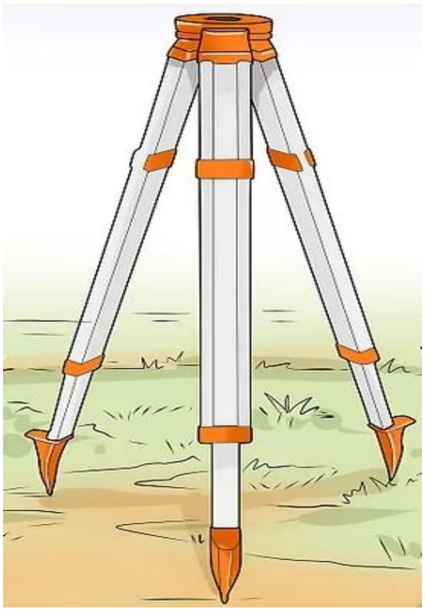


Figure: Setting a tripod

Step3: Connect your device to the tripod and position it over 2 leveling screws. Screw your dumpy level onto the tripod's base plate, and then connect the base plate to the main tripod body. Once the instrument is securely attached, turn the dumpy level's telescope so that it sits parallel with 2 of the device's leveling screws.

- If the dumpy level wobbles when tapped, tighten the leveling screws to better secure the device.

Figure: Connection of a device to the tripod

Steps 4: Level the device by adjusting the 2 leveling screws. Look for a traditional bubble level located somewhere on your device. When you find it, grab the 2 leveling screws that are parallel to the device's telescope and twist them in opposite directions. Do this until the bubble sits in the exact center of the level.

- For the best results, turn the screws with an even amount of force and pressure.
- You'll typically find the bubble level either on top of or below the device's telescope.

Figure: Levelling the device by adjusting the 2 leveling screws

Step 5: Turn your telescope 90 degrees and adjust the third leveling screw. After adjusting your first 2 leveling screws, turn your telescope approximately 90 degrees so that it sits parallel to the device's third leveling screw. Then, adjust this screw until the bubble once again sits in the center of the level.

Vintage dumpy levels often have 4 leveling screws instead of 3. If this is the case for your device, adjust the second pair of screws just like you adjusted the first pair.

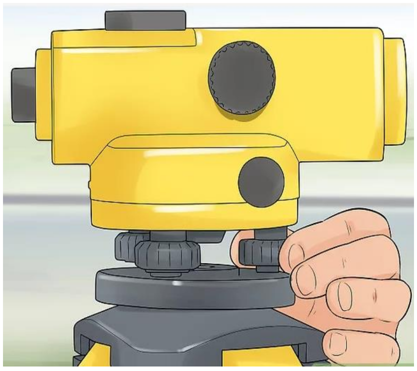


Figure: Adjusting the third leveling screw

Step 6: Check your level's calibration by turning it 180 degrees. After making your initial leveling adjustments, return your telescope to its starting position and check that the bubble still sits in the center of the level. If it does, turn the telescope 180 degrees and check the level again. You can focus the device once all 3 positions show the bubble in the center of the level.

If the bubble is not centered in any of the 3 positions, repeat the leveling process until it is.

Figure: Check level's calibration by turning it 180 degrees

Focusing the Level

Step 1: Remove your dumpy level's lens cap. The lens cap protects your device's lens from unwanted dirt, grime, and debris. To avoid damaging your instrument, leave the lens cap on until you're ready to use the device.

If your lens is dirty, wipe it down with a pre-moistened lens wipe. You can find these at most camera stores and a number of big-box stores.

Figure: Removal dumpy level's lens cap

Step2: Adjust the eyepiece until you can see the device's crosshairs. Place a sheet of paper or a similar object directly in front of your device's lens to occupy its entire field of vision. Then, turn the eyepiece's focusing knob until you can clearly see the dumpy level's crosshairs.

When finished, your crosshairs should appear dark, sharp, and easily noticeable.

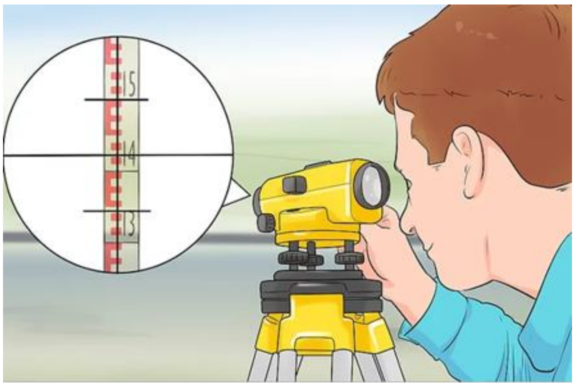


Figure: Adjusting of eyepiece to see the device's crosshairs

Step 3: Twist the device's focusing knob until the image is clear. Once you can see the crosshairs, point your device's telescope toward your benchmark spot. Look for a large, distinct object in the area, such as a tree or hilltop, and then twist your device's primary focusing knob until the object comes into focus.

If you're having trouble focusing, ask a friend or colleague to hold an E staff near the benchmark spot. This metered measuring stick will give you an easy object to focus on.

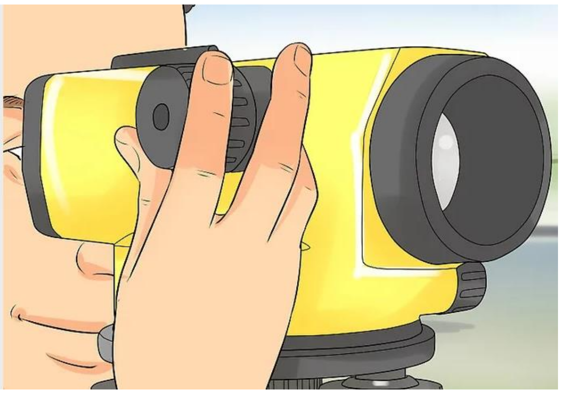


Figure: Twisting the device's focusing knob until the image is clear

ii) Theodolite positioning

- **The adjustments of a theodolite**

The adjustments of a theodolite are of two kinds: Permanent adjustments and temporary adjustments.

Permanent adjustments: are made to establish the relationship between the fundamental lines of the theodolite and, once made; they last for a long time. They are essential for the accuracy of observations.

The permanent adjustments in case of transit theodolites are:

i) Adjustment of Horizontal Plate Levels. The axis of the plate levels must be perpendicular to the vertical axis.

ii) Collimation Adjustment. The line of collimation should coincide with the axis of the telescope and the axis of the objective slide and should be at right angles to the horizontal axis.

iii) Horizontal axis adjustment. The horizontal axis must be perpendicular to the vertical axis.

iv) Adjustment of Telescope Level or the Altitude Level. The axis of the telescope levels or the altitude level must be parallel to the line of collimation.

v) Vertical Circle Index Adjustment. The vertical circle Vernier must read zero when the line of collimation is horizontal

Temporary adjustments of theodolite: are a set of operations necessary in order to make a theodolite ready for taking observations at a station. These include its setting up, centering, leveling up and focusing of eyepiece; they are achieved in four steps:

i. Setting up - fixing the theodolite onto a tripod along with approximate levelling and centering over the station mark.
ii. Centering - bringing the vertical axis of theodolite immediately over station mark using a centering plate also known as a tribrach.
iii. Levelling - leveling of the base of the instrument to make the vertical axis vertical usually with an in-built bubble-level.
iv. Focusing – removing error by proper focusing of objective and eye-piece. The eye-piece only requires adjustment once at a station. The objective will be re-focused for each subsequent sighting from this station because of the different distances to the target.

There are some words mostly used in adjustment; positioning and surveying using theodolite instruments, such as:

- **Transiting:** Transiting is also known as plunging or reversing. It is the process of turning the telescope about its horizontal axis through 180^0 in the vertical plane thus bringing it upside down and making it point, exactly in opposite direction.
- **Swinging the telescope:** It means turning the telescope about its vertical axis in the horizontal plane. A swing is called right or left according as the telescope is rotated clockwise or counter clockwise.
- **Face Left**: If the vertical circle of the instrument is on the left side of the observer while taking a reading, the position is called the ***face left*** and the observation taken

on the horizontal or vertical circle in this position, is known as the ***face left observation***

- **Face Right:** If the vertical circle of the instrument is on the right side of the observer while taking a reading, the position is called the ***face right*** and the observation taken on the horizontal or vertical circle in this position is known as the ***face right observation***.
- **Changing Face:** It is the operation of bringing the vertical circle to the right of the observer, if originally it is to the left, and vice–versa. It is done in two steps: Firstly revolve the telescope through 180^0 in a vertical plane and then rotate it through 180^0 in the horizontal plane means first transit the telescope and then swing it through180^0.
- **Line of Collimation:** is also known as the line of sight. It is an imaginary line joining the intersection of the cross- hairs of the diaphragm to the optical center of the object-glass and its continuation.

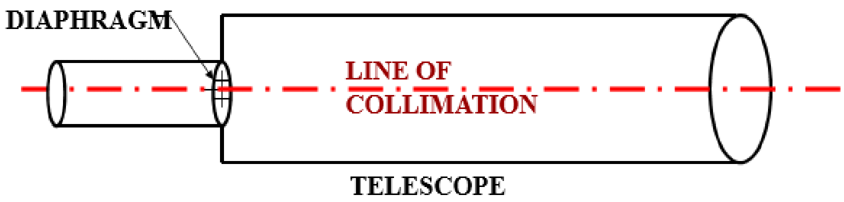


Figure92: line of Collimation

- **Axis of the telescope:** is also known an imaginary line joining the optical center of the object- glass to the center of eye piece.

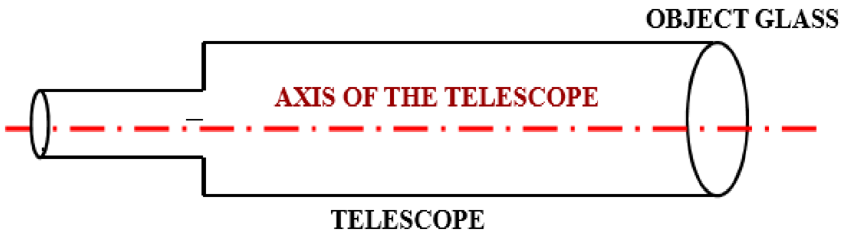


Figure: Axis of the telescope

- **Axis of the Level Tube:** It is also called the bubble line. It is a straight line tangential to the longitudinal curve of the level tube at the center of the tube. It is horizontal when the bubble is in the center.

- **Vertical Axis:** It is the axis about which the telescope can be rotated in the horizontal plane.
- **Horizontal Axis:** It is the axis about which the telescope can be rotated in the vertical plane. It is also called the *trunnion axis*.

Detailed steps of theodolite positioning or temporary adjustment

1.Mark the point at which the theodolite will be set up with a surveyor's nail or a stake.

2.Set up the tripod, make sure that the tripod head is approximately level and the tripod feet are firmly fixed in the ground and make sure the height of the tripod allows the instrument (the theodolite) to be eye-level. The centered hole of the mounting plate should be over the nail or stake.

The **tripod head should be horizontal;** height -middle to upper chest height and drive the tripod legs into the ground using the brackets on the sides of each leg. This should be done before removing the theodolite from its box.

Figure: Checking that the tripod head is approximately level and the tripod feet are firmly fixed in the ground.

The tripod is placed over the station with its legs widely spread so that the center of the tripod head lies above the station point and its head approximately level (by eye estimation).

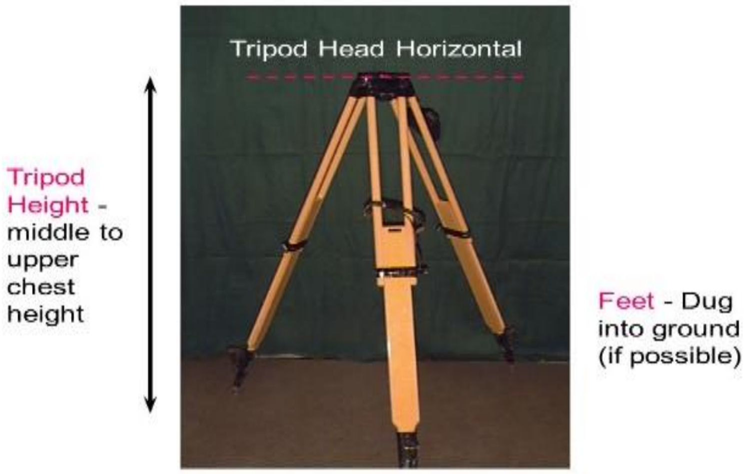


Figure: Completed tripod set up

3. Place the theodolite on top of the tripod, and tighten the centering screwit in place with the mounting knob toclamp the theodolite centrally on the tripod head. Don't forget or pay attention that the instrument is fixed with the tripod by screwing through the trivet.

The height of the instrument should be such that observer can see through telescope conveniently. After this, a plumb bob is suspended from the bottom of the instrument and it should approximately align with the station mark. In this context" ***Centering***"means setting the theodolite exactly over an instrument- station so that its vertical axis lies immediately above the station- mark. It can be done by means of plumb bob suspended from a small hook attached to the vertical axis of the theodolite. The center shifting arrangement if provided with the instrument helps in easy and rapid performance of the centering.

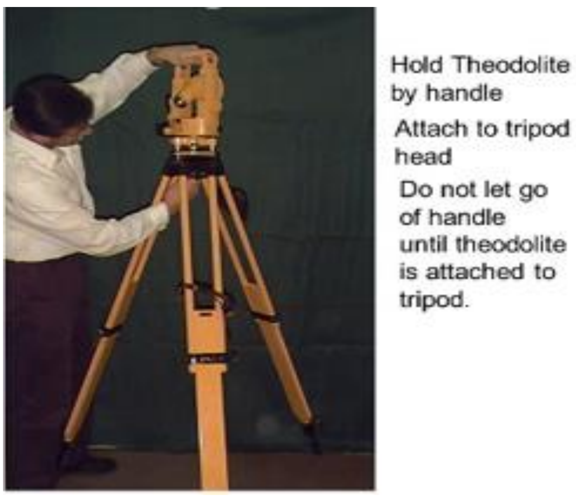


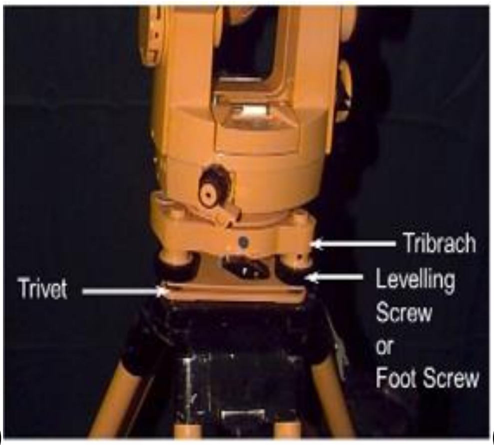
Figure: Mounting a theodolite

4. Tribrach Levelling Screw or Foot Screw Trivet, Level the theodolite by adjusting using the bulls-eye level and slight tunings with the leveling knobs to get it just right. The "***Levelling***" of an instrument is done to make it vertical axis with respect to the apparent force of gravity at the station. The simplest way is the following:

a) Bring one of the level tubes parallel to any two of the foot screws, by rotating the upper part of the instrument.
b) The bubble is brought to the center of the level tube by rotating both the foot screws either inward or outward. The bubble moves in the same direction as the left thumb.
c) The bubble of the other level tube is then brought to the center of the level tube by rotating the third foot screw either inward or outward.
d) Repeat Step b and step c in the same quadrant till both the bubble remain central.
e) By rotating the upper part of the instrument through 180°, the level tube is brought parallel to first two-foot screws in reverse order. The bubble will remain in the center if the instrument is in permanent adjustment.

The same principle applies for a bulls-eye level:

a) Bring the level parallel to any two of the foot screws, by rotating the upper part of the instrument.
b) The bubble is brought to the center of the level tube by rotating both the foot screws either inward or outward.
c) Rotate the upper part of the instrument through 180°, so the level is over the remaining foot screw. The bubble will remain in the center if the instrument is in permanent adjustment. If not adjust this screw to halve the error. Then rotate back through 180 degrees and check the error. Adjust those screws to halve the residual error. Continue until the bubble is always central on the ring

(Fig. a)

(Fig.b)

Figure: Theodolite levelling main parts

5. Standing axis Slow motion tangent screw(up / down); Internal Focus (For sighting object); Collimation Axis; Slow motion tangent screw (left / right); Trunnion axis; Eyepiece Focus (For crosshairs) Telescope clamp (up / down) Upper plate clamp (left / right), these are the main elements to be considered in focusing . **"Focusing"**: is done to obtain an accurate clear sighting, the cross hairs should be in focus; adjust the eyepiece to do this.

Focusing of eyepiece lens: For focusing of the eye piece, point the telescope to the sky or hold a piece of white paper in front of telescope. Move the eye-piece in and out until a distinct sharp black image of the cross-hairs is seen. This confirms proper focusing. To clearly view the object being sighted Focus the objective lens.

Focusing of objective lens: is done for each independent observation to bring the image of the object in the plane of cross hairs.

It includes following steps of operation: First, direct the telescope towards the object for observation. Next, turn the focusing screw until the image of the object appears clear and sharp as the observer looks through properly focused eye-piece. If focusing has been done properly, there will be no parallax i.e., there will be no apparent movement of the image relative to the cross hairs if the observer moves his eye from one side to the other or from top to bottom.

The objective will be re-focused for each subsequent sighting from this station because of the different distances to the target.

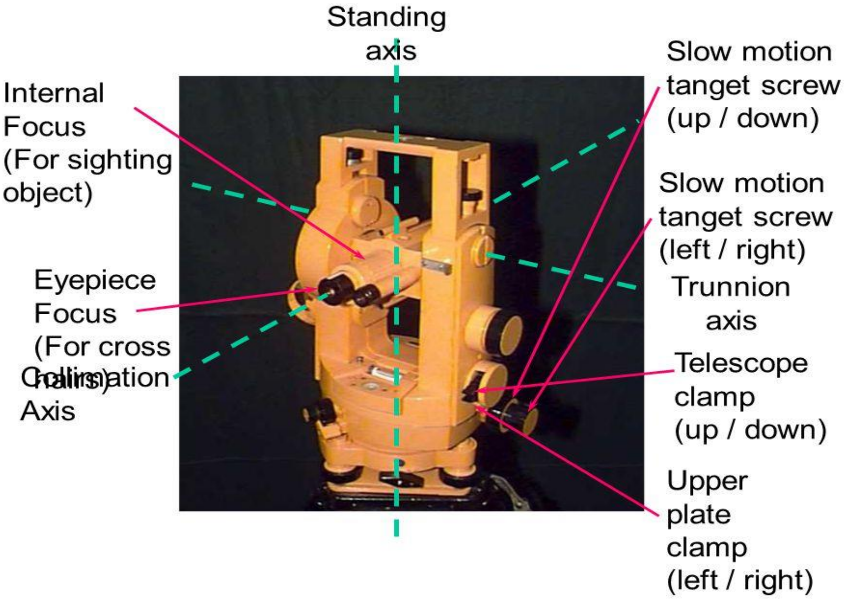


Figure: Different theodolite axis

6.All three axes should be mutually at right angles. Collimation Axis, Standing Axis, Trunnion Axis

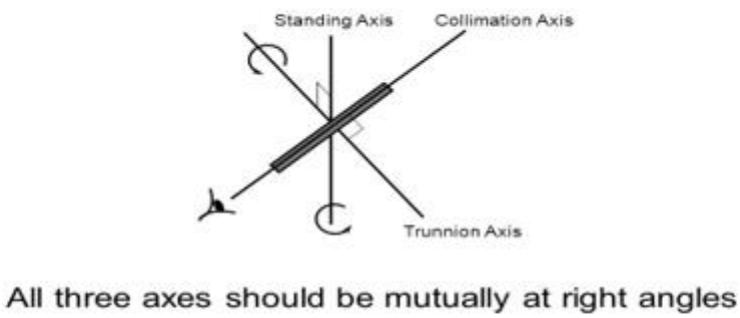


Figure: Theodolite axis and right angles

7.Align the crosshairs in the main scope at the point to be measured. Use the locking knobs on the side of the theodolite to keep it aimed on the point. Record the horizontal and vertical angles using the viewing scope found on the theodolite's side.

Sightings are taken by the surveyor, who adjusts the telescope's vertical and horizontal angular orientation so the cross-hairs align with the desired sighting point. Both angles are read either from exposed or internal scales and recorded. The next object is then sighted and recorded without moving the position of the instrument and tripod.

Figure: Theodolite in use with cones to protect tripod positioning

- <u>Content /Topic 3: Digital equipment configuration</u>

Local projection parameters: spheroid, datum, false easting, false northing, scale, longitude origin, latitude origin.

Digital surveying equipment requires a set of parameters that you must define.

The parameters specify the origin and customize a projection for your area of interest. Angular parameters use the geographic coordinate system (GCS)units, while linear parameters use the projected coordinate system (PCS) units.

A geographic coordinate system (GCS) uses a three-dimensional spherical surface to define locations on the earth. A GCS is often incorrectly called a datum, but a datum is only one part of a GCS. **A GCS includes an angular unit of measure, a prime meridian, and a datum** (based on a spheroid).

A point is referenced by its longitude and latitude values. The following illustration shows the world as a globe with longitude and latitude values.

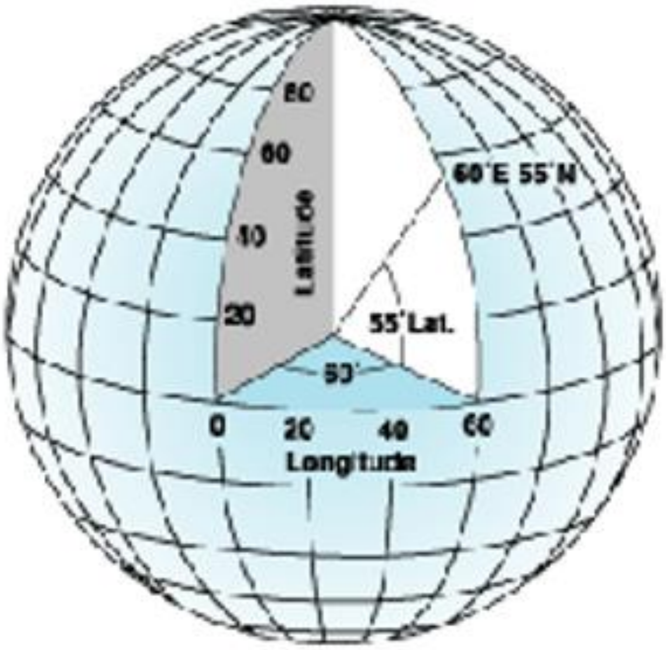


Figure: World as a globe with longitude and latitude values.

In the spherical system, horizontal lines, or east–west lines, are lines of equal latitude, or parallels. Vertical lines, or north–south lines, are lines of equal longitude, or meridians

The line of latitude midway between the poles is called the equator. It defines the line of zero latitude. The **line of zero longitude is called the prime meridian**. For most geographic coordinates, the prime meridian is the longitude that passes through Greenwich, England. The origin of the gratitude **(0,0)** is defined by where the equator and prime meridian intersect.

Latitude and longitude values are traditionally measured either in decimal degrees or in degrees, minutes, and seconds (DMS). Latitude values are measured relative to the equator and range from –90° at the South Pole to +90° at the North Pole. Longitude values are measured relative to the prime meridian. They range from –180° when traveling west to 180° when traveling east.

It may be helpful to equate longitude values with **x** and latitude values with **y**. A physical location will usually have different coordinate values in different geographic coordinate systems.

The global or spherical coordinate system such as latitude-longitude is often referred to as geographic coordinate systems and projected coordinate systems are referred to as map projections.

i) Spheroids

The shape and size of a geographic coordinate system's surface is defined by a sphere or spheroid. Although the earth is best represented by a spheroid, the earth is sometimes treated as a sphere to make mathematical calculations easier.

Definition of a spheroid

A sphere is based on a circle, while a spheroid (or ellipsoid) is based on an ellipse.

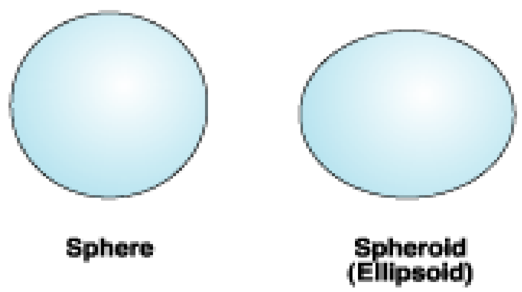


Figure: Sphere and spheroid

The shape of an ellipse is defined by two radii. The longer radius is called the semimajor axis, and the shorter radius is called the semiminor axis

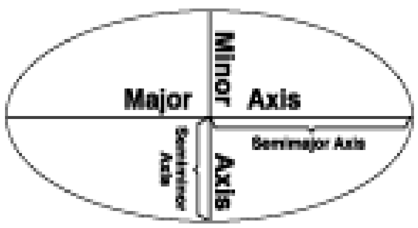


Figure: Major axis, minor axis, semi major and semi minor axis. Rotating the ellipse around

The earth has been surveyed many times to better understand its surface features and their peculiar irregularities. The surveys have resulted in many spheroids that represent the earth.

ii) Datum

A datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines.

Geocentric datums

In the last 15 years, satellite data has provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the earth's center of mass. An earth-centered, or geocentric, datum uses the earth's center of mass as the origin. The most recently developed and widely used datum is WGS84. It serves as the framework for locational measurement worldwide.

Local datums

A local datum aligns its spheroid to closely fit the earth's surface in a particular area. A point on the surface of the spheroid is matched to a particular position on the surface of the earth. This point is known as the origin point of the datum. The coordinates of the origin point are fixed, and all other points are calculated from it.

False easting and false northing,

The terms" ***easting"*** and "***northing*** "are geographic coordinates for a point. Easting refers to the eastward-measured distance (or the x-coordinate), while northing refers to the northward-measured distance (or the y-coordinate).

Easting and northing coordinates are commonly **measured in meters** from the axes of some horizontal datum. However, other units (e.g., survey feet) are also used.

Note: False easting is a linear value applied to the origin of the x-coordinates. False northing is a linear value applied to the origin of the y-coordinates.

iii) Scale

The scale in site configuration or scale factor means the degree of reduction or enlargement necessary to fit a curved Earth onto a flat projection surface.

For example, because the curved surface of the earth is longer than the surface onto which it is projected, features must be reduced in scale relative to the point of true scale. The default value is 1.0.

iV) Longitude origin, latitude origin

Longitude of origin defines the origin of the x-coordinates. The central meridian and longitude of origin parameters are synonymous. Latitude of origin defines the origin of the y-coordinates.

Although longitude and latitude can locate exact positions on the surface of the globe, they are not uniform units of measure. Only along the equator does the distance represented by one degree of longitude approximate the distance represented by one degree of latitude.

This is because the equator is the only parallel as large as a meridian. (**Circles with the same radius as the spherical earth are called great circles. The equator and all meridians are great circles.)**

Above and below the equator, the circles defining the parallels of latitude get gradually smaller until they become a single point at the North and South Poles where the meridians converge. As the meridians converge toward the poles, the distance represented by one degree of longitude decreases to zero. Because degrees of latitude and longitude don't have a standard length, you can’t measure distances or areas accurately or display the data easily on a flat map or computer screen.

The combination of meridians of longitude and parallels of latitude establishes a framework or grid by means of which exact positions can be determined in reference to the prime meridian and the Equator: a point described as 40° N, 30° W, for example, is located 40° of arc north of the Equator and 30° of arc west of the Greenwich meridian.

Figure: Longitude and latitude origin

Everything north of the equator has positive latitude values. Whereas, everything south of the equator has negative latitude values.

In a geographical coordinate system, the prime meridian is the line that has 0° longitude.

LO 2.5 – MEASURE TOPOGRAPHICAL PARAMETERS ACCORDING TO THE REQUIRED DATA

- Content /Topic 1: Topographical parameters

i) Elevation and Altitude

When the height of a point is its vertical distance above or below the surface of a reference plane you have selected, it is called the **elevation** of that point.

When the height of a point is its vertical distance above or below mean sea level (as the reference plane), it is called the **altitude** of the point.

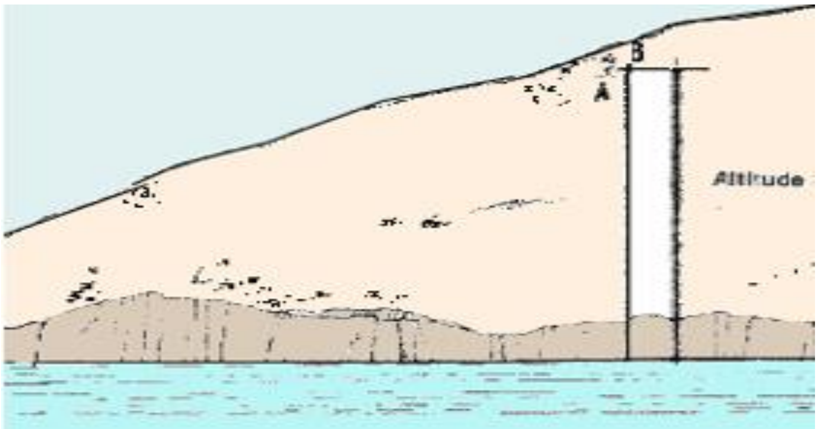


Figure: Altitude

ii) LATITUDE AND LONGITUDE

Just like every actual house has its address (which includes the number, the name of the street, city), every single point on the surface of earth can be specified by the *latitude and longitude coordinates*. Therefore, by using latitude and longitude we can specify virtually any point on earth.

iii. SLOPE

A slope is the rise or fall of the land surface and the slope of field is expressed as a ratio, in the same way it is the vertical distance or difference in height between two points in a field divided by horizontal distance between these two points.

The formula is:

$$The\ slope = \frac{Height\ difference\ (m)}{Horizontal\ distance\ (m)}$$

$$The\ slope\% = \frac{Height\ difference\ (m)}{Horizontal\ distance\ (m)} * 100$$

$$The\ slope\ {}^{o}/_{oo} = \frac{Height\ difference\ (m)}{Horizontal\ distance\ (m)} * 1000$$

Slope in ${}^{o}/_{oo}$=Slope in % * 10

The slope can also be expressed in degrees, as the measurement of the vertical angle made by the slope and the horizontal plane.

iv. HORIZONTAL DISTANCE

In topographical surveys, you measure distances along straight lines. These lines either join two fixed points or run in one direction starting **from** one fixed point. They are plotted in the field with pegs, pillars or ranging poles**.**

Expressing distances as horizontal measurements

You should always measure distances as horizontal distances. You may have to measure on ground which has no slope, or only a very small slope that is less than or equal to 5 percent. The distance measured on this type of ground will be equal to or very close to the horizontal distance. When the slope of the terrain is greater than 5 percent, however, you will have to find the horizontal distance. To do this, you must either correct any measurements you made along the ground or use another method of measurement. Unlevelled ground also requires particular methods of measurement.

iv) HORIZONTAL ANGLE

In topography, the angle made by two ground lines is measured horizontally, and is called a horizontal angle. You may replace these ground lines by two lines of sight AB and AC. These lines of sight are directed from your eyes, which form the summit A of the angle BAC, towards permanent landmarks such as a rock, a tree, a termite mound, a telephone pole or the corner of a building.

v) VERTICAL ANGLE

A vertical angle is an angle formed by two connected lines in the vertical plane, that is, between a low point and two higher points.

Since these angles are in the vertical plane, the lines that form them will usually be lines of sight.

The slope of a line is called the gradient. It may be defined as:

- The change in vertical distance or elevation over a given horizontal distance, or the change in horizontal distance over a given vertical distance;
- The ***vertical angle made by the sloping line*** and a horizontal line.

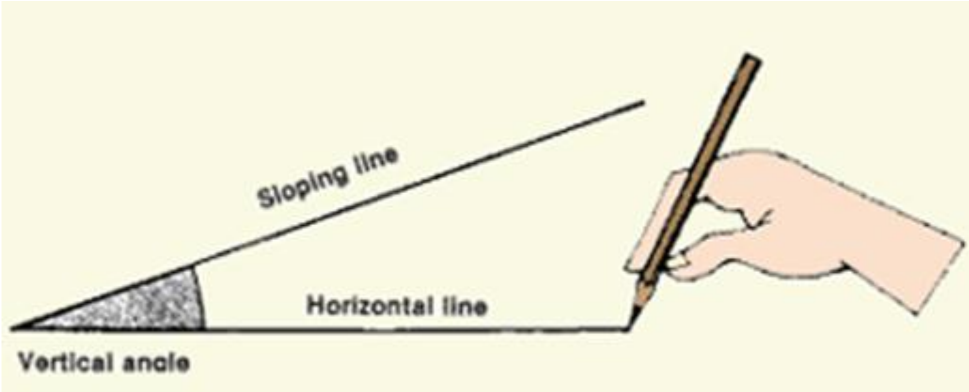


Figure: Vertical Angle and sloping line

vi) AREA

In agriculture, area is one of the main purposes of topographical survey. Sometimes they want to set different activities of production, or based on area other related activities will be able to be designed.

In land surveying, you should regard land areas as horizontal surfaces, not as the actual area of the ground surface

- Content /Topic 2: Measure topographical parameters

ELEVATION AND ALTITUDE

By direct levelling, you can measure both the elevation of points and the differences in elevation between points, using a level and a levelling staff.

Direct levelling is where you measure differences in elevation directly. This is the most commonly used method and **indirect levelling** is where you calculate differences in elevation from measured slopes and horizontal distances.

There are **two kinds of direct levelling: differential levelling** and **profile levelling**.

In **differential levelling**, you find the difference in elevation of points which are some distance apart. In the simplest kind of direct levelling, you would survey only two points A and B from one central station. But you may need to find the difference in elevation between: either several points A, B, ... E, surveyed from a single levelling station; or several points A ... F, surveyed from a series of levelling stations S1 ... S6 ....Sn, for example.

Example for differential levelling.

a) You can best understand differential levelling by first considering only two points, A and B , both of which you can see from one central levelling station, LS . Sight with a level from LS at the levelling staff on point A. The point where the line of sight meets the levelling staff is point X. Measure AX. This is called a backsight (BS).

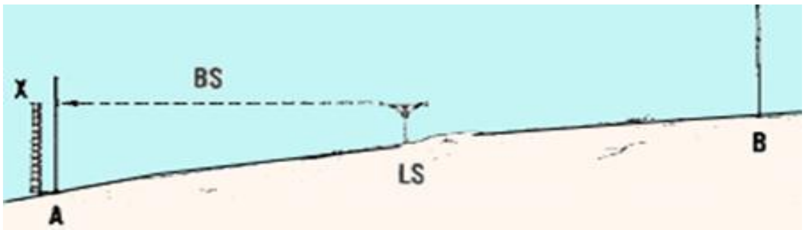


Figure: Backsight

b) Turn around and sight from LS at the levelling staff on point B. The point where the line of sight meets the levelling staff is point Y. Measure BY. This is called a foresight (FS).

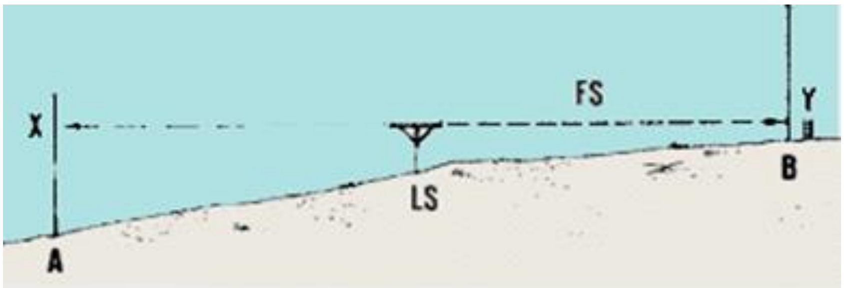


Figure: Foresight

c) The difference in elevation between point A and point B equals BC or (AX- BY) or (backsight BS - foresight FS)

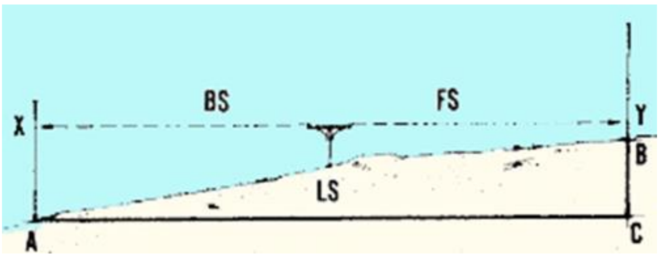


Figure: Difference in elevation from BS-FS

d) If you know the elevation of A, called E(A), you can calculate the elevation of B, called E(B), as BS -FS + E(A).

But " *HI = BS + E(A)*",the height of the instrument or the elevation of the line of sight directed from the level.

Therefore, (the elevation at point B being equal to the height of the levelling instrument, minus the foresight).

E(B) = HI - FS

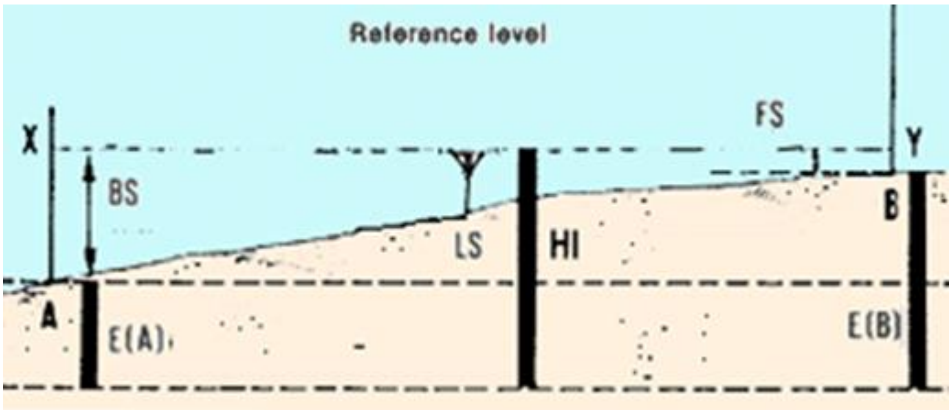


Figure: Elevation of unknown point by HI-FS

Often you will not be able to see at the same time the two points you are surveying, or they might be far apart. In such cases, you will need to do a series of differential levelings. These are similar to the type explained above, except that you will use intermediate temporary points called turning points (TP).

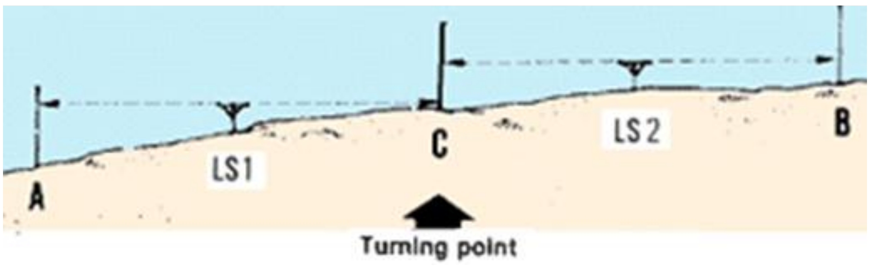


Figure: Turning point

You can make the calculations more easily if you record the field measurements in a table. ***"All BS's and all FS's must be added separately*. *The sum FS is subtracted from the sum BS** to find the **difference in elevation from point A to point B**".*

- A positive difference means that B is at a higher elevation than A.
- A negative difference means that B is at a lower elevation than A.

Note: -The turning points and the levelling stations do not have to be on a straight line, but try to place each levelling station about halfway between the two points you need to survey from it.

From each levelling station of differential levelling, measure a backsight (BS) and a foresight (FS), except: at starting point A, where you have only a backsight measurement and at ending point B, where you have only a foresight measurement.

Checking on levelling errors

Checking on the arithmetic calculations does not tell you how accurate your survey has been. To fully check on your accuracy, level in the opposite direction, from the final point to the starting point, using the same procedure as before. You will probably find that the elevation of point A you obtain from this second levelling differs from the known elevation. **This difference is the closing error**.

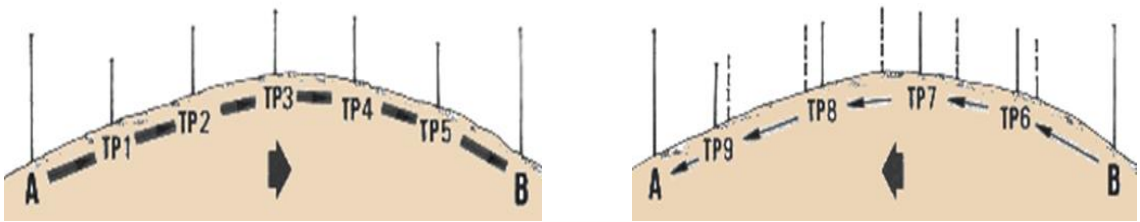


Figure: Checking closing error

Topographical survey can be done along an open traverse joining points A and B or can be done by a closed traverse. You should use each perimeter summit A, B, C, D, E and F of the polygon as a survey point, and plot turning points between these summits, and use differential levelling to find the elevation of each perimeter point.
If you do not know the exact elevation of starting point A, you can assume its elevation, for example E (A) = 100 m. Start the survey at point A, and proceed clockwise along the perimeter of the area. Take levelling staff readings at TP1, TP2, B, TP3,.....TPn, until you reach starting point A again and close the traverse.

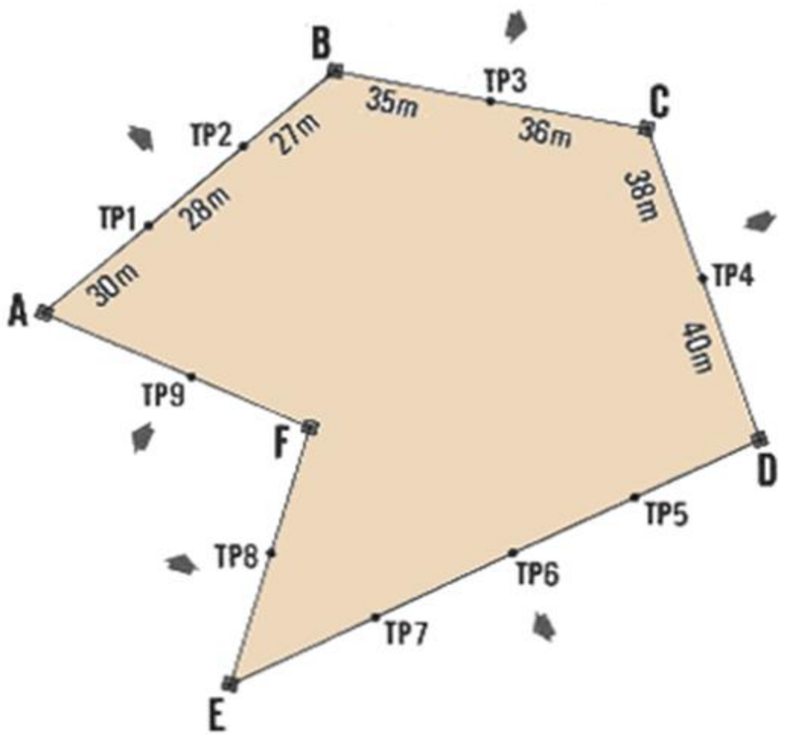


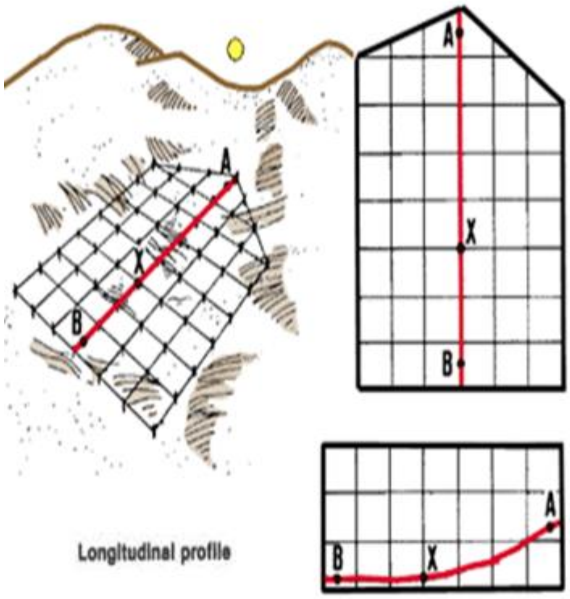
Figure: Closed differential survey

Profile levelling

In **profile levelling**, you find the elevations of points placed at short measured intervals along a known line, such as the center-line of a water supply canal or the lengthwise axis of a valley. You find elevations for cross-sections with a similar kind of survey.

The purpose of profile levelling is to determine the changes in the elevation of the ground surface along a definite line. This definite line AB might be the center-line of a water-supply canal, a drainage ditch, a reservoir dam, or a pond dike. This line might also be the path of a river bed through a valley, where you are looking for a dam site, or it might be one of several lines, perpendicular to a river bed, which you lay out across a valley when you are surveying for a suitable fish-farm site or any water storage**.**

This can be done by ***longitudinal profiles*** by profile levelling along a line which is the main axis of the survey or by survey ***cross-section profiles*** along a line which is perpendicular to a surveyed longitudinal profile, using its points of known elevation as bench-marks.



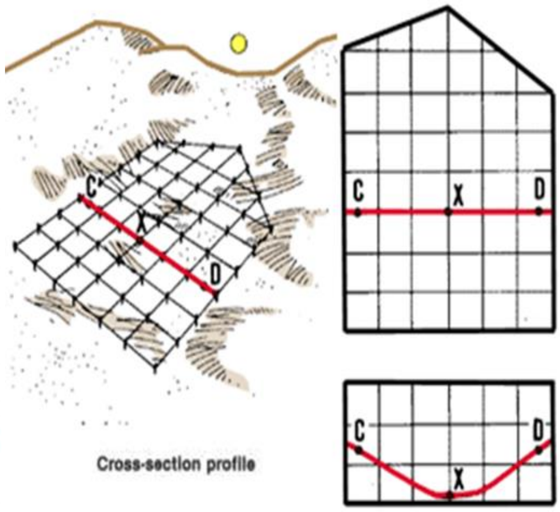


Figure: Longitudinal profile   Figure: Cross –section profile

The following is the procedure.

1. From levelling station1, read foresights FS on as many points of line AB as possible, starting from the initial point A.

2. When you need to move the level to a new station so that you can take readings on the points ahead.

3. When you need to move the level to a new station so that you can take readings on the points ahead:

- first, choose a turning point TP and take a foresight FS to find its elevation from LS1;
- move to the next levelling station LS2, from which you can see the turning point TP;
- Take a backsight BS on this turning point to find the new height of the instrument HI.

4. Read foresights FS on as many points as possible until you reach the end point of AB. If necessary, use another turning point and a new levelling station as described above.

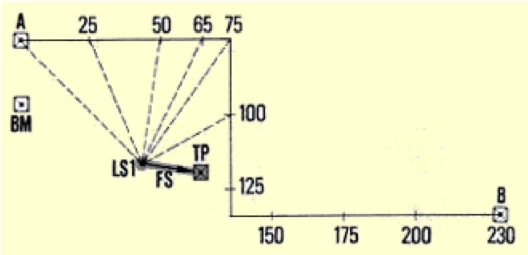


Figure:a

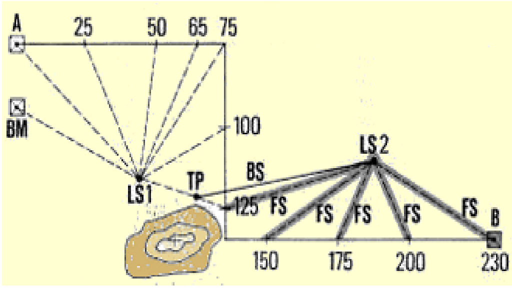


Figure:b

Figure:Profile levelling

Note: Difference in height can also be calculated from vertical angles

If you have measured vertical angle ABC in degrees, you can calculate the height difference AC from: either the ground distance BC along the slope,

AC = BC x sinABC,

or the horizontal distance BA

AC = BA x tanABC.

LATITUDE AND LONGITUDE

Both latitude and longitude are measured in degrees, which are in turn divided into minutes and seconds. For example, the tropical zone which is located to the south and to the north from the Equator is determined by the limits of 23°26'13.7'' S and 23°26'13.7'' N. Or. For example, the geographical coordinates of the mount Ngauruhoe in New Zealand, famous with its being the filming area for the Lord of the Rings movie, has the geographic coordinates of 39°09'24.6''S 175°37'55.8''E.

SLOPE

The steps of measuring the slope using A-frame

- ✓ Have one person stand on the slope holding one pole and the other person stand exactly down the slop from him holding the other pole with string running through the top notch.
- ✓ Make the string level. The person at the top of the slope should move the string to the different notches on his pole until the level suspended from the middle of the string shows a level setting.

- ✓ Calculate the slope by measuring the distance from the notch where the string was placed to the top of the pole. Slope is a percentage, meaning the number of units falls or rises in 100 units of horizontal distance.

Learn the formula for slope percent: slope percent = $\frac{rise}{run}$ x 100

HORIZONTAL DISTANCE

When you have to measure a short distance on horizontal terrain, mark each end of the distance with ranging poles. Place your ruler on the ground with its end at the first ranging pole, making sure the ruler follows the straight line. Put a marking peg at the other end of the ruler. Then take the ruler and place its first end at this marking peg. Continue in this way until you reach near the end of the line, keeping an accurate count of the number of ruler lengths. You will usually need to use only part of the ruler's length to measure the last part of the line. Take care then to read the graduations on the ruler correctly.

When you need to measure a distance **on sloping terrain,** your ruler will be very useful for finding horizontal distances. You proceed downhill, and for each measurement:

- make sure that the ruler is horizontal, using a mason's level ;
- Determine the point where you need to place the marking peg, using a plumb-line at the end of the ruler.

Note: when you measure a distance on sloping ground, remember that you should proceed downhill**.**

-The following is one of the simple method for measuring horizontal and vertical distance.

Step1:Two pegs (A and B) are driven into the soil in such a way that their tops are at the same height above the ground level.

Fig: Measurement of horizontal and vertical distances, Step 1

Step2:The zero point of the rod is placed on top of peg A. A carpenter level is placed on the rod; move the end of the rod up or down until the bubble of the level is between the marks: the measuring rod is horizontal.

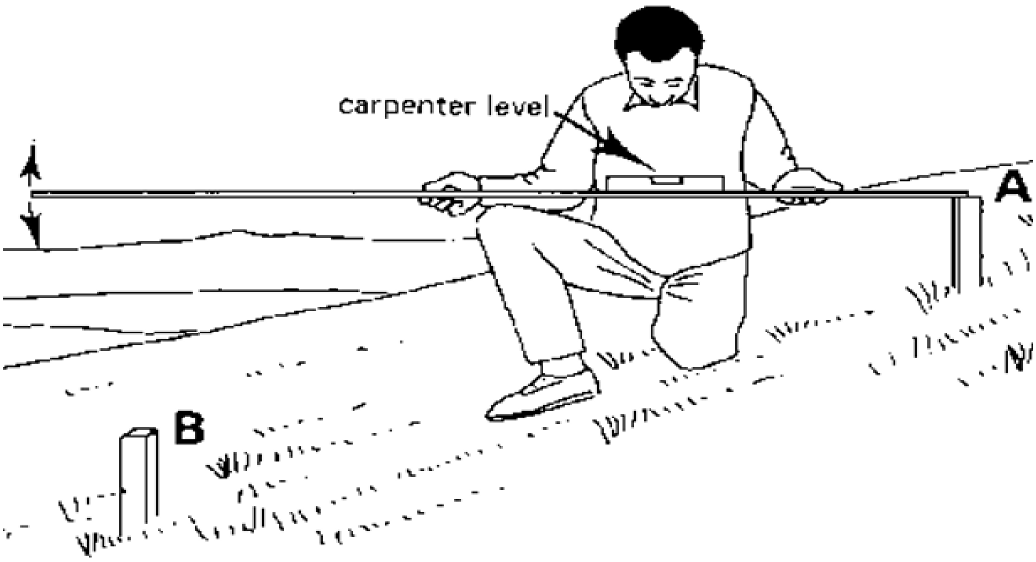


Fig: Measurement of horizontal and vertical distances, Step 2

Step3:Hang a plumb bob just above the centre of peg B and read the horizontal distance on the measuring rod.

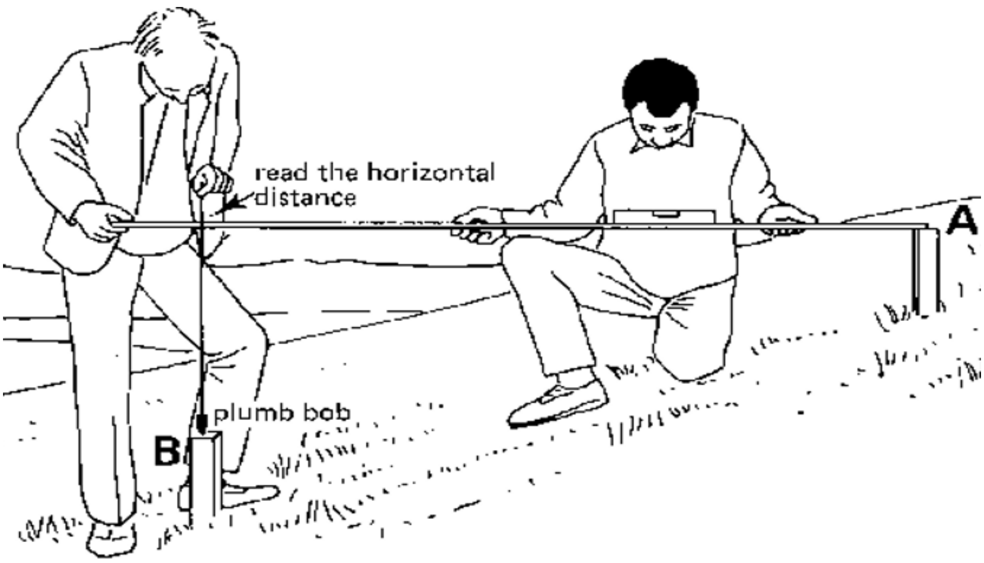


Fig: Measurement of horizontal and vertical distances, Step 3

Step 4:The measuring rod is maintained horizontal. The vertical distance between peg A and peg B is measured with a ruler or tape along the plumb bob, from the top of peg B to the bottom of the rod.

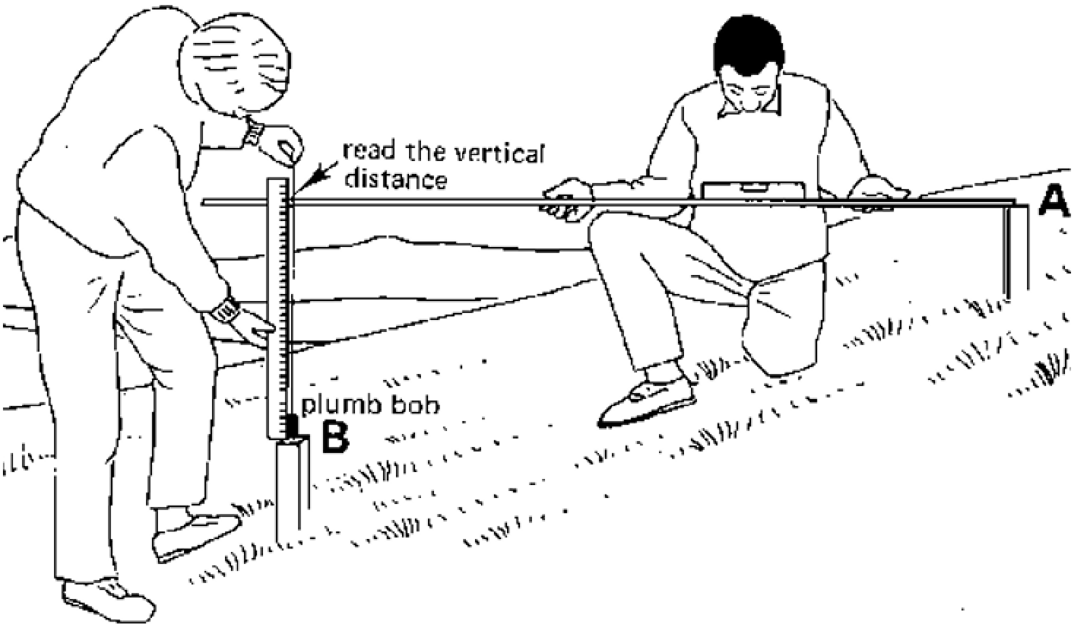


Fig: Measurement of horizontal and vertical distances, Step 4

Often, however, the distance between the two pegs is longer than the length of the measuring rod. In this case, intermediate pegs are. placed in line with A and B, at intervals of not more than one rod length.

To measure the distances between all the intermediate pegs, steps 1 to 4 (see above) are repeated.

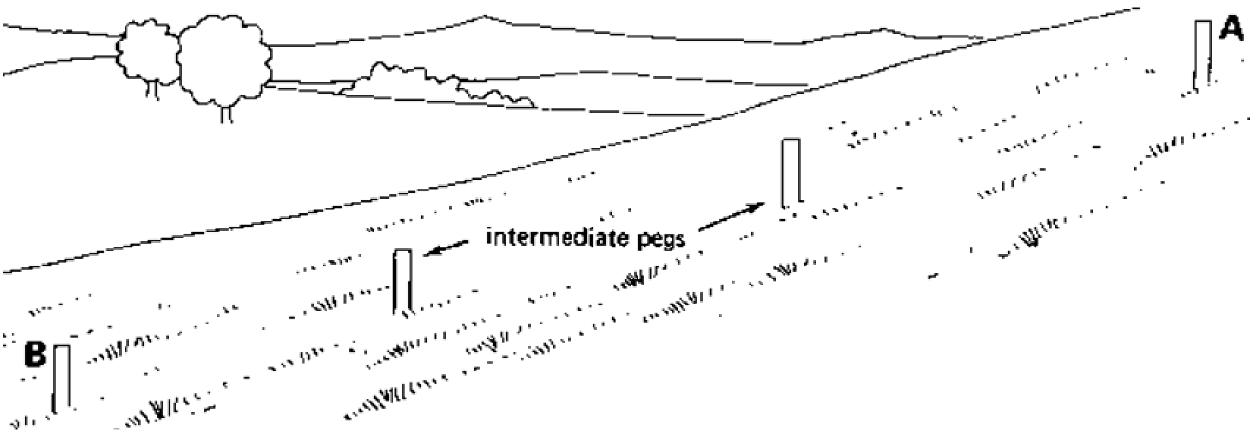


Fig: Measurement of horizontal and vertical distances when using intermediate pegs, Step 1

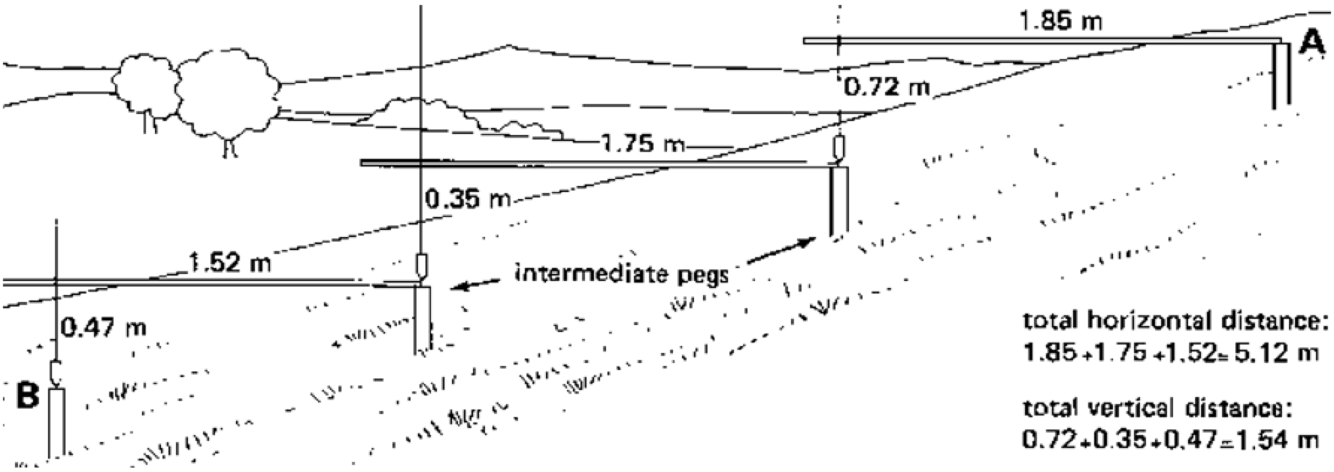


Fig: Measurement of horizontal and vertical distances when using intermediate pegs, Step 2

The total horizontal (or vertical) distance between pegs A and B is the sum of the horizontal (or vertical) distances measured between all the intermediate pegs.

You should always measure distances as horizontal distances. You may have to measure on ground which has no slope, or only a very small slope that is less than or equal to 5 percent. The distance measured on this type of ground will be equal to or very close to the horizontal distance. When the slope of the terrain is greater than 5 percent, however, you will have to find the horizontal distance. To do this, you must either correct any measurements you made along the groundor use another method of measurement. Unlevelled ground also requires particular methods of measurement.

Choosing the most suitable method

There are many good ways to measure horizontal distances. The method of measurement you use will depend on several factors:

- the accuracy of the result needed;
- the equipment you have available to use; and
- The type of terrain you need to measure.

When you have to measure a short distance on horizontal terrain, mark each end of the distance with ranging poles. Place your ruler on the ground with its end at the first ranging pole, making sure the ruler follows the straight line. Put a marking peg at the other end of the ruler. Then take the ruler and place its first end at this marking peg. Continue in this way until you reach near the end of the line, keeping an accurate count of the number of ruler lengths. You will usually need to use only part of the ruler's length to measure the last part of the line. Take care then to read the graduations on the ruler correctly.

When you need to measure a distance **on sloping terrain,** your ruler will be very useful for finding horizontal distances. You proceed downhill, and for each measurement:

- make sure that the ruler is horizontal, using a mason's level ;
- Determine the point where you need to place the marking peg, using a plumb-line at the end of the ruler.

Note: when you measure a distance on sloping ground, remember that you should proceed downhill**.**

-The following is one of the simple method for measuring horizontal and vertical distance.

Step1:Two pegs (A and B) are driven into the soil in such a way that their tops are at the same height above the ground level.

Fig: Measurement of horizontal and vertical distances, Step 1

Step2:The zero point of the rod is placed on top of peg A. A carpenter level is placed on the rod; move the end of the rod up or down until the bubble of the level is between the marks: the measuring rod is horizontal.

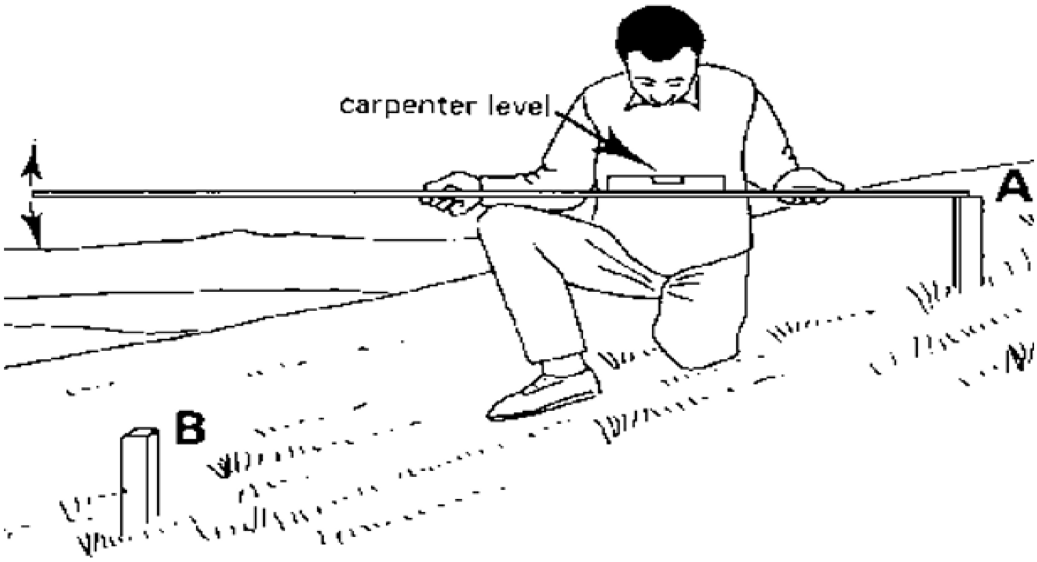


Fig: Measurement of horizontal and vertical distances, Step 2

Step3:Hang a plumb bob just above the centre of peg B and read the horizontal distance on the measuring rod.

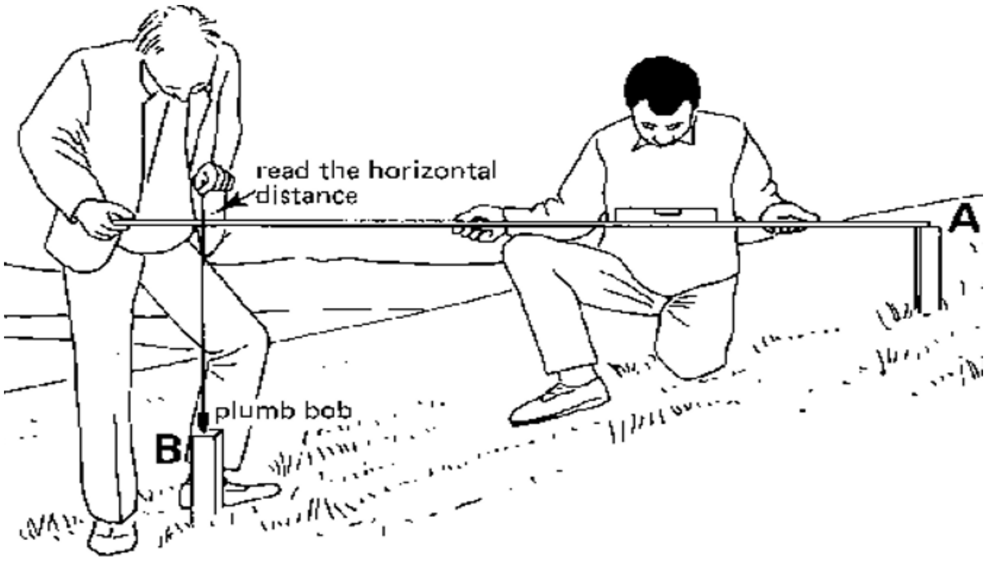


Fig: Measurement of horizontal and vertical distances, Step 3

Step 4:The measuring rod is maintained horizontal. The vertical distance between peg A and peg B is measured with a ruler or tape along the plumb bob, from the top of peg B to the bottom of the rod.

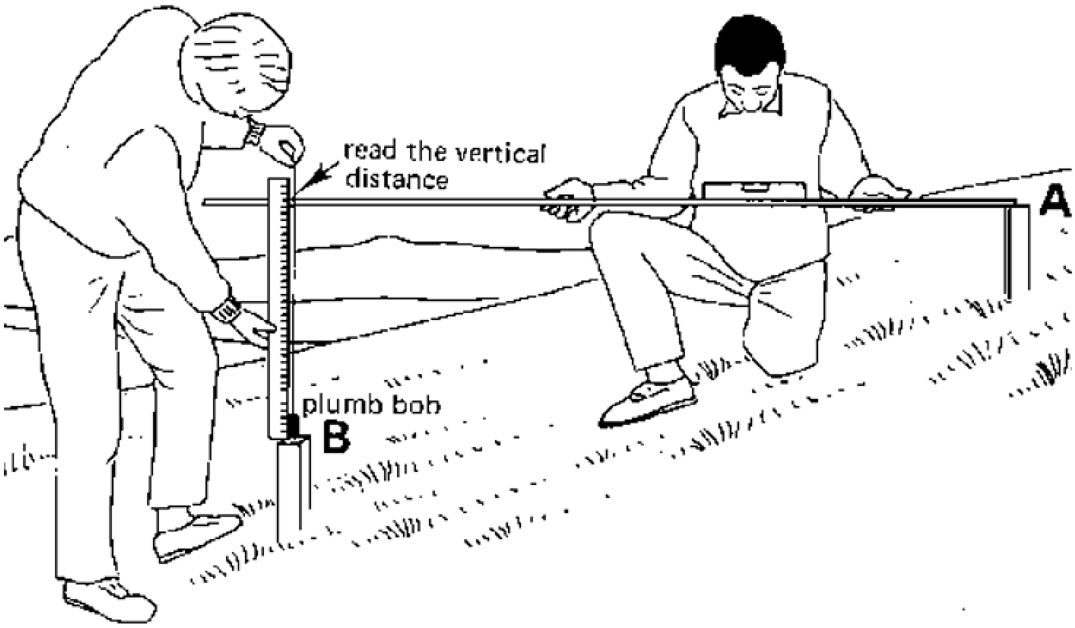


Fig: Measurement of horizontal and vertical distances, Step 4

Often, however, the distance between the two pegs is longer than the length of the measuring rod. In this case, intermediate pegs are. placed in line with A and B, at intervals of not more than one rod length.

To measure the distances between all the intermediate pegs, steps 1 to 4 (see above) are repeated.

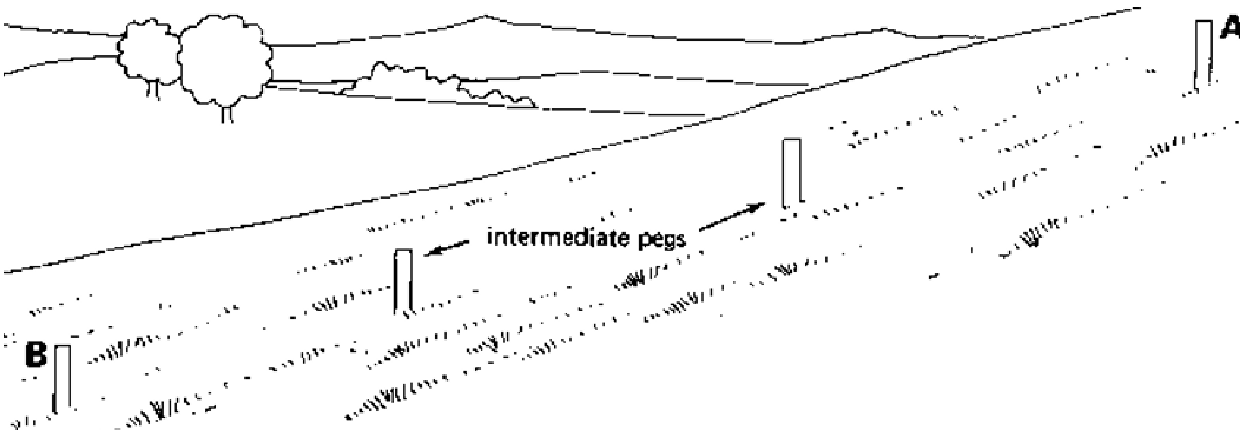


Fig: Measurement of horizontal and vertical distances when using intermediate pegs, Step 1

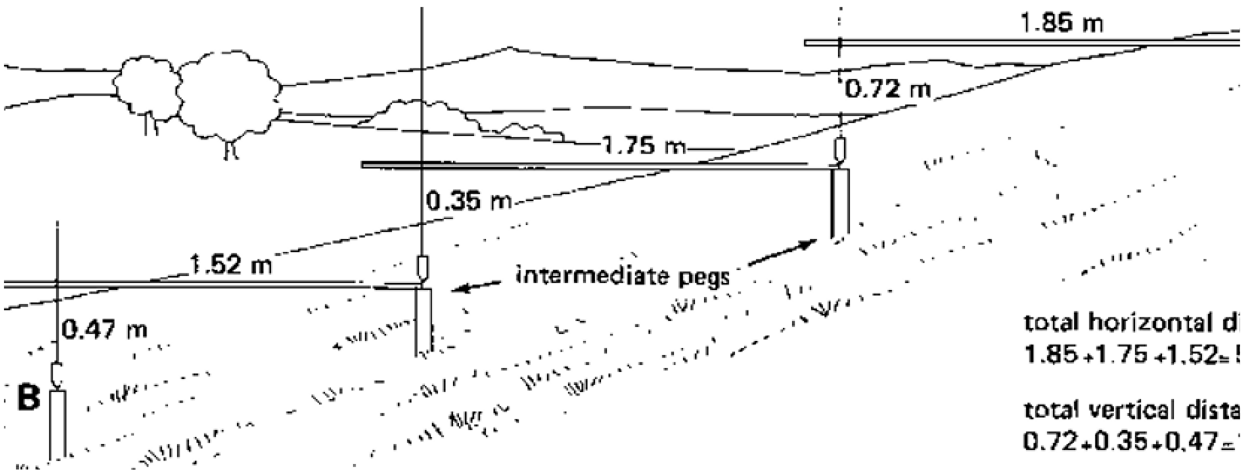


Fig: Measurement of horizontal and vertical distances when using intermediate pegs, Step 2

The total horizontal (or vertical) distance between pegs A and B is the sum of the horizontal (or vertical) distances measured between all the intermediate pegs.

How to measure distances by pacing?

a. You may measure distances roughly by pacing. This means you count the number of normal steps which will cover the distance between two points along a straight line**.** Pacing is particularly useful in reconnaissance surveys, for contouring using the grid method and for quickly checking chaining measurements.

b. To be accurate, you should know the average length of your step when you walk normally. This length is called your normal pace. Always measure your pace from the toes of the foot behind to the toes of the foot in front.

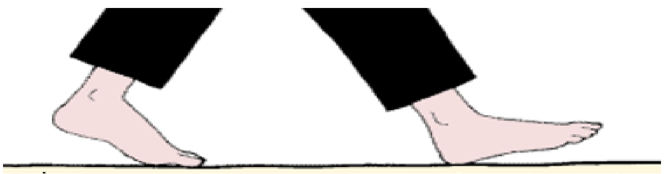


Figure: Count your steps as you walk

c. To measure the average length of your **normal pace** (the pace factor, or **PF**):

- Take 100 normal steps on horizontal ground, starting with the toes of your back foot from a well marked point, A, and walking along a straight line.

- Mark the end of your last step with peg B, at the toes of your front foot.
- measure the distance AB (in meters) with, for example, a tape and calculate your pace factor PF (in meters) as follows:

  PF= AB÷100

Measuring horizontal distances by pacing

- Clearly plot the straight lines you have to measure, using wooden pegs or ranging poles.
- If necessary, remove any high vegetation standing in the way.
- Walk along the straight lines, carefully counting your steps
- Multiply the number of steps N by your pace factor PF (in meters) to get a rough estimate of the distance in meters, as follows:

$$\textbf{Distance (m)} = N \times PF$$

Measuring horizontal distances with a rope

Clearly plot the straight lines you want to measure, using wooden pegs, for example. On either side of each of these lines, clear a narrow strip of ground completely, removing vegetation and large stones.

If the distances are shorter than your rope, or about the same length, you can take their measurements directly. If the distances are longer than your rope, you will need to use one of the chaining methods described above.

Measuring horizontal distances with a steel band or a tape

Plot the straight lines you need to measure. If the lines are the same length as your measuring band or tape or shorter, you can measure the distances directly. To do this, stretch the band or tape from one peg to the next one. If the lines are longer than your band or tape, use one of the methods described above.

Measuring horizontal distances with a chain

The chain is used for measuring the lengths of straight lines, which should be marked at each end with a ranging pole. You will need an assistant to help you. The method of chaining you use depends on the type of terrain you are measuring.

How to measure horizontal distances by the stadia method

The stadia method is rapid and accurate for measuring long distances, but to apply this method, you need to get expensive surveying equipment and learn how to use it.

The equipment used with this method includes a highly technical sighting device called a telescope. To use it, you must sight through two crossed hairs; there are also two extra horizontal hairs called stadia hairs. Most surveyor's levels have these stadia hairs at an equal distance above and below the horizontal cross-hair.

Set up the surveyor's level at the point from which you will measure the distance. Signal to your assistant to place the levelling staff vertically at the next point of the line. The distance between you and the staff may be several hundred meters.

Look through the telescope and read the graduations on the levelling staff that line up with the upper stadia hair and the lower stadia hair. Note these measurements down in your field-book.

Subtract the smaller reading from the larger reading. This represents the interval between the two hairs, called the stadia interval.

To find the distance (in meters), multiply the stadia interval by a fixed value called the stadia factor. It is given for each telescope, but on most instruments this factor equals 100.

Using height differences to calculate horizontal distances

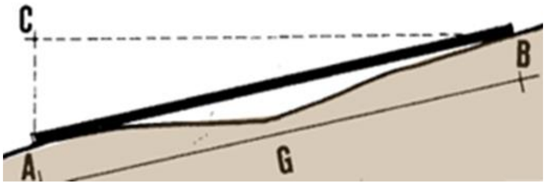
Another way of correcting distance measurements is to use measurements of heightdifferences in the following formula:

Horizontal distance = $\sqrt{\mathbf{G}^2 - \mathbf{H}^2}$

where G = AB is the distance measurement (in metres) along the sloping ground and

H = AC is the height difference (in metres) between the two points.

CB=$\sqrt{G^2 - H^2}$



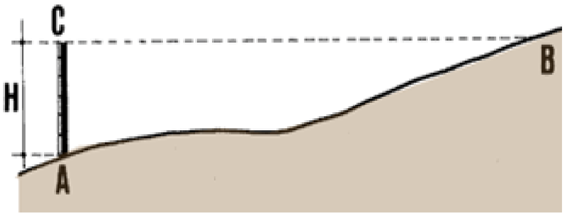


Figure:a Figure:b

Figure:Calculation of horizontal distance using height difference

- **HORIZONTAL ANGLE**

For measuring horizontal angle, it is easier to position the measuring instrument above the station on the ground and make it horizontal without sighting with the 0° to 180º line. Just make sure that the left side AB of the angle is to the right of this 0° to 180° line. Then take two readings, for both the left side AB and the right side AC of the angle. The value of the angle equals the difference between these two readings.

Note: To use this method, you must be able to reach the summit A of the angle.

Measuring an angle with an inaccessible summit

When you cannot reach the summit, you have a choice of this method**.**

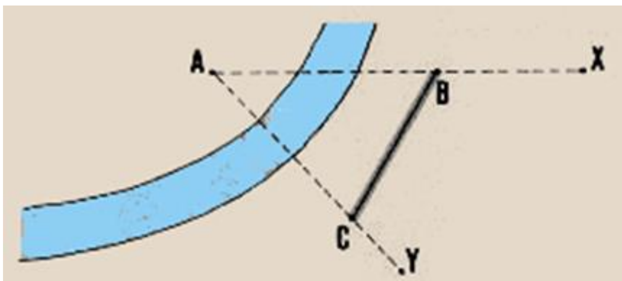


Figure: Measuring horizontal angle when you cannot reach the summit of the angle A

You can set out a line CB from any point on one of the angle's sides to any point on its other side, making a triangle within the angle. Measure the two angles made by this new line and the angle's sides. The angle at the inaccessible summit of the triangle you have made equals the difference between 180° and the sum of the other two angles.

Measuring consecutive angles

At one station, you may have to measure several angles formed by a series of lines which meet at one point, called ***converging lines.*** The angles they form are called consecutive angles.

To measure consecutive angles from one station, first measure all the angles by using the line furthest left as the reference line. Then, by simple subtraction, you can calculate the individual angles.

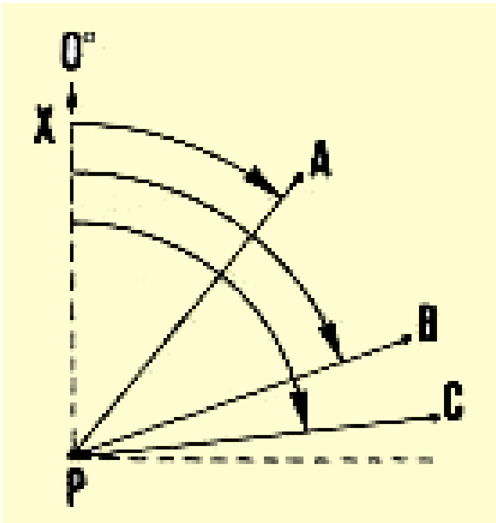


Figure: XPA, APB and BPC are consecutive angles

Measurement of horizontal angles using theodolite

The procedure is as follows:

a) Accurately center and level the theodolite over a ground mark

b) Sight the left hand target (face left) with a small reading on the plate using the lower plate clamp and slow motion screw. Do not touch the lower plate again during this round of angles. If several rounds of angles are to be observed, the initial plate setting is changed by about 90 each time.

c) Sight on to the right hand target(s) using the upper plate clamp and slow motion screw, noting the reading each time.

d) When the last target has been sighted, change face, this is done by rotating the telescope vertically through 180 and the upper plate horizontally though 180 to sight back onto the last target.

e) If face right re-observe all the targets.

f) It is essential that the plate readings are checked for accuracy on completion of each round of angles. Check that there are 180 differences between the readings. Any variation from the 180 difference is an indication of instrumental error and should be reasonably constant. This will discover gross errors due to misreading scales, using wrong slow motion screws, sighting wrong targets, etc. The targets can be re-sighted and the readings corrected before changing the lower plate.

g) Horizontal plate readings and reduced angles can be recorded in a standard field book. Note the different initial plate settings for each round, the use of the remarks column and the summary 66 of angles. The operation of one second theodolites is practically the same as that outlined above. The only difference occurs during the initial sighting of the left hand target. Sight the target first and then set the required plate reading.

VERTICAL ANGLE

There are several good ways to measure vertical angle and slopes.

Theodolite and optical clinometer (clinometer is a precise pocket instrument for measuring vertical angles and estimating tree heights. It is commonly used by foresters) are most used when sighting vertical angle and slope (Remember that a vertical angle can be converted in slope percent as well as slope percent can be converted in vertical angle).

Measurement of vertical angles by Theodolite

a) Sight the target with the horizontal cross wire

b) Level the altitude bubble, unless the instrument has automatic vertical indexing in which case there may be a release button to press

c) After adjusting the micrometer note the plate reading.

d) Change face and repeat.

The orientation of the vertical circle varies from one instrument to another. Study your theodolite carefully as it is necessary to reduce vertical angles.

- **AREA**

You may determine areas either directly from field measurements, or indirectly, from a plan or map. In the first case, you will find all the measurements of distances and angles you need by surveying and you will calculate the areas from them. In the second case, you will draw a plan or map first. Then you will get the dimensions you need from the scale, and determine the area on that basis.

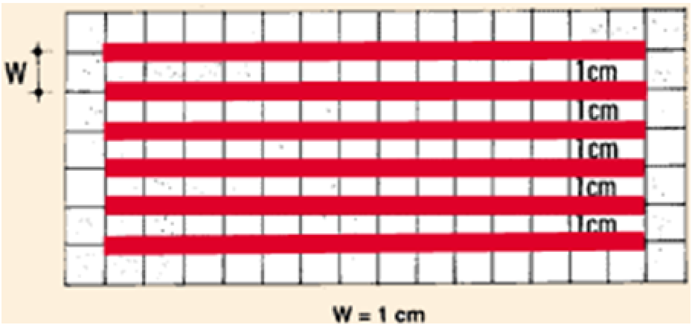
There are several simple methods available for measuring areas. Some of these are graphic methods, where you compare the plan or map of the area you need to measure to a drawn pattern of known unit sizes. Others are geometric methods, where you use simple mathematical formulas to calculate areas of regular geometrical figures, such as triangles, trapeziums, or areas bounded by an irregular curve.

- ✓ **Use the strips method for measuring areas**

1. Get a piece of transparent paper, such as tracing paper or light-weight square-ruled millmetric paper. Its size will depend on the size of the mapped area you need to measure.

2. On this paper, draw a series of strips, by drawing a series of parallel lines at a regular, fixed interval. Choose this strip width W to represent a certain number of metres. You can follow the scale of the plan or map to do this.

Example

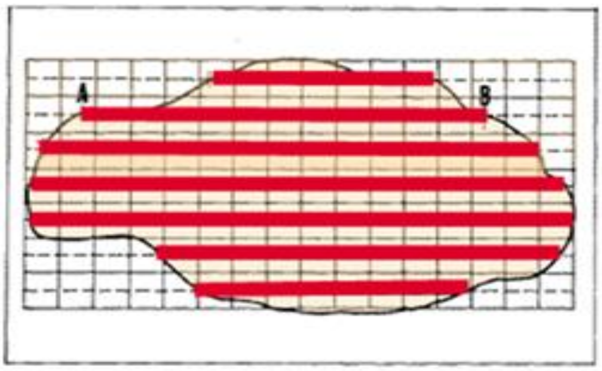


Scale 1: 2000; strip width W= 1cm= 20m.

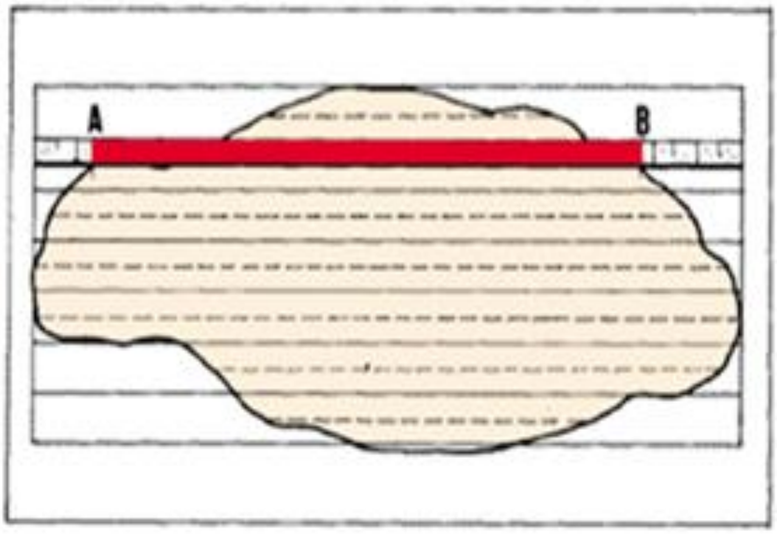
Scale 1: 50000; strip width W = 1cm = 500m.

Note: The smaller the strip width, the more accurate your estimate of the land area will be.

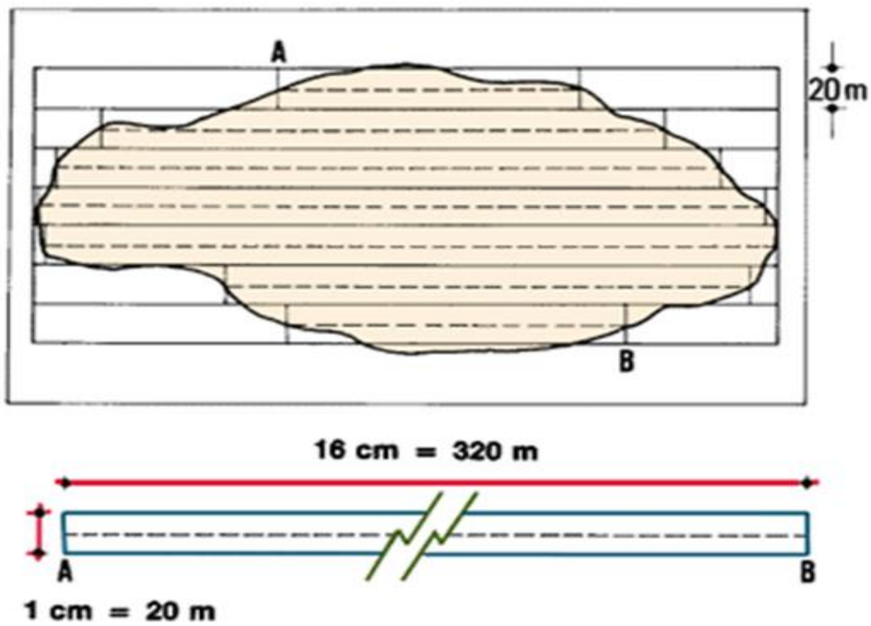
3. Place the sheet of transparent paper over the plan or map of the area you need to measure, and attach it securely with drawing pins or transparent tape.



4. For each strip, measure the distance AB in centimeters along a central line between the boundaries of the area shown on the map.



5. Calculate the sum of these distances in centimeters. Then, according to the scale you are using, multiply to find the equivalent distance in the field, in meters



7. Repeat this procedure at least once to check on your calculations.

- ✓ **Use the square-grid method for measuring areas**

1. Get a piece of transparent square-ruled paper, or draw a square grid on transparent tracing paper yourself. To do this, trace a grid made of 2 mm x 2 mm squares inside a 10 cm x 10 cm square, using the example given on the page.

Note: if you use smaller unit squares on the grid, your estimate of the land area will be more accurate; but the minimum size you should use is 1 mm x 1 mm = 1 mm^2.

2. Place this transparent grid over the drawing of the area you need to measure, and attach it to the drawing securely with thumbtacks or tape. If your grid is smaller than this area, start at one edge of the drawing. Clearly mark the outline of the grid, then move to the next section and proceed in this way over the entire area.

3. Count the number of full squares included in the area you need to measure. To avoid mistakes, mark each square you count with your pencil, making a small dot.

Note: towards the center of the area, you may be able to count larger squares made, for example, of 10 x 10 = 100 small squares. This will make your work easier.

4. Look at the squares around the edge of the drawing. If more than one-half of any squaresare within the drawing, count and mark it as a full square. Ignore the rest.

5. Add these two sums (steps 3 and 4), to obtain the total number T of full squares.

6. Add the sums again at least once to check them.

7. Using the distance scale of the drawing, calculate the equivalent unit area for your grid. This is the equivalent area of one of its small squares.

Example

Scale 1:2000 or 1 cm = 20 m or 1 mm = 2 m

Grid square size is 2 mm x 2 mm

Equivalent unit area of grid = 4 m x 4 m = 16 m^2

8. Multiply the equivalent unit area by the total number T of full squares to obtain a fairly good estimate of the measured area.

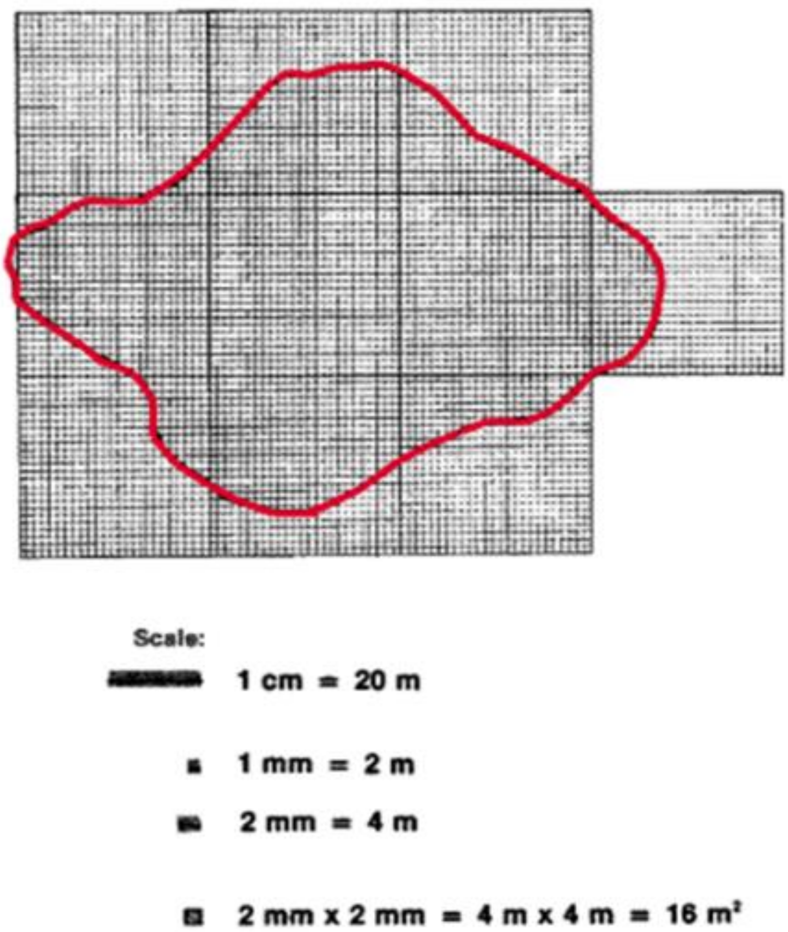


Figure: Area calculation using square-grid method

- ✓ **Subdivide the area into regular geometrical figures**

When you need to measure areas directly in the field, divide the tract of land into regular geometrical figures, calculate area of each one and find the total area.

- **Measuring areas by triangles**

You can easily calculate the area of any triangle when you know the dimensions of all three sides a, b and c

Area = $\sqrt{s(s-a)\,(s-b)\,(s-c)}$

where :s $=\frac{a+b+c}{2}$;

When Two sides (b, c) and the angle BAC between them (called the included angle) are known:

Area = (bc sin BAC) ÷ 2

- **Using a base line to subdivide land areas**

When the shape of the land is polygonal, you should usually subdivide the total area you need to measure into a series of regular geometrical figures

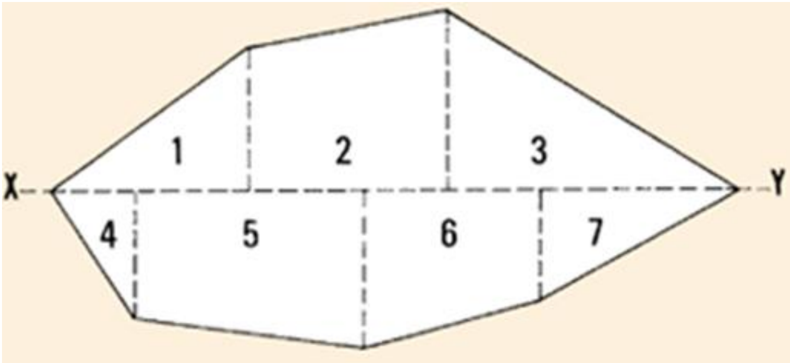


Figure: A base line X,Y used to subdivide land area

When you are choosing a base line, remember that it should:

- be easily accessible along its entire length;
- provide good sights to most of the summits of the polygon;
- be laid out along the longest side of the land area to keep the offsets as short as possible;
- Join two polygon summits.

Add together all these partial areas to find the total land area.

- **Subdividing land areas without base lines**

When the shape of the land is more complicated than the ones you have just learned to measure, you will have to use more than one base line, and subdivide the area into triangles, and trapeziums of various shapes. Usually there will be no existing right angle for you to work with and you will have to calculate the area of the trapeziums by taking additional measurements, which will determine their heights along perpendicular lines.

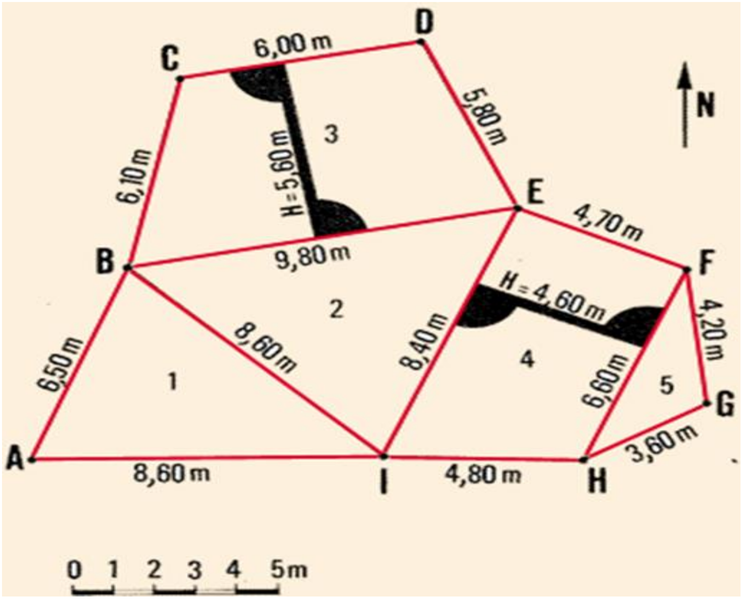


Figure: area calculation without common base

Calculate the areas of triangles 1, 2 and 5, using the lengths of their three sides and the following formulas:

s = (a + b + c) ÷ 2
area = $\sqrt{s(s-a)(s-b)(s-c)}$

Calculate the areas of trapeziums 3 and 4, determining their heights and base lengths, and using the following formula:

area = height x (base 1 + base 2) ÷ 2

Add the total area of the triangles to the total area of the trapeziums to obtain total land tract area.

Measuring area bounded by a curve

This area is calculated by the following formula: **Area=** $\frac{\boldsymbol{interval} \times (\boldsymbol{h_o} + \boldsymbol{h_n} + 2\boldsymbol{h_i})}{\mathbf{2}}$

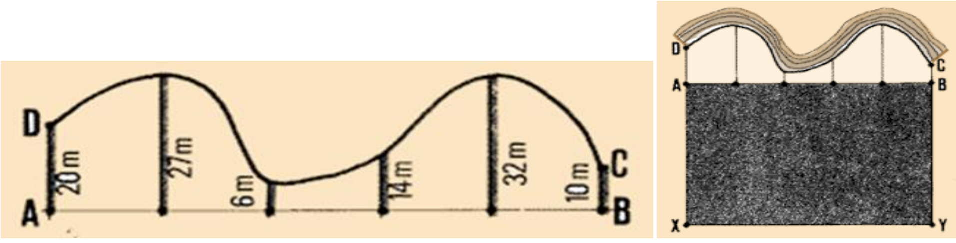


Figure: Area bounded by curve

Note: remember that you must still calculate the area of AXYBA and add it to the area of ABCDA to get the total area DAXYBCD.

Or

Area= interval $\times$ **h**$_i$

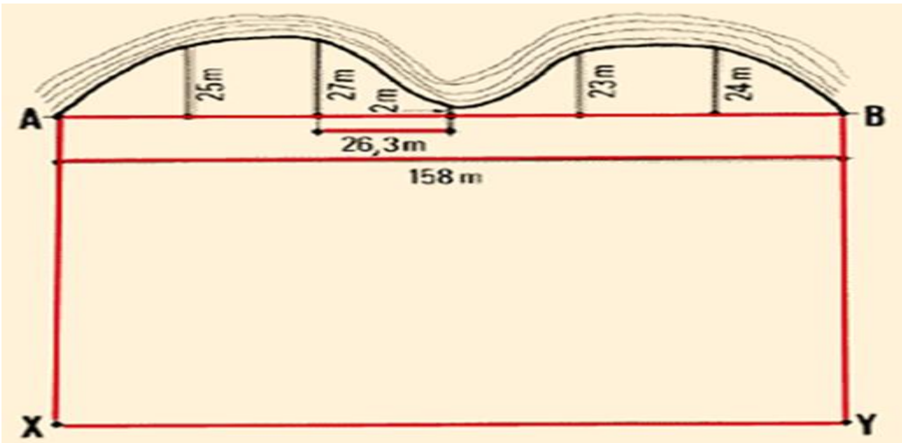


Figure: example of area culcuration for area bounded by curve

LO 2.6 – Maintain tools and equipment according to the operator manual

- Content /Topic 1: Maintenance techniques

Like other instruments, topographic tools and equipment require proper care and maintenance to ensure the best results and reduce wear and tear on the instrument.

Tools and equipment	Maintenance or care
Dumpy level	•Protect the equipment from impact and vibration •While an observation is being made, do not touch the instrument

	except as necessary to make a setting; and do not move about. •Always use the sunshade. Attach or remove it by a clockwise motion, in order to unscrew the objective. •Avoid carrying the instrument on the shoulder while passing through doorways or beneath low-hanging benches; carry it under the arm, with the head of the instrument in front. •Return the instrument regularly to a manufacturer's representative or qualified instrument repair shop for cleaning, maintenance and repair.
TAPING EQUIPMENT	Keep the tape straight when in use, any tape will break when kindled or subject to a strong pull. Steel tapes rust readily and for this reason should be wiped-dry after being used. Use special care when working near electric power line. Fatal accidents have resulted from throwing a metallic tape over a power line. Do not use the flag pole as a bar to loosen stakes or stones, such use bends the steel point and Soon renders the point unfit for lining purposes.
Tripods	A stable tripod is required for precision in measuring angles. A tripod should not have any loose joints or parts that might cause instability. Some suggestions for proper tripod care are: • Maintain in firm snugness in all metal fittings; but never tighten them to the point where they will unduly compress or injure the wood; strip threads; or twist off bolts or screws • Tighten leg hinges only enough for each leg to just sustain its own weight when legs are spread out in their normal working positions • Keep metal tripod shoes tight • Keep wooden parts of tripods well pointed or varnished to reduce moisture absorption and swelling or drying out and shrinking. • Replace the top caps on tripods when they are not in use or store the tripods such that the tops are not damaged.

	• The most damage occurs to tripods when being placed into or taken out of survey vehicles. The life and usefulness of tripods can be significantly extended if compartments are constructed such that the tripods is not riding on or against other equipment • Wet tripods should not be stored with the leg extensions clamped
Rod	Some suggestions for proper rod care are: • Protect rods from moisture, dirt, dust and abrasion • Clean graduated faces with a damp cloth and wipe dry. Touch graduated face can come into contact with other tools, objects, matter or materials or may become soiled • Do not abuse a rod by placing it where it might fall; do not throw, drop or drag a rod, or use it as a vaulting pole • Keep the metals shoes clean and avoid using it to scrape foreign matter off a bench mark or other surveys points. • If possible, leave a wet rod uncovered, unenclosed and extended until it is thoroughly dry • Store rods either vertically (not leaning) or horizontally with at least 3 point support, in dry place and in their protective cases. • Periodically check all screw and hardware for snugness and operation

LO 2.7 – Record data complying with the required format

- Content /Topic 1: Data to be recorded

Data to be recorded discussed within this context are topographic survey data. These data have been explained in this content in part of topographic data.

The data to be recorded are:

- ✓ Altitude
- ✓ Latitude
- ✓ Longitude
- ✓ Slope
- ✓ Horizontal distance
- ✓ Height difference
- ✓ Horizontal angle
- ✓ Vertical angle
- ✓ Area

- <u>Content /Topic 2: Format of topographic parameters recording</u>

The field notebook

It is on this field notebook that will meet all topographic parameters measured and make the calculations. In a field notebook, one always writes using pencil to ensure that the data will not be erased if it is exposed to the rain. It is very important to write the data legibly; this to prevent any confusion between the digits (numbers).

Before you start, it is necessary to note the following points: Date, Location of survey, raised by and Office notebook done by.

Example of a filed notebook

Date:

Location of survey:

Recoded by:

Office notebook done by:

Segment	Length on the ground

Record of the difference in level between points on the surface of the ground

Booking levels

There are two main methods of booking levels: such as *rise and fall method and height of collimation method*

a. 1. Rise & Fall Method

Date:

Location of survey:

Recoded by:

Office notebook done by:

Back-sight	**Inter-mediate**	**Fore-sight**	**Rise**	**Fall**	**Reduced level**	**Distance**	**Remarks**
							DatumRL+m
							Sum of B-sight & F-sight, Sum of Rise & Fall
							Take smaller from greater
							Difference should be equal

The millimeter reading may be taken by estimation to an accuracy of 0.005 metres or even less.

1. Back- sight, intermediate sight and for- sight readings are entered in the appropriate columns on different lines. However, as shown in the table above back- sights and foresights are place on the same line if you change the level instrument.
2. The first reduced level is the height of the datum, benchmark or R.L.
3. If an intermediate sight or foresight is **smaller** than the immediately preceding staff reading then the difference between the two readings is place in the **rise** column.
4. If an intermediate sight or foresight is **larger** than the immediately preceding staff reading then the difference between the two readings is place in the **fall** column.
5. A rise is added to the preceding reduced level (RL) and a fall is subtracted from the preceding RL

Height of collimation method (height of instrument)

Date:

Location of survey:

Recoded by:

Office notebook done by:

Back-sight	**Inter-mediate**	**Fore-sight**	**Height of collimation**	**Reduced level**	**Distance**	**Remarks**
						DatumRL+m
						Sum of B-sight & F-sight, Difference between RL's
						Take smaller from greater
						Difference should be equal

1. Booking is the same as the rise and fall method for back-, intermediate- and foresights. There are no rise or fall columns, but instead a height of collimation column.
2. The first back- sight reading (staff on datum, benchmark or RL) is added to the first RL giving the height of collimation.
3. The next staff reading is entered in the appropriate column but on a new line. The RL for the station is found by subtracting the staff reading from the height of collimation
4. The height of collimation changes only when the level is moved to a new position. The new height of collimation is found by adding the back- sight to the RL at the change point.

5. Please note there is no check on the accuracy of intermediate RL's and errors could go undetected.

Recording using the flexible tube water level

Date:

Location of survey:

Recoded by:

Office notebook done by:

Between pegs	**Back Reading (m)**	**Front Reading (m)**
A and C		
C and D		
D and E		
E and B		
Total		

Recording using the hand level

Date:

Location of survey:

Recoded by:

Office notebook done by:

Between points:	**Back Reading (m)**	**Front Reading (m)**	**Difference in Elevation (m)**
A and C			
C and D			
D and E			
E and F			
F and B			
Total			

Field notebook where the data were taken with Compass.

Date:

Location of survey:

Recoded by:

Office notebook done by:

Point No	**Front Bearing(°)**	**Back Bearing(°)**	**Distance (m)**	**Slope (%)**	**Observations**
1 to 2					
2 to 3					
3 to 4					
4 to 5					
5 to 1					

Learning Unit 3 – Display Survey Results

LO 3.1 – ARRANGE DATA ACCORDING TO THE TOPOGRAPHICAL MEASUREMENTS

- Content/Topic 1: Data entry methods

Survey data are recorded either by:

- ✓ Hand: is a hand writing that indicate the work done, the time taken and the cost incurred.
- ✓ Computer (MS Excel): is soft writing which enables o convert document containing handwriting notes and hand printed test into editable computer files such as excel document.

- Content/Topic 2: Data filtering

Coming back at the office, when the land survey is completed and all data recorded in the field notebook, the topographer must:

i. Choose the scale at which he/she will draw up its survey

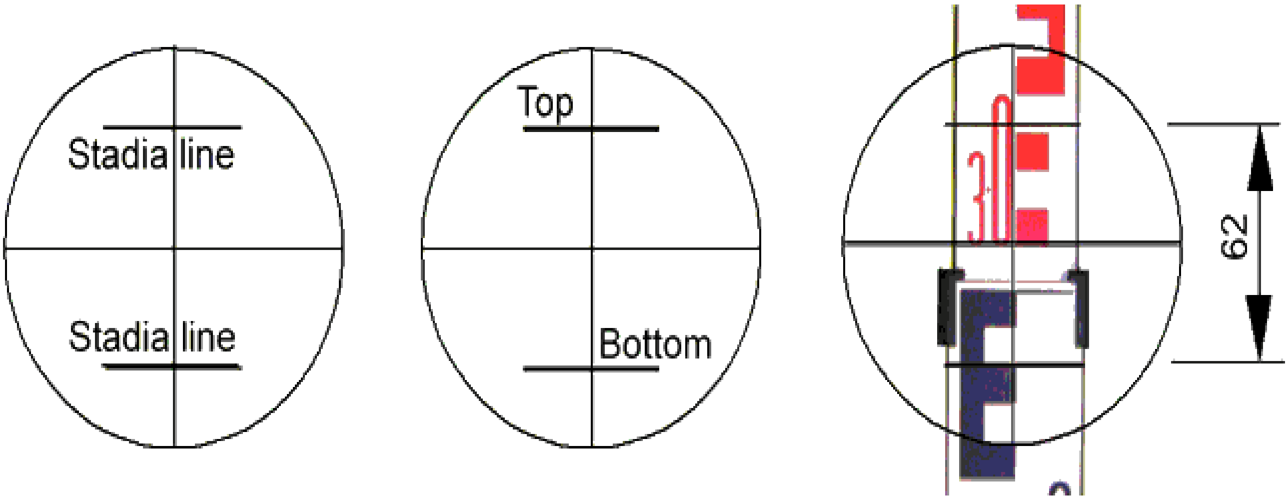
ii. Make the office notebook

iii. Drawing the topographic plan

The office notebook is presented in a tabular form.

- ✓ **Levelling (upper and lower reading)**

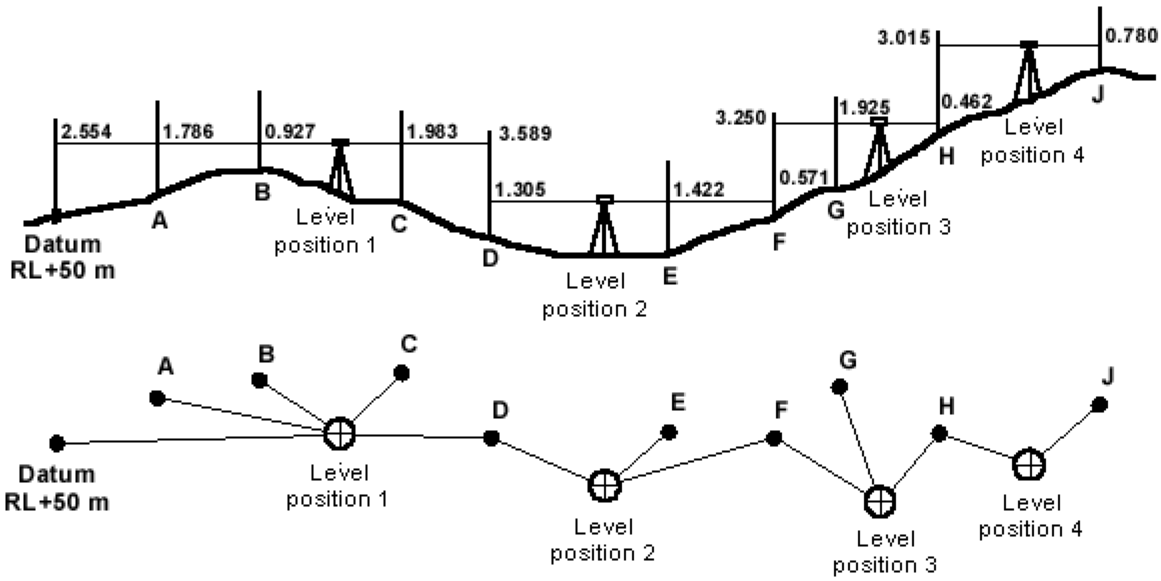
The stadia lines on the reticle can be used for simple distance measurement. The distances intercepted on the vertically-held rod between two stadia hairs seen in the eyepiece gives the distance. Just multiply the difference on the rod between the top and bottom stadia lines by 100* as shown in the figure below.



In the example above the distance between the top and bottom stadia hair is 62 mm. Therefore, the distance to the staff is 62 × 100 = 6200 mm or 6,2metres.The 100 figure should be checked before beginning any survey by measuring the known distance with a tape.

- ✓ **Distance using stadia tacheometry method (intermediate reading)**

The leveling or field procedure that should be followed is shown in Figure below:



- Content /Topic3: Converting measures

The slope of a line in the plane containing the y (rise) and x (run) axes may be represented as:

(a) gradient (1:50; 1:2)

(b) percentage (2%; 50%)

(c) decimal fraction (0.02; 0.5)

(d) angle (1.146°; 26.565°)

Here are the calculation example of the figures shown in the "**Straight edge**" section

(a) **Gradient:** 200 : 3000 = 1 : x x = 15 **Gradient = 1 :15**

(b) **Decimal fraction:** 200/3000 = 0.066666 **Fraction = 0.0667**

(c) **Percentage:** multiply decimal fraction by 100

0.06666 × 100 = 6.666 **Percentage = 6.667%**

(d) **Angle** in degree inverse tan-function rise over run (**tan**$_{-1}$ function on calculator)

tan a = 200/3000 = 0.06666 **a = 3.814°**

Degrees are subdivided into 60 minutes (60'), each minute equalling 60 seconds (60"); a right angle equals 90º, and therefore a slope is always measured between 0º (horizontal) and 90º (vertical);

1 degree is about 1.75 percent;

1 percent is about 0°35';

A 45° slope = a 100 percent slope.

From percent into degrees:

Percent	Degrees/min/s
0.5	0°17'10''
1	0°35'
2	1°08'40''
5	2°51'40''
10	5°42'40''
20	11°18'36''
30	16°42'
40	21°48'05''
50	26°33'55''
100	45°

Examples:

A slope of 17 percent is equal to (10 + 5 + 2) percent,

Which is equivalent to 5°42'40'' + 2°51'40" + 1°08'40"

= 8°101'120'' = 8°103'= <u>9°43';</u>

From degrees into percent:

Degrees	Percent	Degrees	Percent
0.25(15')	0.44	11	19.44
0.50(30')	0.87	12	21.26
0.75(45')	1.31	13	23.09
1	1.75	14	24.93
2	3.49	15	26.79

3	5.24	16	28.68
4	6.99	17	30.57
5	8.75	18	32.49
6	10.51	19	34.43
7	12.28	20	36.40
8	14.05	30	57.74
9	15.84	40	83.91
10	17.63	45	100

Example:

A slope of 9º43' is equal to (9º + 30' + 15'),

This is equivalent to 15.84 percent + 0.87 percent + 0.44 percent = 17.15 percent or 17 percent.

SCALES

Concept of scale

To present a ground figure on a plan, it is necessary to reduce its size, so you can draw up it on a sheet of paper of the limited sizes. This transformation of real (true) dimensions of ground to the plan sizes is done using a scale.

The scale of a plan is the ratio between the distance on the plan and on the ground, these distances being expressed in the same unit and the numerator having 1 value.

Scale= $\frac{\text{the distance on the plan}}{\text{the distance on the ground}} = \frac{1}{x}$

The scale can be expressed in different ways, for example 1:1000; 1:10000 : What means that one unit on the map (plan) represents 10000 units on the ground. The scale has never unit because it is a ratio between two same units.

Example: $\frac{4\text{m}}{1\text{km}}=\frac{400\text{cm}}{100000\text{cm}}=\frac{1}{2500}$

The scale particularity is to reduce all distances measured on the ground in the same proportion, so that the portrait being similar to the model. Therefore, the value of the horizontal angles measured on the ground is the same on the plan (map).

Note: In developing a plan, the lines that a topographer traces will always be the horizontal distance of the land reduced to the scale.

The size of scale

Small scale	**Medium scale**	**Large scale**
We call the small scales those ranging from 1:1000000 to 1:250000 Example: 1:400000; 1:500000; 1:900000. The small scales are used for the plans representing an entire state or continent.	We call intermediate (medium) scale those ranging from 1:200000 to 1:25000 Example :1:40000, 1:50000 , 1:10000.The medium scale are used for regional topographic maps .	We call large scales those ranging from 1:20000 to 1:1000 Example :1:20000, 1:10000, 1:1000. The large scales are used for the plans of forest plantation, farm, town or building.

LO 3.2 – Calculate the topographical measurements complying with required results

- <u>Content/Topic 1: Topographic data computation</u>

i. SLOPE

The slope of field is expressed as a ratio. It is the vertical distance or difference in height between two points in a field divided by horizontal distance between these two points. The formula is:

$$The\ slope = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)}$$

The slope can also be expressed as in percent,

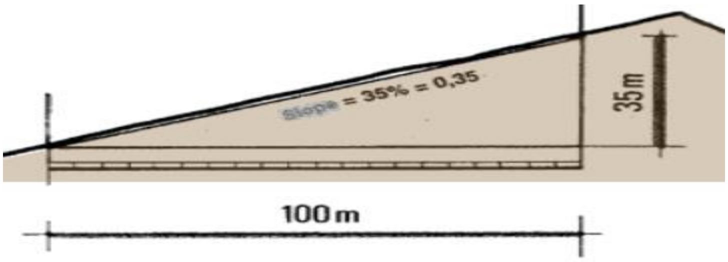


Figure: slope Percent

The formula used is then:

$$Theslope\% = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 100$$

The slope can be expressed per 1000, the formula used then:

$$Theslope\ ^{o}/_{oo} = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 1000$$

Note: Slope in $^{o}/_{oo}$=Slope in % * 10

Example:

What is the slope in percent and per mil of a field with horizontal length of 200m and height difference of 1.5 m between the bottom and the top of land?

Solution:

$Theslope\% = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 100$ $=\frac{1.5}{200} * 100$=0.75%

$Theslope\ ^{o}/_{oo} = \frac{Heightdifference\ (m)}{Horizantaldistance\ (m)} * 1000$ =$slope\%$*10=0.75*10 =7.5‰

The slope can also be expressed in degrees, as the measurement of the vertical angle made by the slope and the horizontal plane.

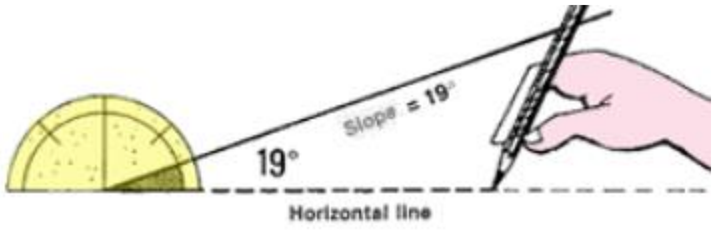


Figure: A slope expressed in degrees

ii. **HEIGHT DIFFERENCE**

- **Measuring the difference in elevation between two distant points using the flexible tube water level**

EXAMPLE:

Between pegs	**Back Reading (m)**	**Front Reading (m)**
A and C	0.75	1.25
C and D	0.52	1.48
D and E	1.23	0.77
E and B	0.41	1.59
Total	**2.91**	**5.09**

The difference in elevation between point A and point B is given by the formula:

Difference in elevation = sum of the back readings - sum of the front readings

In our example:

Measured

Sum back readings = 2.91 m

sum front readings = 5.09 m

Answer

Difference in elevation between A and B = 2.91 m - 5.09 m = - 2.18 m

The negative result means that point B is below point A. A positive result would indicate that point B is above point A.

- **Measuring the difference in elevation between two distant points using the hand level**

Difference in elevation between A and B = sum of back readings - sum of front readings

EXAMPLE:

Between points:	Back Reading (m)	Front Reading (m)	Difference in Elevation (m)
A and C	0.65	1.40	- 0.75
C and D	0.20	1.25	- 1.05
D and E	1.80	0.50	+ 1.30
E and F	1.75	0.95	+ 0.80
F and B	1.37	1.24	+ 0.13
Total	5.77	5.34	+ 0.43

Difference in elevation between A and B = Sum of back readings - sum of front readings = 5.77 - 5.34 = + 0.43 m

The difference in elevation is positive, which means that point B is above point A.

- **Calculations of the difference in level between points on the surface of the ground**

Rise & Fall Method

Back-sight	**Inter-mediate**	**Fore-sight**	**Rise**	**Fall**	**Reduced level**	**Distance**	**Remarks**
2.554					50.00	0	**Datum** RL+50 m
	1.783		0.771		50.771	14.990	**A**
	0.926		0.857		51.628	29.105	**B**
	1.963			1.037	50591	48.490	**C**

1.305		3.587		1.624	48.967	63.540	**D** / change point **1**
	1.432			0.127	48.840	87.665	**E**
3.250		0.573	0.859		49.699	102.050	**F /** change point **2**
	1.925		1.325		51.024	113.285	**G**
3.015		0.496	1.429		52.453	128.345	**H** / change point **3**
		0.780	2.235		54.688	150.460	**J**
10.124		**5.436**	**7.476**	**2.788**	**54.688**		Sum of B-sight & F-sight, Sum of Rise & Fall
-5.436			-2.788		-50.000		Take smaller from greater
4.688			**4.688**		**4.688**		Difference should be equal

Height of collimation method (height of instrument)

Back-sight	**Inter-mediate**	**Fore-sight**	**Height of collimation**	**Reduced level**	**Distance**	**Remarks**
2.554			52.554	50.00	0	**Datum** RL+50 m
	1.783			50.771	14.990	**A**
	0.926			51.628	29.105	**B**
	1.963			50591	48.490	**C**
1.305		3.587	50.272	48.967	63.540	**D** / change point **1**
	1.432			48.840	87.665	**E**
3.250		0.573	52.949	49.699	102.050	**F /** change point **2**
	1.925			51.024	113.285	**G**
3.015		0.496	55.468	52.453	128.345	**H** / change point **3**
		0.780		54.688	150.460	**J**
10.124		**5.436**		**54.688**		Sum of B-sight & F-sight, Difference between RL's
-5.436				-50.000		Take smaller from greater

4.688				**4.688**		Difference should be equal

Exercises

Q1. Data from a differential leveling have been found in the order of BS, FS,…etc starting with the initial reading on BM (elevation 150.485 m) are as follows 1.205, 1.860, 0.125, 1.915, 0.395, 2.615, 0.880,1.760, 1.960, 0.920, 2.595, 0.915, 2.255, 0.515, 2.305, 1.170. The final reading closes on BM…. Put the data in complete field note form and carry out reduction of level by rise and fall method. All units are in maters.

Answer:

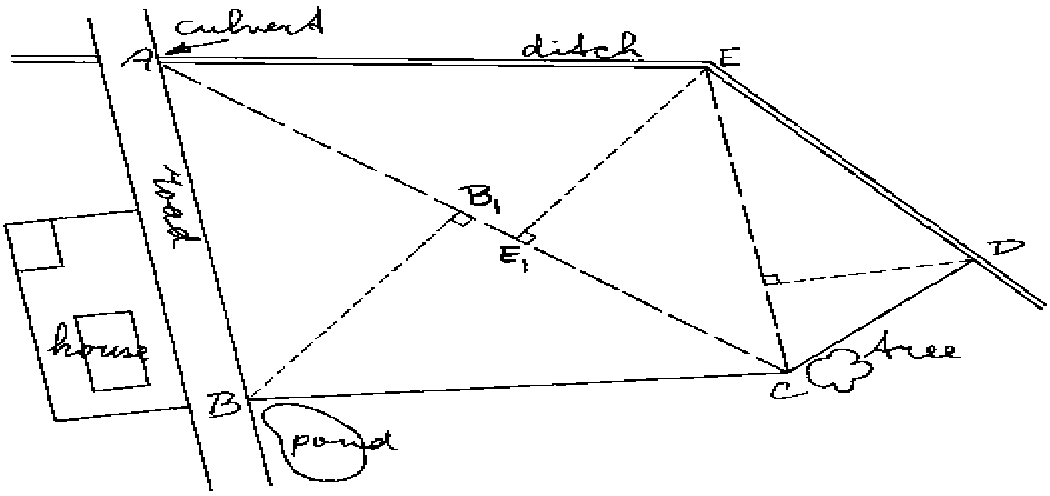
BS(m)	FS(m)	Rise(m)	Fall (m)	Elevation (m)	Remark
1.205				150.485	BM
0.125	1.860		0.655	149.830	
0.395	1.915		1.790	148.040	
0.880	2.615		2.220	145.820	
1.960	1.760		0.880	144.940	
2.595	0.920	1.040		145.980	
2.255	0.915	1.680		147.660	
2.305	0.515	1.740		149.450	
	1.170	1.135		150.535	BM

iii. AREA

Calculating surface areas of irregular shaped fields

The fields are often irregular which makes direct calculation of their areas difficult. In such case fields are divided into a number of regular areas (triangles, rectangles, etc.), of which the surfaces can be calculated with simple formulas. All areas are calculated separately and the sum of these areas gives the total area of the field.

Example 1: the following Figure shows a field with an irregular shape of which the surface area must be determined.(see the procedure as described in the above content).



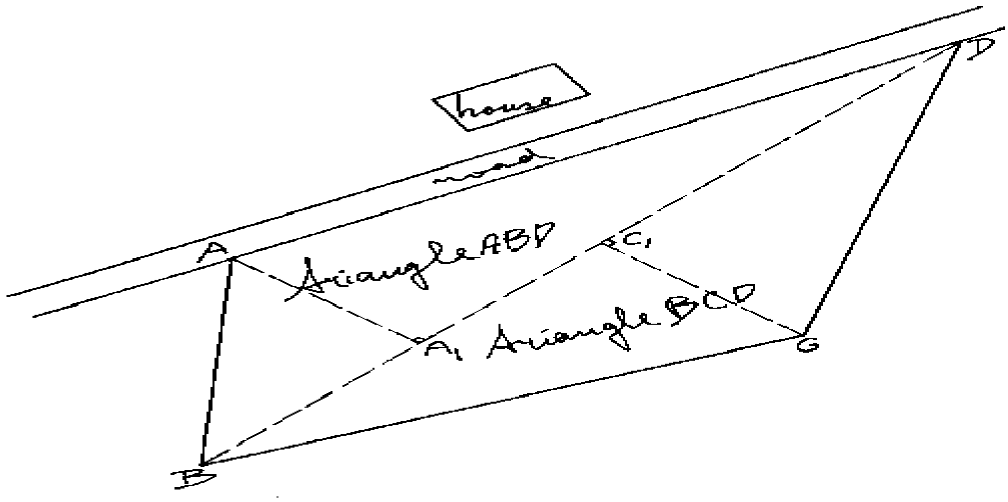
. The final calculation can be done as follows:

Measured	Answer
Triangle ABC: base = AC = 130 m height = BB_1 = 55 m	Area = 0,5 x base x height = 0.5 x 130 m x 55 m = 3 575 m^2
Triangle ACE: base = AC = 130 m height = EE_1 = 37 m	Area = 0.5 x 130 m x 37 m = 2 405 m
Triangle CDE: base = EC = 56 m height = DD_1 = 55 m	Area = 0.5 m x 56 m x 55 m= 1 540 m^2
	<u>Field ABCDE:</u> Area of triangle ABC = 3 575 m^2 Area of triangle ACE = 2 405 m^2 Area of triangle CDE = 1 540 m^2 Total Area = 3 575 m^2 + 2 405 m^2 + 1 540 m^2 = 7 520 m- = 0.752 ha

Example 2: The surface area of the field shown in Fig. below has to be determined at a time that the field is covered by a tall crop (e.g. maize or sugarcane).

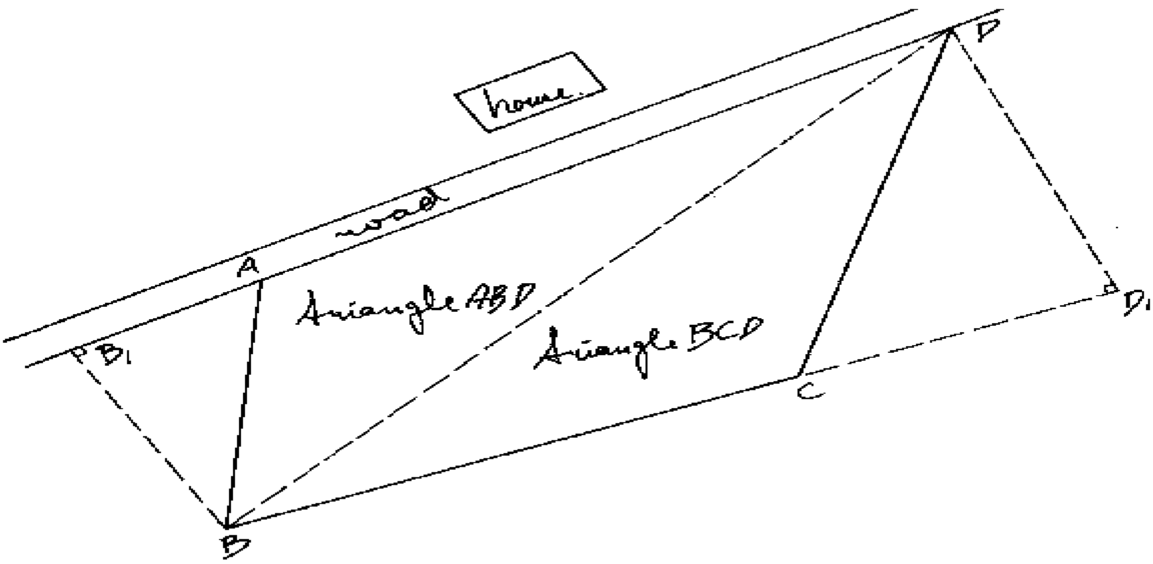
The field can be divided into two triangles ABD and BCD. Unfortunately, because of the tall crop, setting out and measurement of the base BD and the two heights AA_1 and CC_1 is impossible.

Division of the field in two triangles



In this case, the area of triangle ABD can be calculated using AD as the base and BB_1 as the corresponding height. BB_1 can be set out and measured outside the cropped area. In the same way, triangle BCD can be calculated using base BC and the corresponding height DD_1.

Determination of the areas of the two triangles



The procedure to follow on the field is:

Step 1: Mark the 4 corners (A, B, C and D) with ranging poles.

Step 2: Line AD is set out with ranging poles and extended behind A. Line BC is also set out and extended behind C. Measure the distances AD (base of triangle ADB) and BC (base of triangle BCD).

Step 3: Set out line BB_1 (height of triangle ABD) perpendicular to the extended base line AD using one of the methods described in Chapter 4. In the same way, line DD_1 (height of triangle BCD) is set out perpendicular to the extended base line BC. Measure the distance BB_1 and DD_1.

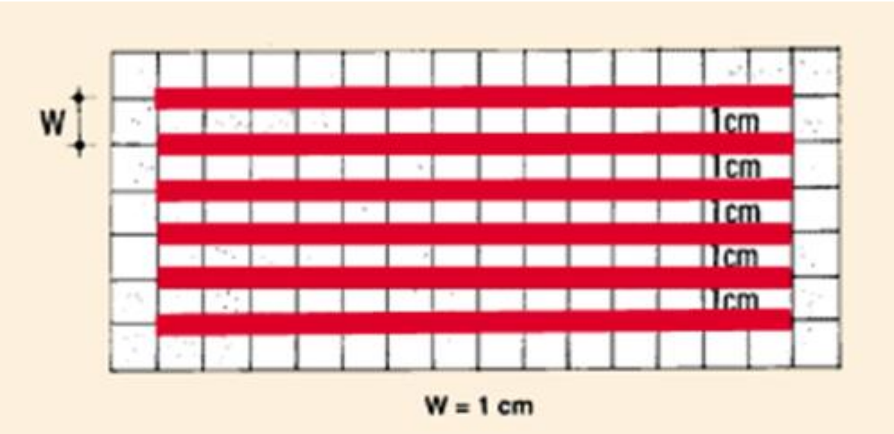
Step 4: The base and height of both triangles have been measured. The final calculations can be done as follows:

Measured	Answer
Triangle ABD: base = AD = 90 m height = BB_1 - 37 m Triangle BCD: base = BC = 70 m height = DD_1 - 50 m	Area = 0.5 x base x height = 0.5 x 90 m x 37 m = 1 665 m^2 Area = 0.5 x 70 m x 50 m = 1 750 m^2 <u>Field ABDC:</u> Area triangle ABD = 1 665 m^2 Area triangle BCD = 1 750 m^2 Total Area = 1 665 m^2 + 1 750 m^2 = 3 415 m^2 = 0.3415 ha $^=$ approx. 0.34 ha

Use the strips method for measuring areas

1. Get a piece of transparent paper, such as tracing paper or light-weight square-ruled millmetric paper. Its size will depend on the size of the mapped area you need to measure.

2. On this paper, draw a series of strips, by drawing a series of parallel lines at a regular, fixed interval. Choose this strip width W to represent a certain number of metres. You can follow the scale of the plan or map to do this.



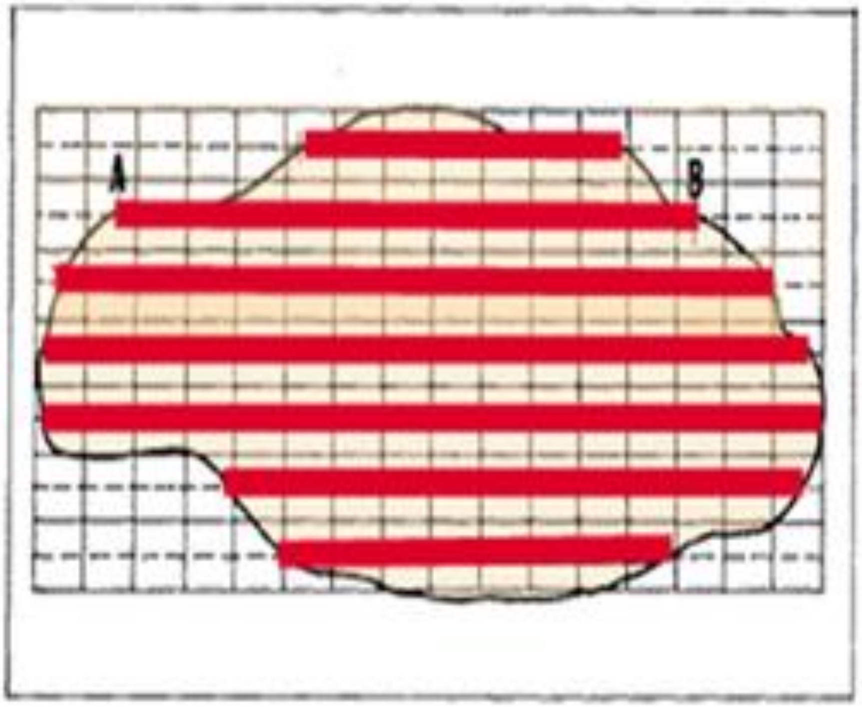
Example

Scale 1: 2000; strip width W= 1cm= 20m.

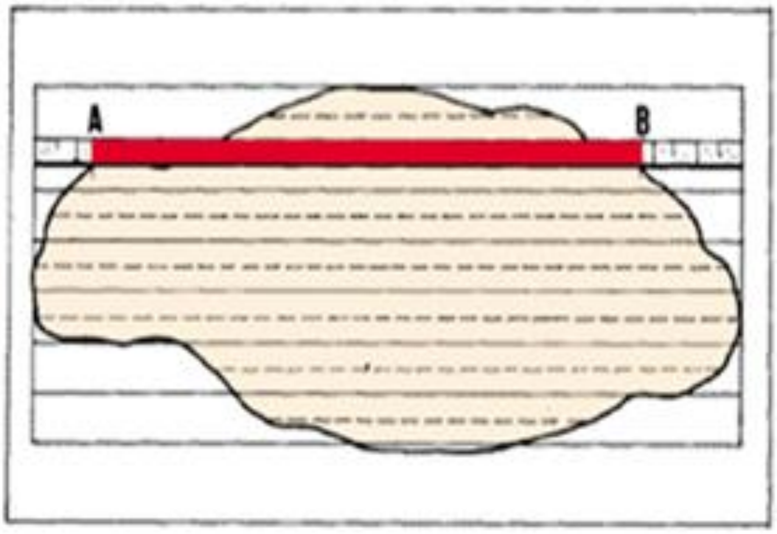
Scale 1: 50000; strip width W = 1cm = 500m.

Note: The smaller the strip width, the more accurate your estimate of the land area will be.

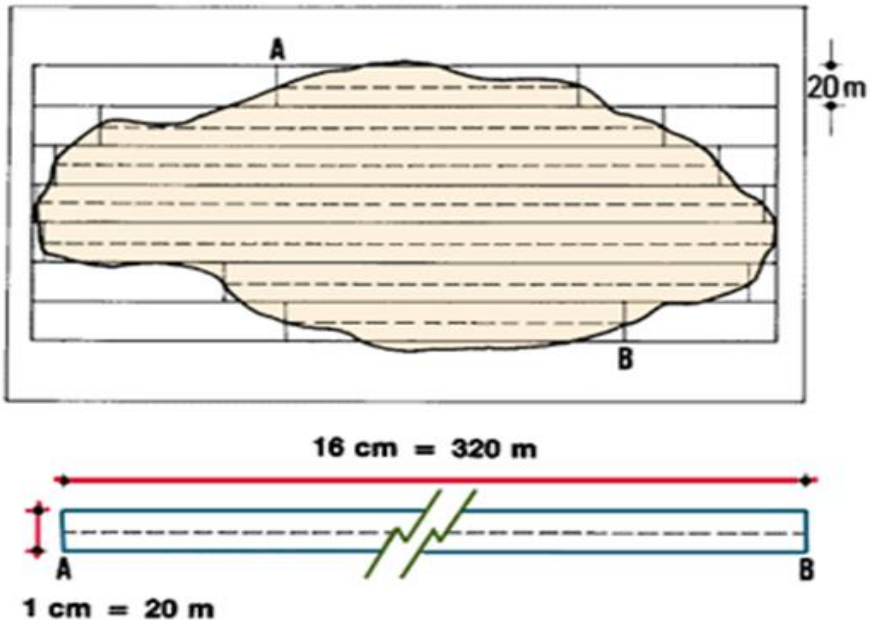
3. Place the sheet of transparent paper over the plan or map of the area you need to measure, and attach it securely with drawing pins or transparent tape.



4. For each strip, measure the distance AB in centimeters along a central line between the boundaries of the area shown on the map.



6. Calculate the sum of these distances in centimeters. Then, according to the scale you are using, multiply to find the equivalent distance in the field, in meters



Example

Scale is 1:2000 and 1 cm = 20 m.

Sum of distances = 16 cm.

Equivalent ground distance: 16 x 20 m = 320 m.

Multiply this sum of real distances (in meters) by the equivalent width of the strip W (in meters) to obtain a rough estimate of the total area in square meters.

Example

Sum of equivalent distances is 320 m.

Strip width (1 cm) is equivalent to 20 m.

Land area: 320 m x 20 m = 6 400 m^2 or 0.64 ha

Note: 10000 m^2 = 1 hectare (ha)

7. Repeat this procedure at least once to check on your calculations.

Use the square-grid method for measuring areas

1. Get a piece of transparent square-ruled paper, or draw a square grid on transparent tracing paper yourself. To do this, trace a grid made of 2 mm x 2 mm squares inside a 10

cm x 10 cm square, using the example given on the page.

Note: if you use smaller unit squares on the grid, your estimate of the land area will be more accurate; but the minimum size you should use is 1 mm x 1 mm = 1 mm^2.

2. Place this transparent grid over the drawing of the area you need to measure, and attach it to the drawing securely with thumbtacks or tape. If your grid is smaller than this area, start at one edge of the drawing. Clearly mark the outline of the grid, then move to the next section and proceed in this way over the entire area.

3. Count the number of full squares included in the area you need to measure. To avoid mistakes, mark each square you count with your pencil, making a small dot.

Note: towards the center of the area, you may be able to count larger squares made, for example, of 10 x 10 = 100 small squares. This will make your work easier.

4. Look at the squares around the edge of the drawing. If more than one-half of any squares are within the drawing, count and mark it as a full square. Ignore the rest.

5. Add these two sums (steps 3 and 4), to obtain the total number T of full squares.

6. Add the sums again at least once to check them.

7. Using the distance scale of the drawing, calculate the equivalent unit area for your grid. This is the equivalent area of one of its small squares.

Example

Scale 1:2000 or 1 cm = 20 m or 1 mm = 2 m

Grid square size is 2 mm x 2 mm

Equivalent unit area of grid = 4 m x 4 m = 16 m^2

8. Multiply the equivalent unit area by the total number T of full squares to obtain a fairly good estimate of the measured area.

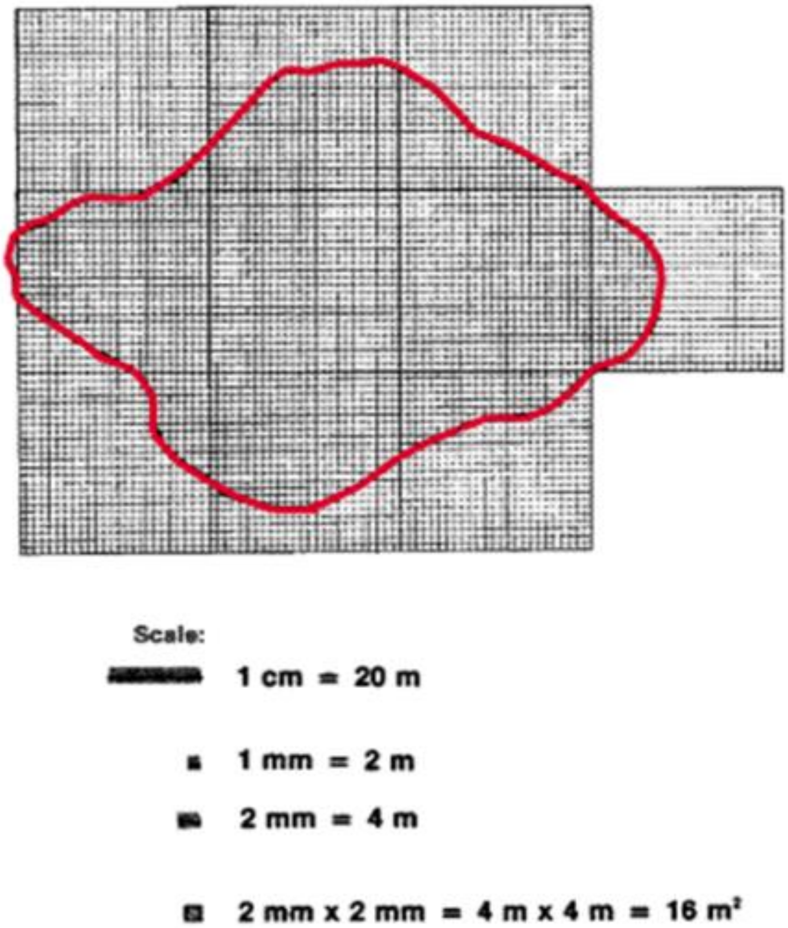


Figure: Area calculation using square-grid method

Example

Total count of full squares T = 256

Equivalent unit area = $16m^2$

Total area = 256 x 16 m^2 = 4096 m^2

Subdivide the area into regular geometrical figures

1. When you need to measure areas directly in the field, divide the tract of land into regular geometrical figures, calculate area of each one and find the total area.

Measuring areas by triangles

3. You can easily calculate the area of any triangle when you know the dimensions of: all three sides a, b and c

Area = $\sqrt{s(s - a)(s - b)(s - c)}$

where :s = $\frac{a+b+c}{2}$;

Example

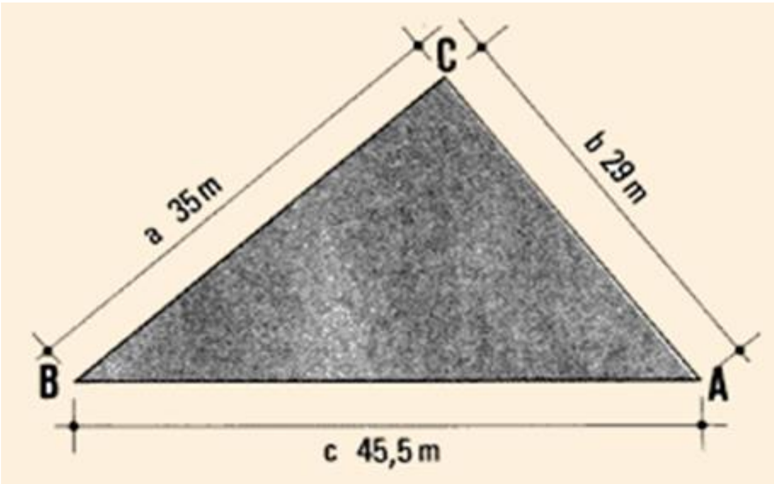


Figure: Area of any triangle

If a = 35 m; b = 29 m; and c = 45.5 m.

Then s = (35 m + 29 m + 45.5 m) ÷ 2 = 54.75 m

$Area^2$= 54.75 m (54.75m - 35 m) (54.75 m - 29 m)(54.75 m - 45.5 m)

= 54.75 m x 19.75 m x 25.75 m x 9.25 m = 257 555 m^4

Area = $\sqrt{(257\ 555\ \mathrm{m4})}$ = 507 m^2

Two sides (b, c) and the angle BAC between them (called the included angle)

Area = **(bc sin BAC) ÷ 2**

Example

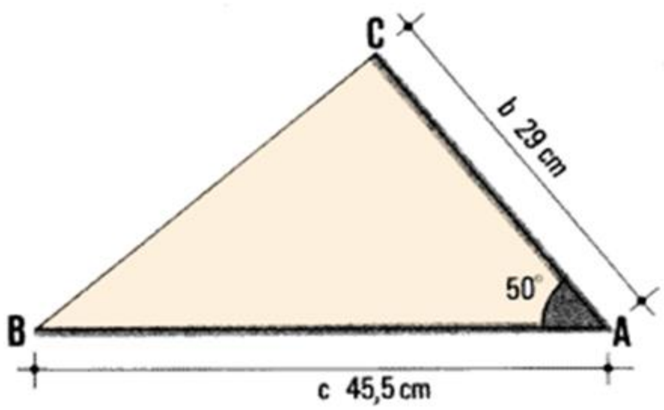


Figure: Area calculation using Sin method

If b = 29 m; c = 45.5 m; and angle BAC = 50°.

Then sin BAC= 0.7660

Area = (29 m x 45.5 m x 0.7660) ÷ 2 = 1010.737 ÷ 2 = 505.3685 m2

Using a base line to subdivide land areas

When the shape of the land is polygonal, you should usually subdivide the total area you need to measure into a series of regular geometrical figures

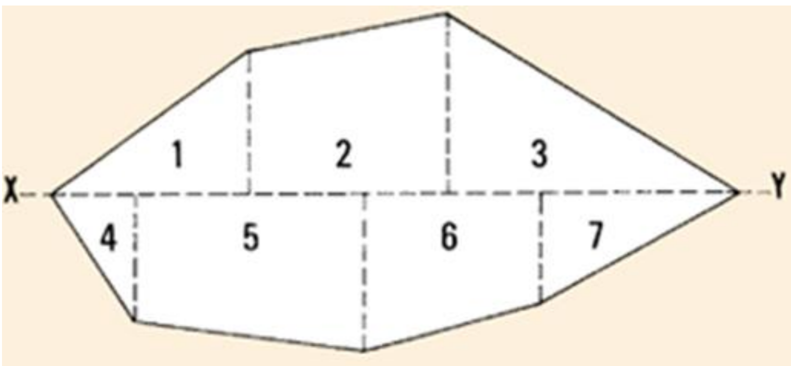


Figure: A base line X,Y used to subdivide land area

When you are choosing a base line, remember that it should:

- be easily accessible along its entire length;
- provide good sights to most of the summits of the polygon;
- be laid out along the longest side of the land area to keep the offsets as short as possible;

- Join two polygon summits.

Add together all these partial areas to find the total land area.

Subdividing land areas without base lines

When the shape of the land is more complicated than the ones you have just learned to measure, you will have to use more than one base line, and subdivide the area into triangles, and trapeziums of various shapes. Usually there will be no existing right angle for you to work with and you will have to calculate the area of the trapeziums by taking additional measurements, which will determine their heights along perpendicular lines.

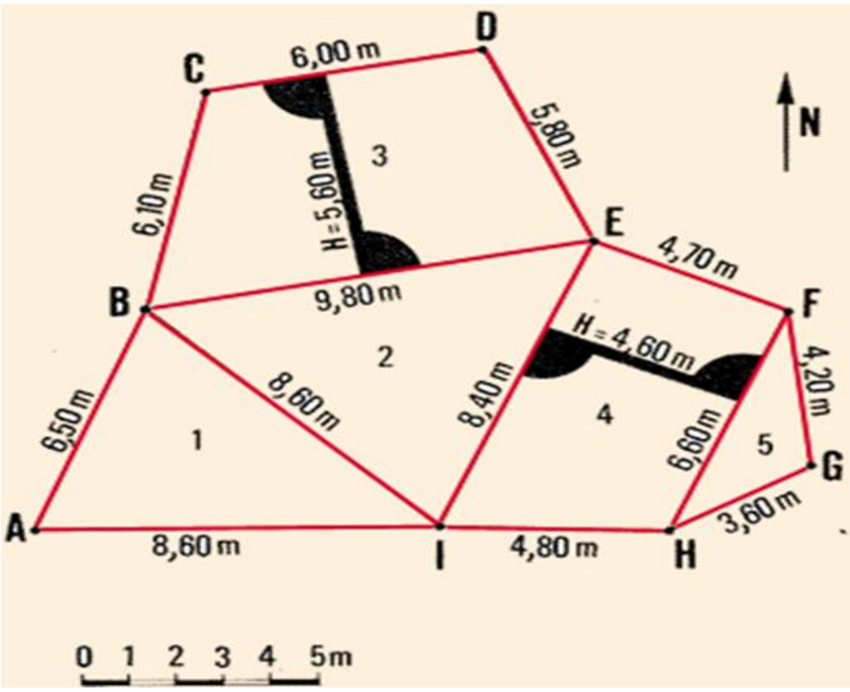


Figure: area calculation without common base

Calculate the areas of triangles 1, 2 and 5, using the lengths of their three sides and the following formulas:

s = (a + b + c) ÷ 2
area = $\sqrt{s(s-a)(s-b)(s-c)}$

Calculate the areas of trapeziums 3 and 4, determining their heights and base lengths, and using the following formula:

area = height x (base 1 + base 2) ÷ 2

Add the total area of the triangles to the total area of the trapeziums to obtain total land tract area.

Example

Total area of triangles= 667337 m^2

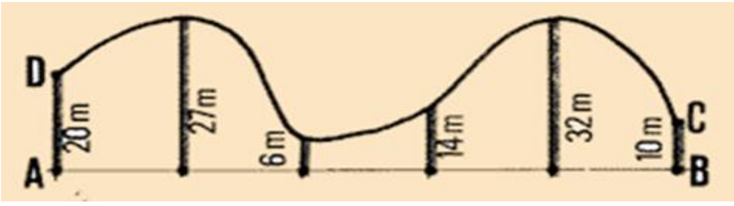
Total area of trapeziums = 787400 m^2

Total land tract area = 1454 737 m^2 or 145.47 ha

Measuring area bounded by a curve

This area is calculated by the following formula: **Area=** $\frac{\boldsymbol{interval} \times (\boldsymbol{h_o} + \boldsymbol{h_n} + \boldsymbol{2\,h_i})}{\boldsymbol{2}}$

Example1



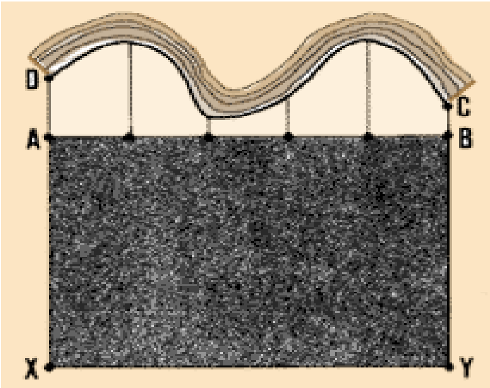


Figure: Area bounded by curve (1)

Suppose that Interval = 112.5 m ÷ 5 = 22.5 m

h_o = 20 m and h_n = 10 m

h_i = 27 m + 6 m + 14 m + 32 m = 79 m

Area ABCDA = $\frac{\boldsymbol{interval \times (h_o + h_n + 2\,h_i)}}{\mathbf{2}}$

$= \frac{\mathbf{22.5m \times (20m + 10m + 158m)}}{\mathbf{2}}$ **= 2115m²**

Note: remember that you must still calculate the area of AXYBA and add it to the area of ABCDA to get the total area DAXYBCD.

Example2

Area= interval × h_i

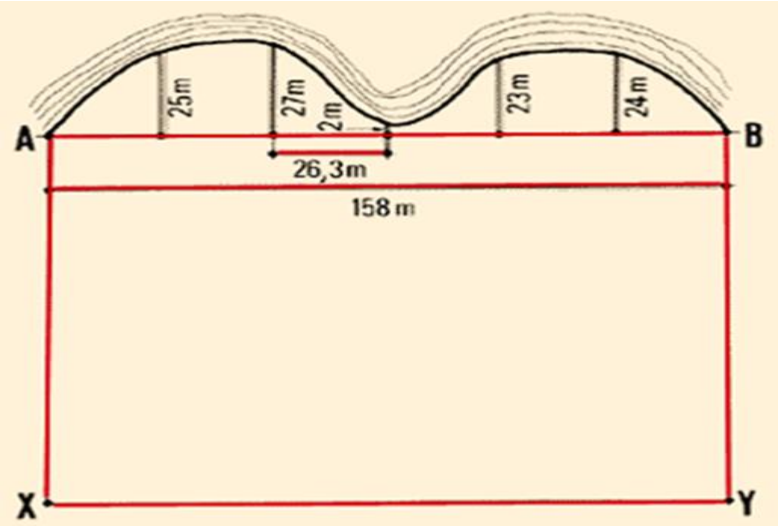


Figure: example of area culcuration for area bounded by curve

Interval = 158 m ÷ 6 = 26.3 m

h_i = 25 m + 27 m + 2 m + 23 m + 24 m = 101 m

Area= 26.3 m x 101 m = 2 656.3 m^2

Note: remember that you must still calculate the area of AXYBA and add it to the area of the curved section to get the total area.

LO 3.3 – Present survey results based on required topographic data

- Content/Topic 1: Presentation techniques

Survey results are presented in the following techniques:

✓ **Non graphical (Tabular form)**

In this technique, Survey results are presented by use of tables.

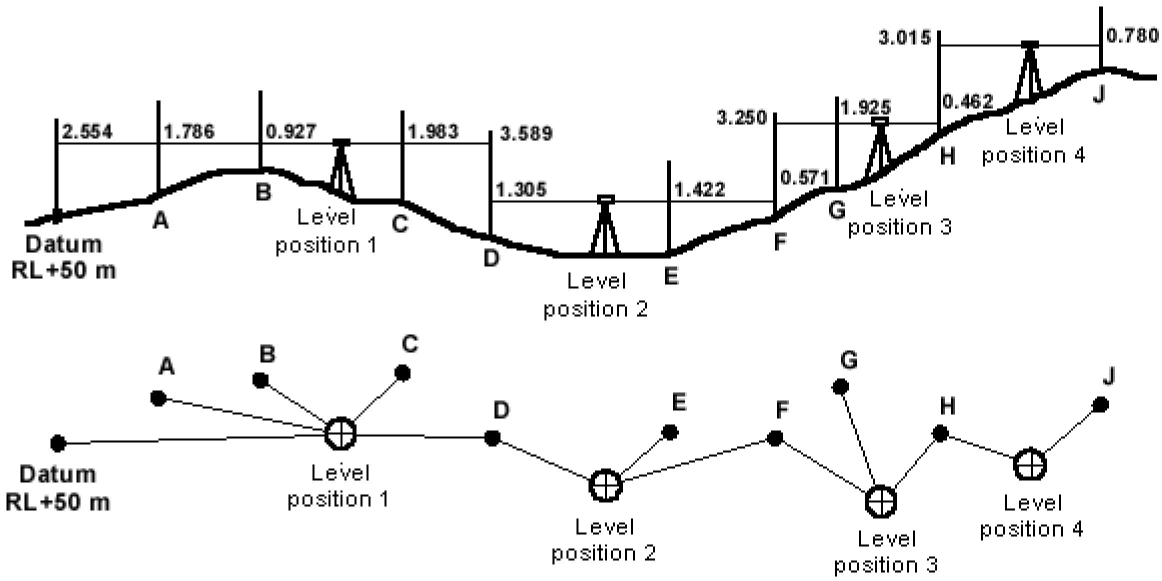
Example: Data from a differential leveling have been found as shown in the following table:

Points	Staff reading		Height of instrument(m)	R.L (m)
	B.S(m)	F.S (m)		
BM1	2.125			
TP1	1.830	2.945		
TP2	2.100	3.225		
TP3	1.650	3.605		
BM2	2.365	2.805		
TP4	2.885	2.530		
TP5	3.065	2.350		
BM3	3.855	1.100		
TP6	3.270	1.660		
TP7	3.865	2.110		
BM1		3.455		

- ✓ **Graphical {Line graph (Leveling nets)}**

In this technique, Survey results are presented by use of graphs.

Example:



- Content/Topic 2: Purpose of data presentation

Data are presented for the following main purpose:

- ✓ To record the information
- ✓ To transmit the information

LO 3.4 – Keep record as required by supervisor

- Content/Topic 1: Data to be recorded

The following are the data to be recorded during the survey activity:

- ✓ Slope

The formula used is:

$$The\ slope\% = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)} * 100$$

The slope can be expressed per 1000, the formula used then:

$$The\ slope\ {}^{o}/_{oo} = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)} * 1000$$

Note: Slope in ${}^{o}/_{oo}$=Slope in % * 10

Example:

What is the slope in percent and per mil of a field with horizontal length of 200m and height difference of 1.5 m between the bottom and the top of land?

Solution:

$The\ slope\% = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)} * 100$ =$\frac{1.5}{200} * 100$ =0.75%

$The\ slope\ {}^{o}/_{oo} = \frac{Height\ difference\ (m)}{Horizantal\ distance\ (m)} * 1000$ =$slope\%$*10=0.75*10 =7.5‰

- ✓ Height difference
  - ➢ **Using the flexible tube water level**

EXAMPLE:

Between pegs	**Back Reading (m)**	**Front Reading (m)**
A and C	0.75	1.25
C and D	0.52	1.48
D and E	1.23	0.77
E and B	0.41	1.59
Total	**2.91**	**5.09**

The difference in elevation between point A and point B is given by the formula:

Difference in elevation = sum of the back readings - sum of the front readings

In our example:

<u>Measured</u>

sum back readings = 2.91 m

sum front readings = 5.09 m

<u>Answer</u>

difference in elevation between A and B

= 2.91 m - 5.09 m = - <u>2.18 m</u>

- **using the hand level**

Difference in elevation between A and B = sum of back readings - sum of front readings

EXAMPLE:

Between points:	**Back Reading (m)**	**Front Reading (m)**	**Difference in Elevation (m)**
A and C	0.65	1.40	- 0.75
C and D	0.20	1.25	- 1.05
D and E	1.80	0.50	+ 1.30
E and F	1.75	0.95	+ 0.80
F and B	1.37	1.24	+ 0.13
Total	5.77	5.34	+ 0.43

Difference in elevation between A and B = Sum of back readings - sum of front readings

= 5.77 - 5.34 = + 0.43 m

The difference in elevation is positive, which means that point B is above point A.

- ✓ Horizontal distance

By pacing:

Distance (m) = N×PF

Example

To measure ABCD, pace distances AB = 127 steps; BC = 214 steps; and CD = 83 steps.

ABCD = 127 + 214 + 83 = 424 steps.

If PF = 0.75 m,

ABCD = 424 x 0.75 m = <u>318 m</u>

By the stadia method:

Example

Upper stadia hair reading: 1.62 m;

Lower stadia hair reading: 0.52 m;

Stadia interval = 1.62 m - 0.52 m = 1.10 m;

Stadia factor = 100;

Distance AB = 1.10 m x 100 = 110 m.

Using height differences

Example

You have measured AB = 45 m along the sloping ground;

The height difference AC from point A to point B equals 9 m;

The horizontal distance

CB=$\sqrt{G^2 - H^2}$

CB =$\sqrt{(45m)^2 - (9m)^2}$ =$\sqrt{2025m^2 - 81m^2}$ = $\sqrt{1944\ m^2}$ = **44.1 m**

- ✓ Area

Measuring areas by triangles

Area = $\sqrt{s(s\ -\ a)\ (s\ -\ b)\ (s\ -\ c)}$

where :s = $\frac{a+b+c}{2}$;

Example

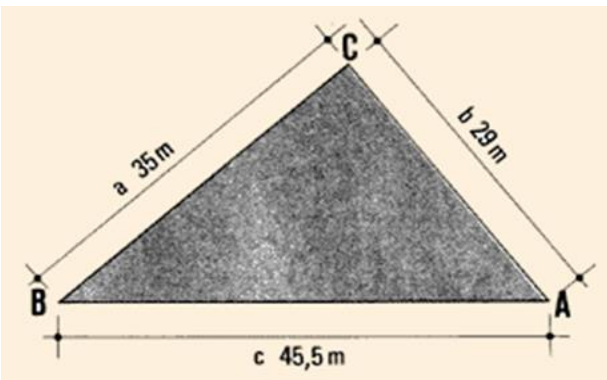


Figure: Area of any triangle

If a = 35 m; b = 29 m; and c = 45.5 m.

Then s = (35 m + 29 m + 45.5 m) ÷ 2 = 54.75 m

Area^2= 54.75 m (54.75m - 35 m) (54.75 m - 29 m)(54.75 m - 45.5 m)

= 54.75 m x 19.75 m x 25.75 m x 9.25 m = 257 555 m^4

Area = $\sqrt{(257\ 555\ \text{m4})}$ = 507 m^2

Two sides (b, c) and the angle BAC between them (called the included angle)

Area = **(bc sin BAC) ÷ 2**

Example

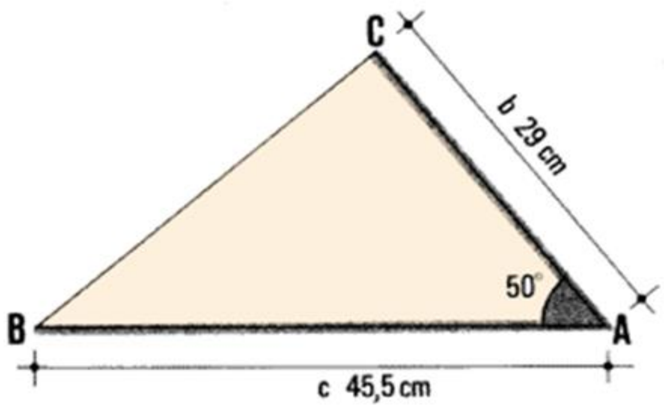


Figure: Area calculation using Sin method

If b = 29 m; c = 45.5 m; and angle BAC = 50°.

Then sin BAC= 0.7660

Area = (29 m x 45.5 m x 0.7660) ÷ 2 = 1010.737 ÷ 2 = 505.3685 m^2

- Content /Topic2: Content format template

Content format template contains the following:

✓ Heading:

- Date of survey
- Location of survey
- Raised by (name of surveyor)
- Office notebook done by

✓ Development:

Booking levels format

There are two main methods of booking levels:

- rise and fall method, and
- height of collimation method

Rise & Fall Method format

Back-sight	Inter-mediate	Fore-sight	Rise	Fall	Reduced level	Distance	Remarks
							DatumRL+m
							Sum of B-sight & F-sight, Sum of Rise & Fall
							Take smaller from greater
							Difference should be equal

The millimeter reading may be taken by estimation to an accuracy of 0.005 metres or even less.

6. Back- sight, intermediate sight and for- sight readings are entered in the appropriate columns on different lines. However, as shown in the table above back- sights and foresights are place on the same line if you change the level instrument.
7. The first reduced level is the height of the datum, benchmark or R.L.

8. If an intermediate sight or foresight is **smaller** than the immediately preceding staff reading then the difference between the two readings is place in the **rise** column.
9. If an intermediate sight or foresight is **larger** than the immediately preceding staff reading then the difference between the two readings is place in the **fall** column.
10. A rise is added to the preceding reduced level (RL) and a fall is subtracted from the preceding RL

Height of collimation method (height of instrument)format

Back-sight	**Inter-mediate**	**Fore-sight**	**Height of collimation**	**Reduced level**	**Distance**	**Remarks**
						DatumRL+m
						Sum of B-sight & F-sight, Difference between RL's
						Take smaller from greater
						Difference should be equal

7. Booking is the same as the rise and fall method for back-, intermediate- and foresights. There are no rise or fall columns, but instead a height of collimation column.
8. The first back- sight reading (staff on datum, benchmark or RL) is added to the first RL giving the height of collimation.
9. The next staff reading is entered in the appropriate column but on a new line. The RL for the station is found by subtracting the staff reading from the height of collimation

10. The height of collimation changes only when the level is moved to a new position. The new height of collimation is found by adding the back- sight to the RL at the change point.
11. Please note there is no check on the accuracy of intermediate RL's and errors could go undetected.

Recording using the hand level format

Between points:	Back Reading (m)	Front Reading (m)	Difference in Elevation (m)
A and C			
C and D			
D and E			
E and F			
F and B			
Total			

Recording using the flexible tube water levelformat

Between pegs	Back Reading (m)	Front Reading (m)
A and C		
C and D		
D and E		
E and B		
Total		

Reference(s):

1. Basic surveying,raymond epaul(author),walterwhyte(author)
2. Bettess,f.1992.surveyingforarchaeologists.universityofdurhamdepartmentofarchaeology.
3. Brinker,russell c. and minnick, roy.the surveying handbook. new york, new york van nostrandreinhold company.1987
4. Brower, c. and *al.,* 1985.*elements of topographic surveying,*rome, italy.
5. c.brouwerand a.goffeau ,j.plusjé, m.heibloem irrigation water management: training manual no. 2 - elements of topographic surveying
6. Electronic vs. conventionalsurveys,r. dixon(author)
7. Fundamentalsofsurveying:sampleexamination,georgem.colepepls(author)
8. Harbin,andrewl.land surveyor reference manual. belmont, california professional publications, inc.1985
9. Http://squidstation.net/surveying.html
10. Http://www.ordnancesurvey.co.uk/benchmarks/; or http://www.benchmarks.org.uk/search
11. Ninthannualseminarpresentedbytheoregondepartmentoftransportationgeometronics,oregon
12. Surveymanual - location & design division, virginia department of highways and transportation