



UNIVERSITY OF GONDAR
INSTITUTE OF TECHNOLOGY
Department of Civil Engineering

Surveying II (CEng 2082)

CHAPTER-1
Topographical Surveying and Mapping

OCTOBER 2019
(Wabiew

B.)

CONTENTS

- **Introduction**

- **Contouring**

- ❖ Contour line and contour interval
- ❖ Characteristics of contours
- ❖ Methods of contouring
- ❖ Uses of contours

INTRODUCTION

GENERAL

- **Topographic Survey** is made to determine the locations of *natural* and *artificial* features on the Earth's surface and to define the configuration (relief) of that surface.
- These features can be represented on maps;
 - ❖ **Natural**: Vegetation, rivers, lakes, oceans, and so on
 - ❖ **Artificial**: Roads, rail roads, buildings, bridges, canals, and so on
 - ❖ **Relief**: Hills, valleys, plains, and other surface irregularities.

TYPES OF MAPS:

➤ Planimetric Map

- Depicts natural and artificial features in the plan (X,Y) view/horizontal position only.
- Do not show topographic features.
- Show accurate horizontal distances.
- Plan view.

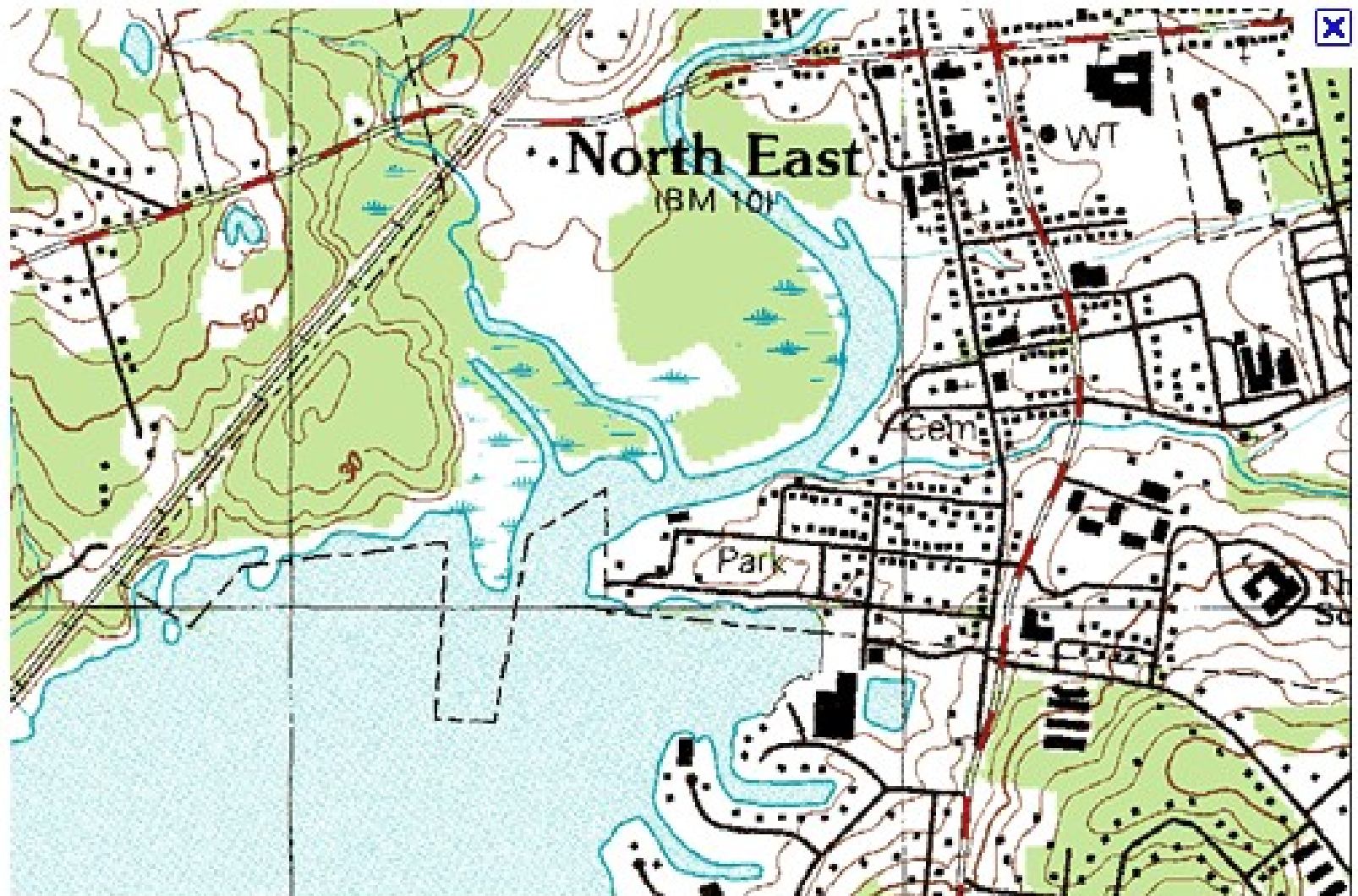
➤ Topographic Map

- Include planimetric features but in addition they show the configuration of the Earth's surface.

▶ PLANIMETRIC MAP(cont...)



► TOPOGRAPHIC MAP(cont...)



- ▶ **APPLICATION OF TOPOGRAPHIC MAP;**
 - ❖ **Engineers and planners:** to determine economical & desirable location of highways, railroads, canals, pipelines, transmission lines, reservoirs, and other facilities;
 - ❖ **Geologists:** to investigate mineral, oil, water, and other resources;
 - ❖ **Foresters:** to locate access- or haul-roads, fire-control routes, and observation towers;
 - ❖ **Architects:** in housing and landscape design;
 - ❖ **Archeologists, geographers, and scientists** in numerous fields.
- ▶ **Note:** The user of the map should be able to interpret the map as a model of the ground.

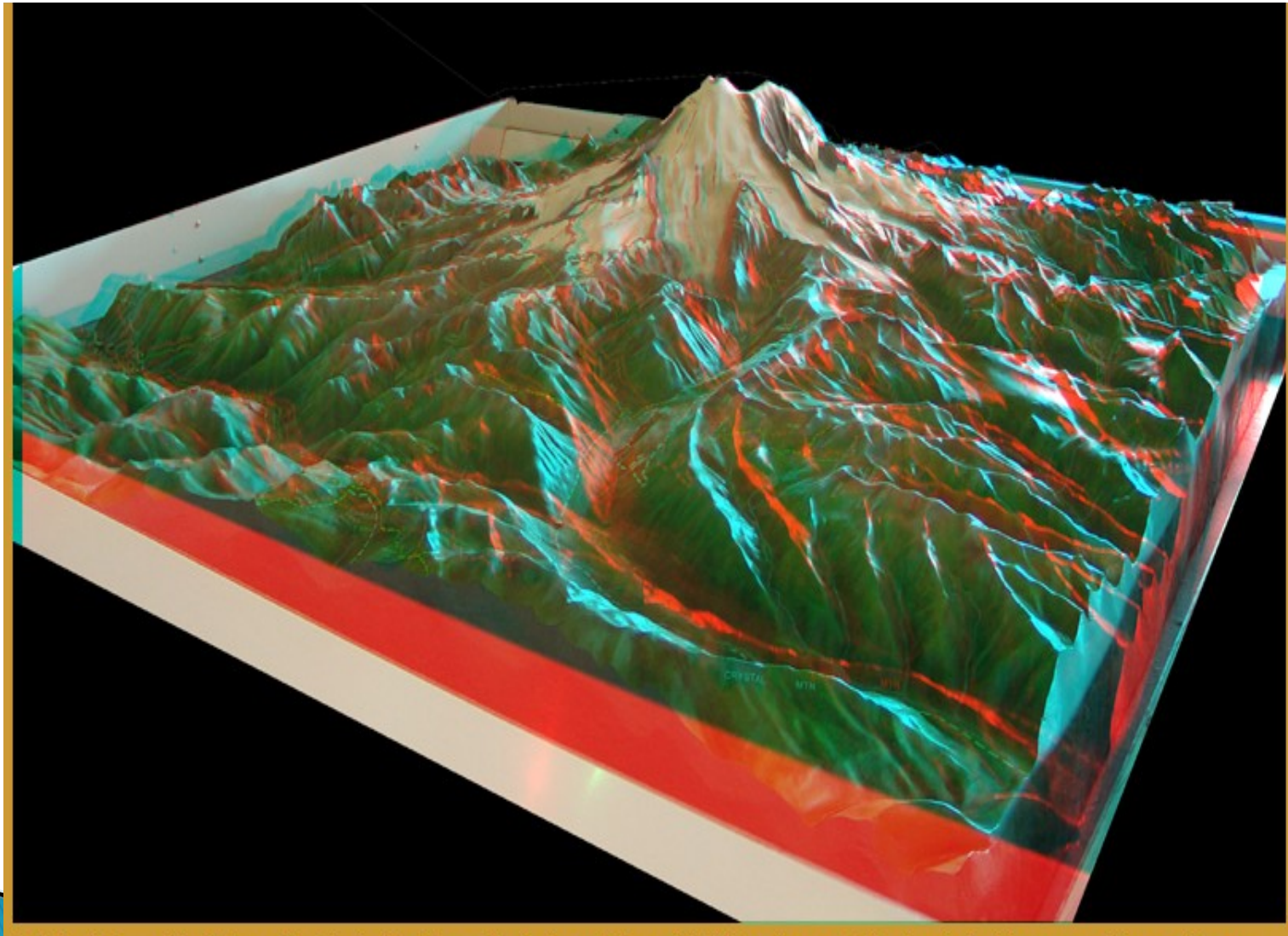
- The purpose of Topographic surveying is to gather data necessary for the construction of the topographic map that displays both the planimeter and topographic features.
- Necessary aids in the design of any engineering project that requires consideration of landforms, elevations or gradients.
 - Industrial Plants
 - Rail ways & high ways
 - Irrigation & drainage scheme
 - Hydroelectric power station
 - A building complex
 - Bridges, tunnels and dams.

- ▶ Topographic surveying and the preparation of a topographic map of the terrain is therefore generally the first step in the planning and designing of a major civil engineering project.
- ▶ The topographic map shows by means of suitable symbols;
 - ✓ The spatial configuration of the earth's surface, which includes such features as hills and valleys;
 - ✓ Other natural features such as trees, streams, oceans, seas, etc. and
 - ✓ Man-made features such as buildings, roads, canals, cultivation, etc.

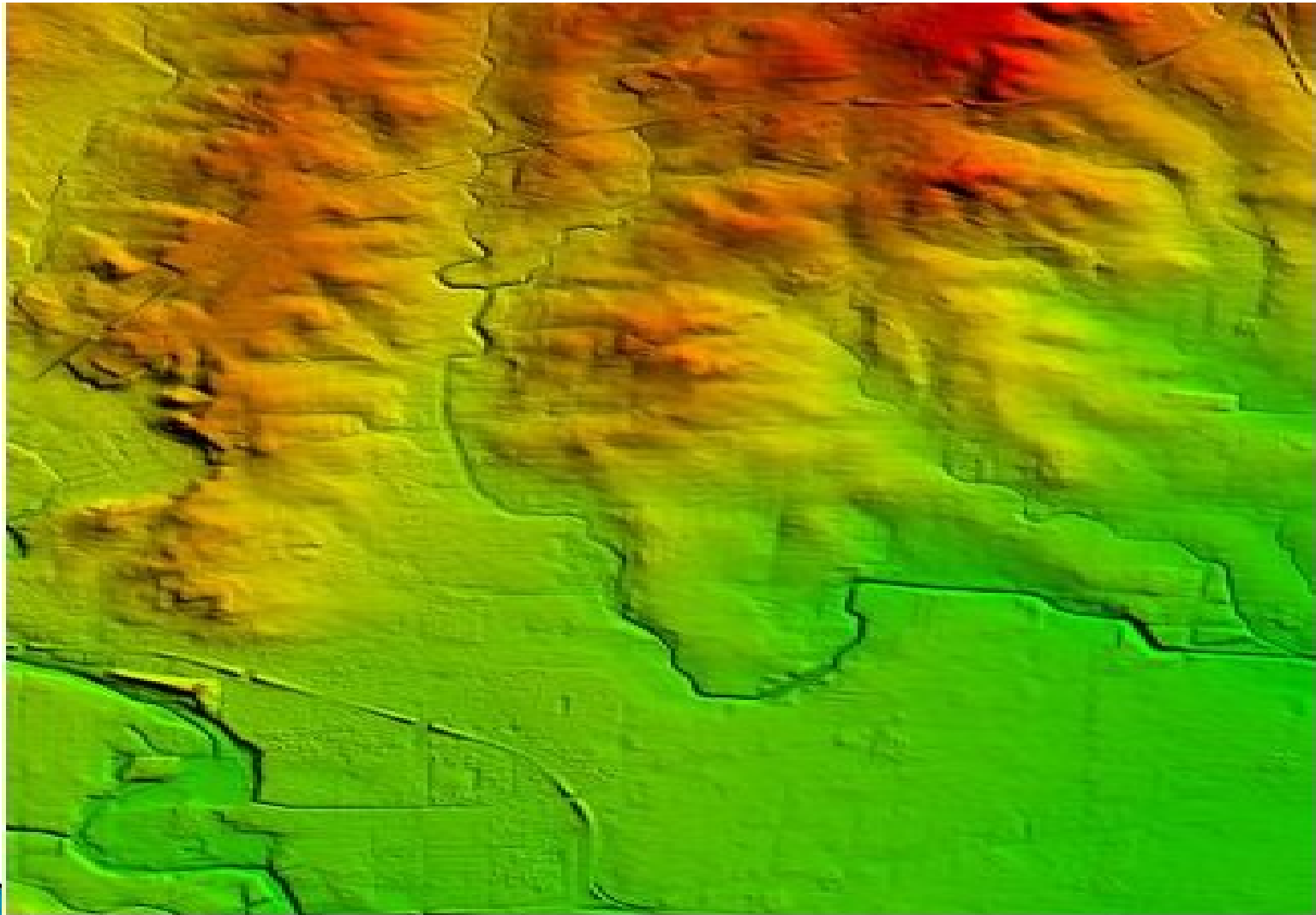
❑ **METHODS OF SHOWING RELIEF ;**

- Contours: the most commonly used
 - Digital Elevation Model (DEM)
 - Three Dimesional Perspective Models
- Newer
methods**
- Hachures
 - Shading
 - Tinting
- Not quantitative enough,
generally unsuitable for
surveying and engineering
work**
- Traditionally, maps were prepared using manual drafting methods.
 - Now however, the majority of maps are produced using computers, computer-aided drafting (CAD) software, and data collectors.

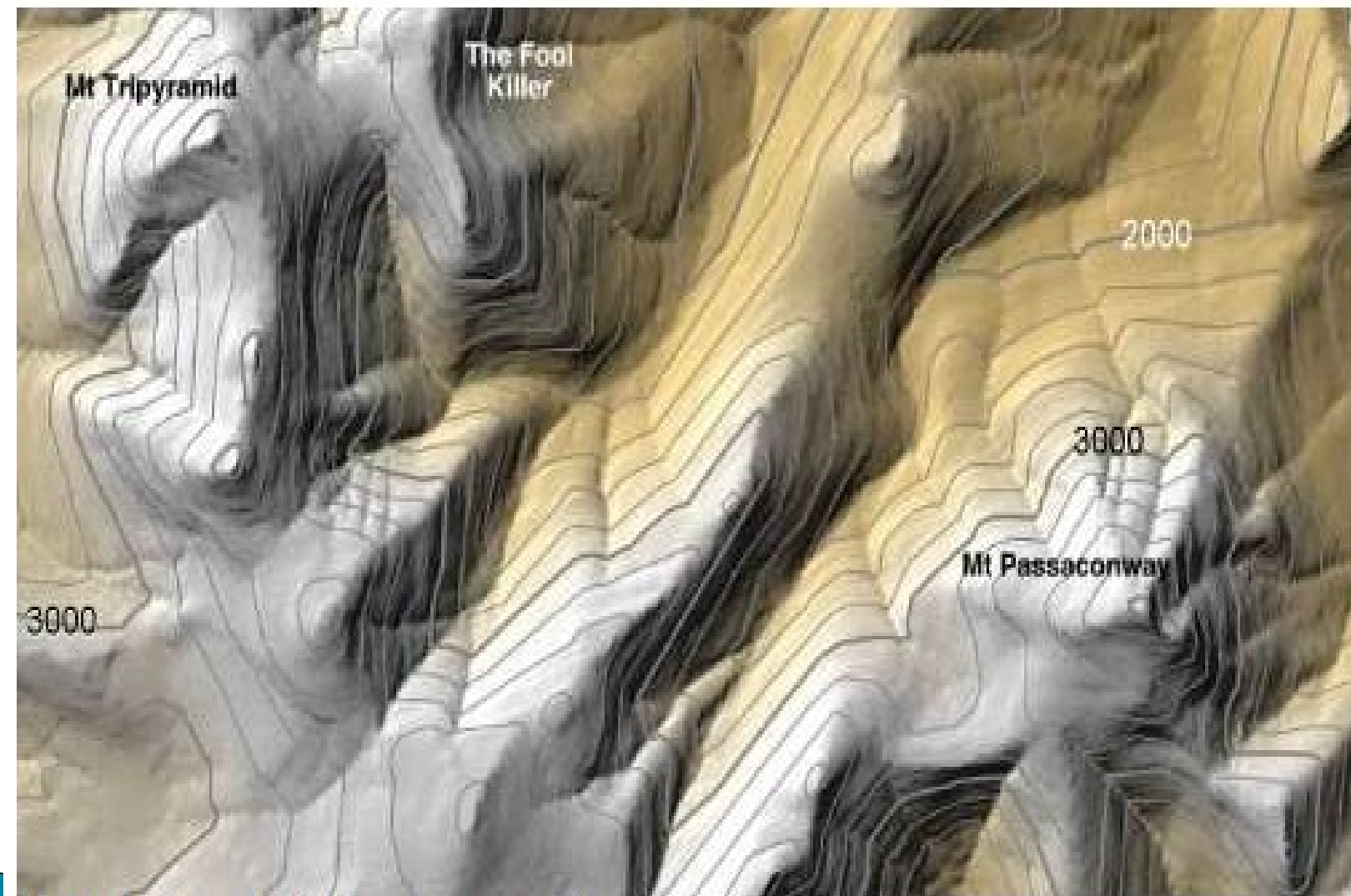
❑ 3D MODEL(cont...)



□ **DIGITAL ELEVATION MODEL(cont...)**



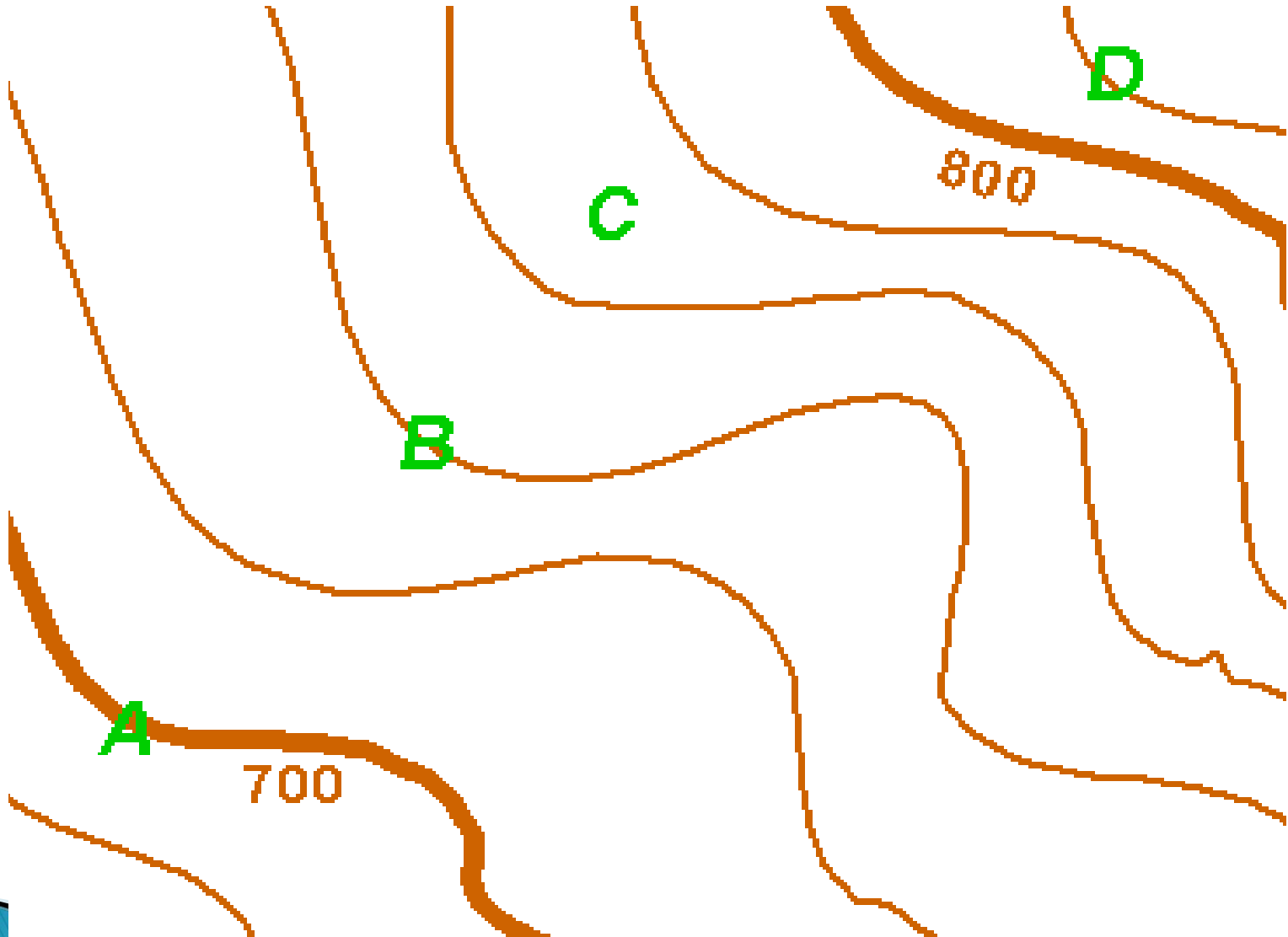
■ SHADED RELIEF(cont...)



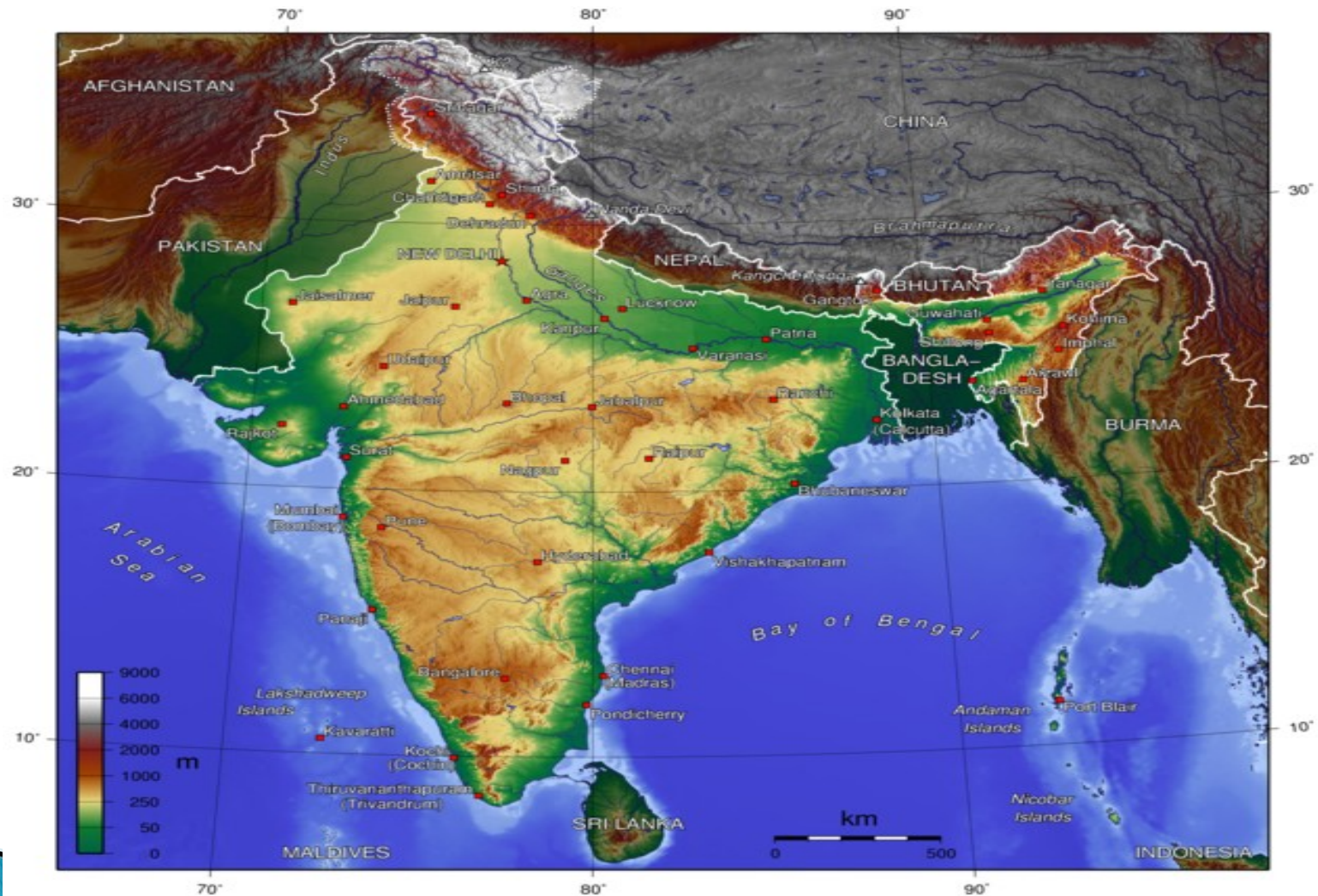
□ HACHURES(cont...)



□ CONTOUR LINE(cont...)



□ TINTING(cont...)



- ▶ **Methods of Preparation of Maps;**
 - Manual drafting
 - Computer, Computer Aided Drafting (CAD) software, and data collectors.

► **METHODS FOR PERFORMING TOPOGRAPHIC SURVEYS;**

- **Aerial (Photogrammetric) Survey:** done stereoscopically(three-dimensionally), preferable for large areas & overcomes the sometimes-difficult access problems to the area to be mapped.
- **Ground (Field) Survey:** done by means of total station or theodolite(stadia tachometer), as well as with levels, tapes.
 - ▢ Economic & suitable for relative small areas, necessary to establish control and field-check mapped features for accuracy.

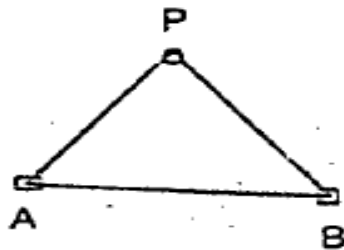
► **CONTROL FOR TOPOGRAPHIC SURVEYS;**

- ❖ Topographic map should be drawn in three phases as;
 1. Develop **horizontal control** producing a frame work for plotting details.
 2. Plot all points of known **elevation and locations** of artificial or natural features for vertical control,
 3. Construct **contour lines** from plotted points of elevation, drawing all features and symbols.
- Horizontal control is provided by two or more points on the ground precisely fixed in position horizontally by distance and direction. It is the basis for map scale and locating topographical features.
- Usual methods are traversing, triangulation, trilateration or inertial or satellite methods.

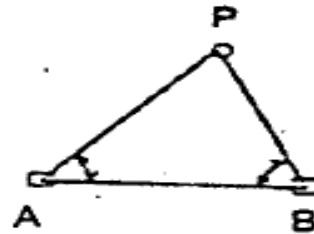
▶ **CONTROL FOR TOPOGRAPHIC SURVEYS(CONT...);**

- ❖ Vertical control is provided by benchmarks in or near the tract to be surveyed,
- ❖ Elevations are found out at all traverse points.
- ❖ Once the horizontal control is obtained, any other point can be obtained by using geometric principles.
- ❖ **The following information's are required:**
 - a) Two distances;
 - b) Two angles;
 - c) One angle and adjacent distance;
 - d) One angle and the opposite distance. The solution is not unique as two points can be obtained;
 - e) One distance and a right angle offset;
 - f) The intersection of two known lines;
 - g) Two angles at the point to be located.

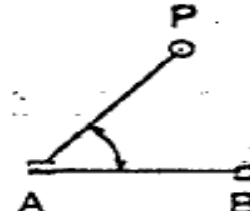
► Control for Topographic



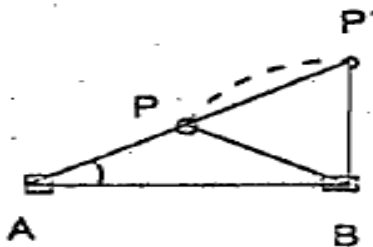
(a) Two distances from A and B are required



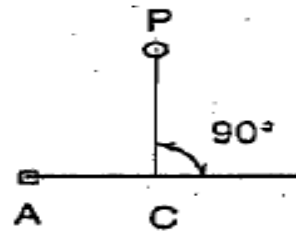
(b) Two angles



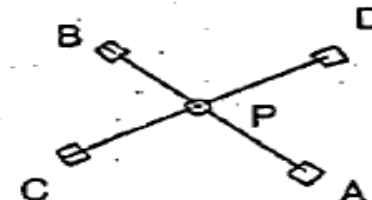
(c) Angle at A and distance AP



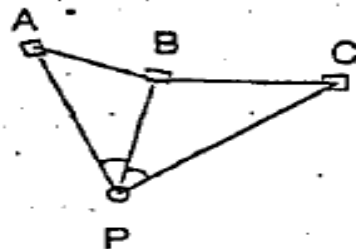
(d) Angle at A and distance PB



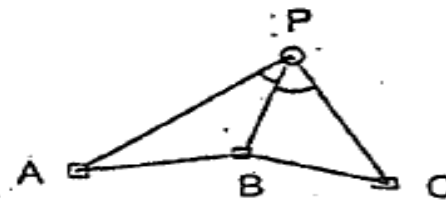
(e) Distance AC or BC and distance CP



(f) From intersection of two known lines AB and CD



(g) Two angles at P from known stations A, B, C



□ **Horizontal Control Establishment Steps;**

- ❖ Identify control points
- ❖ Establish the baseline b/n two C.Ps
- ❖ Set the tripod & instrument
- ❖ Take horizontal angle measurements and distance
- ❖ Computation and adjustment.

❑ **Vertical Control Establishment Steps;**

- Identify the traverse
- Mount the level and tripod
- Setting the level and take measurement backsight and foresight
- Error adjustment and calculation of reduced level.

❑ **Detail Surveying;**

- (1) All natural or artificial features that will appear on the map and
- (2) Enough ground points and spot elevations to make the drawing of contour lines possible.

▶ **Map Drafting;**

➤ Plotting the traverse

■ Plotting horizontal controls

- Select Scale
- Select convenient point from the first station
- Show meridian or Zero angle line through this point.

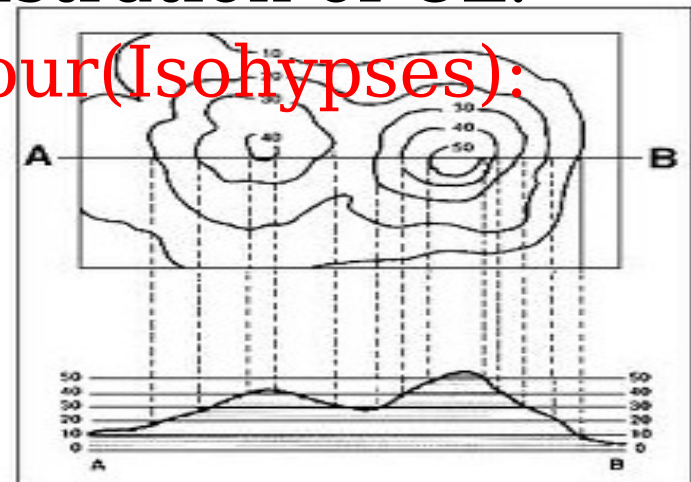
➤ Measure the angle to second point

- Draw line through measured angle and measure the distance on that line.
- Second point is found

- **Map Drafting(cont...);**
- Plotting the details from control points
- Drawing the topography and special data
- ***Relief representation(reliefmodels, shading, color gradients, hachure, form lines or contour lines)***
- Finishing the map.
- **Note:-** Of relief representation techniques, only contour lines indicate elevations directly & quantitatively.

Contour Lines:

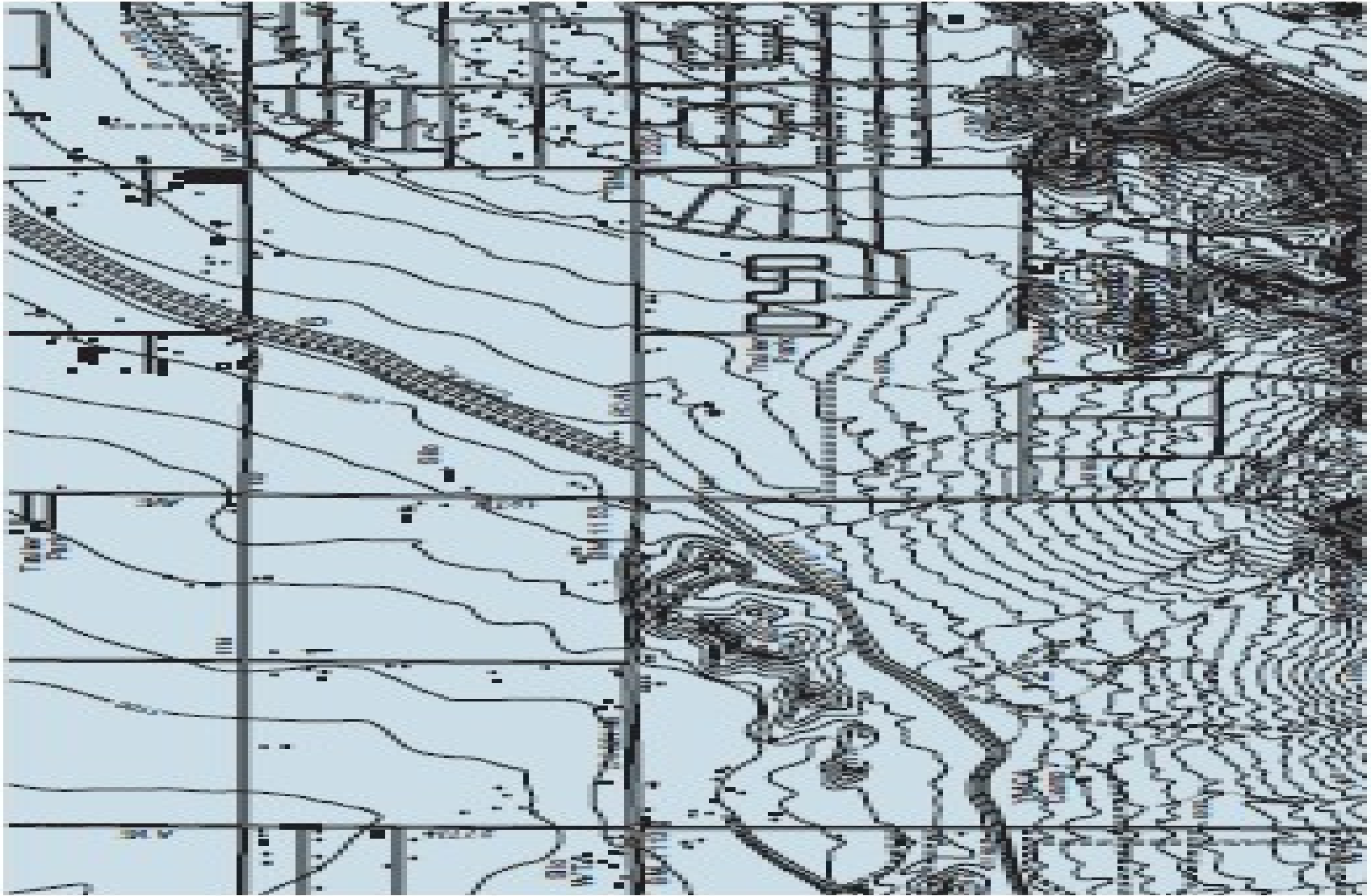
- ▶ A contour line is a line that connects points of equal level on the surface of the Earth.
- ▶ Drawn on a the two-dimensional paper to give the impression of a third dimension.
- ▶ Obtained when the surface of the ground is intersected by a level surface.
- ▶ The shoreline of a body of still water (e.g. lake) is an excellent illustration of CL.
- ▶ The Properties of Contour(Isohyps):
 - Imaginary lines
 - Fixed height interval
 - Known height.



Contour Lines(cont...):

- **Zero Contour:-** normally contours begin at sea level
- **Index Contour:-** starting at zero elevation every fifth contour line with heavier line
- **Intermediate Contour:-** contour lines falling b/n index contours, drawn with a finer line than the index contour and, usually do not have their elevations given.
- ▶ The constant vertical distance (height difference) b/n two consecutive contour lines is called the **Contour Interval**.
- ▶ The horizontal distance between two points on the consecutive contour lines for a given slope, is the **Horizontal Equivalent**.

Contour Lines(cont...):



Contour Lines(cont...):

- ▶ **Contour Interval depends on;**
 - The nature of the terrain
 - The purpose of the survey
 - The extent of the survey
 - The scale of the map.
- ▶ If the terrain is very hilly & the contour intervals too small in r/n to the scale, the contour lines become crowded.
- ▶ In addition, the smaller the contour interval the more points have to be measure in the field & the more time consuming is the plotting. As a result of that the topographic map would become more expensive.

Contour Lines(cont...):

- Contour interval should be selected for the different map

Scales and terrain types:

Scale of the Map	Type of Terrain	Contour Interval
Large 1:1,000 or Larger	Flat Rolling Hilly	0.2-0.5 m 0.5-1.0 m 1.5-2.0 m
Intermediate 1:1,000- 1:10,000	Flat Rolling Hilly	0.5-1.5 m 1.0-2.0 m 2.0-3.0 m
Small 1:10,000 or Smaller	Flat Rolling Hilly Mountainous	1.0-3.0 m 2.0-5.0 m 5.0-10.0 m 10, 25 or 50 m

***A rolling terrain has got gently raising and falling slopes.

Contour Lines(cont...):

- Common contour intervals for different purposes:

Purpose of Survey	Map Scale	Contour Interval
Building Sites	1:1,000 or larger	0.2-0.5 m
Town Planning and Reservoir Planning	1:5,000-1:10,000	0.5-2.0 m
Survey of Extensive Area, Earthwork, etc.	1:5,000-1:20,000	2.0-3.0 m

Contour Lines(cont...):

Flat	0-10 five-metre contours per km. The transverse ground slopes perpendicular to the ground contours are generally below 3%;
Rolling	11-25 five-metre contours per km. The transverse ground slopes perpendicular to the ground contours are generally between 3% and 25%.
Mountainous	26-50 five-metre contours per km. The transverse ground slopes perpendicular to the ground contours are generally above 25%.
Escarpment	Escarpments are geological features that require special geometric standards because of the engineering problems involved. They are characterised by more than 50 five-metre contours per km and the transverse ground slopes perpendicular to the ground contours are generally greater than 50%.

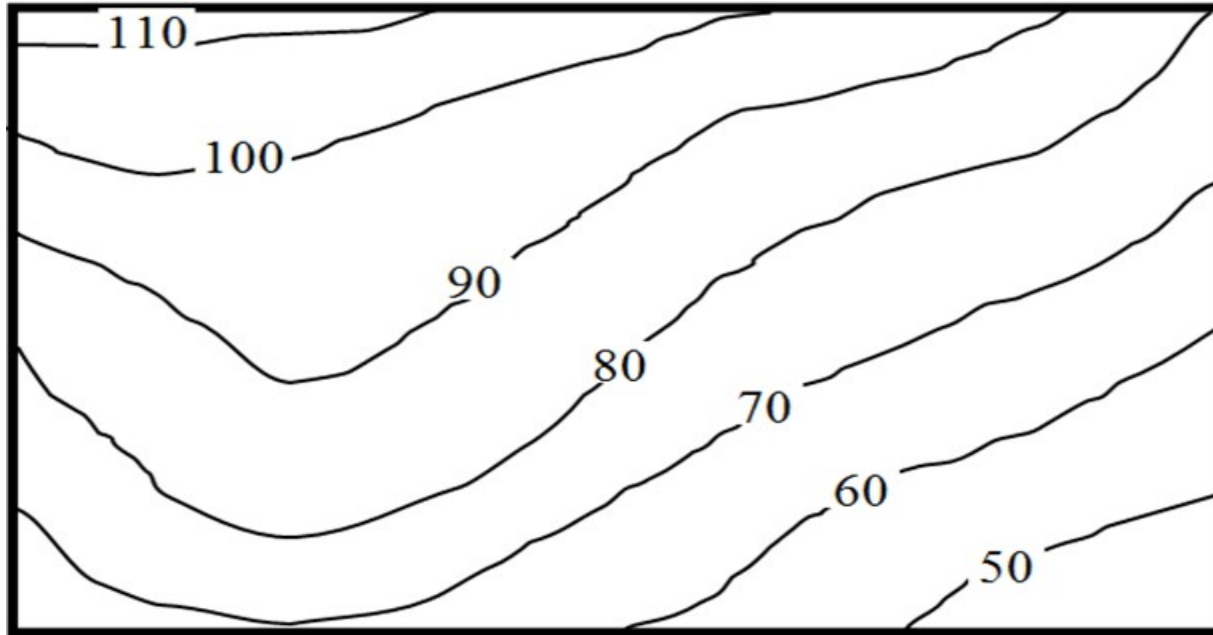
Source: ERA Geometric Design

Characteristics of Contour Line:

- ▶ Although each contour line in nature has a unique shape, all contours adhere to a set of general characteristics.
- Contour lines must close on themselves, either on or off a map. They cannot dead end.
- Contours are perpendicular to the direction of maximum slope.
- The slope between contours of equal intervals is assumed to be uniform and difference in contour divided by the distance gives the steepness of a slope.
- The distance between contours indicates the steepness of a slope. Wide separation denotes gentle slopes; close spacing, steep slopes; even and parallel spacing, uniform slope.

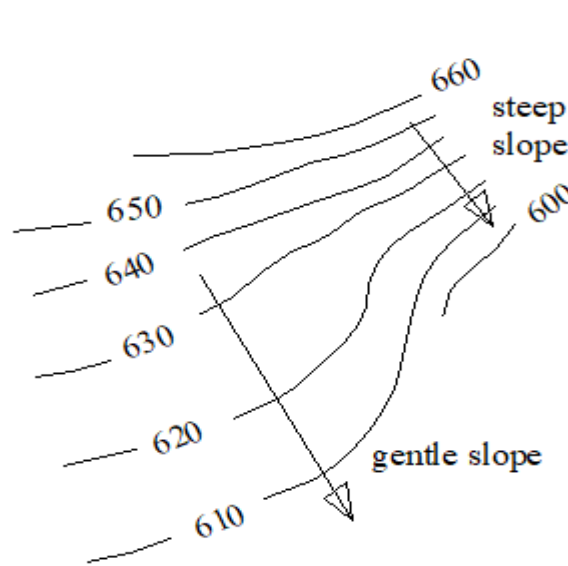
Characteristics of Contour Line(cont...):

E. Contours must be labeled for elevation value.



F. Contours do not have sharp turnings.

Characteristics of Contour Line(cont...):



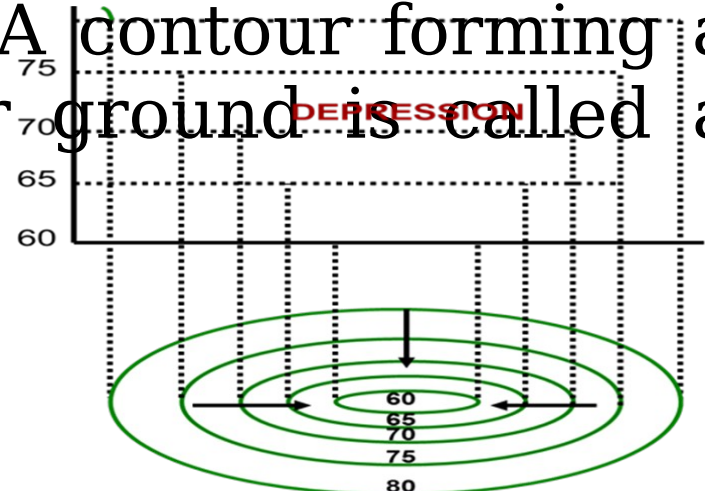
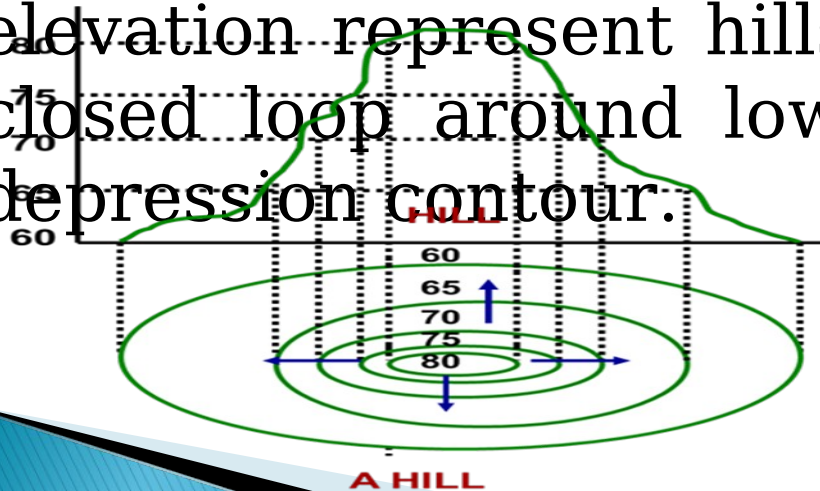
G. As the perpendicular distance between two contour lines is the shortest distance, contours are always perpendicular to the direction of the steepest slope. Therefore, surface water always runs downhill at right angle to the contour lines. These contour lines form U's, pointing downhill .

Characteristics of Contour Line(cont...):

H. In case of a valley lines or streams, the contours run roughly parallel to the valley line or stream and form '^'s pointing uphill where they cross the valley line or stream.

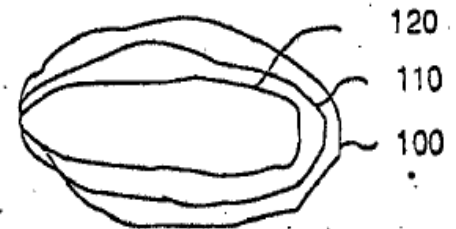
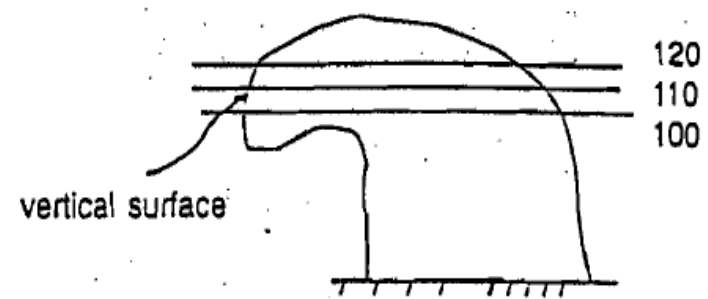
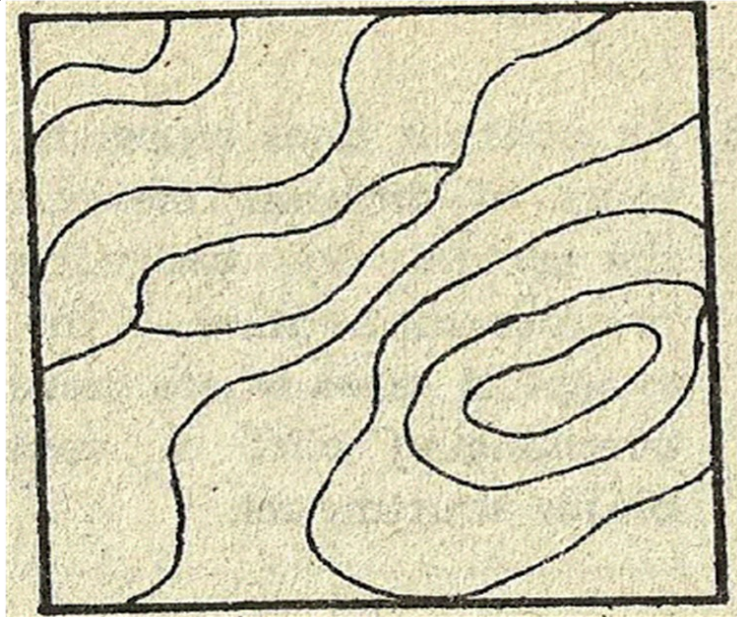
I. Irregular contours signify rough, rugged country. Smooth lines imply more uniformly rolling terrain.

J. Concentric closed contours that increase in elevation represent hills. A contour forming a closed loop around lower ground is called a depression contour.



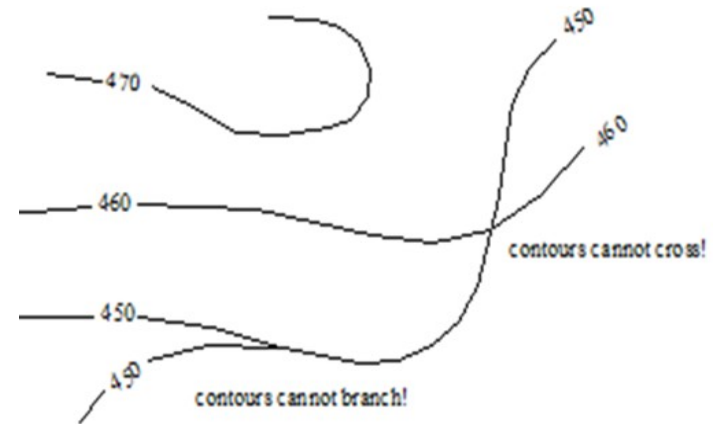
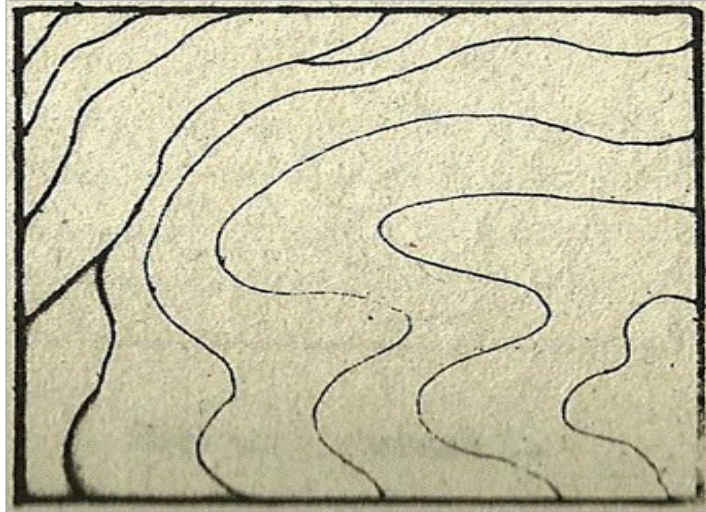
Characteristics of Contour Line(cont...):

K. Contours of different elevations cannot unite (never run into one another) to form one contour, except in the case of a vertical cliff. In this case, several contours coincide and the horizontal equivalent becomes zero.

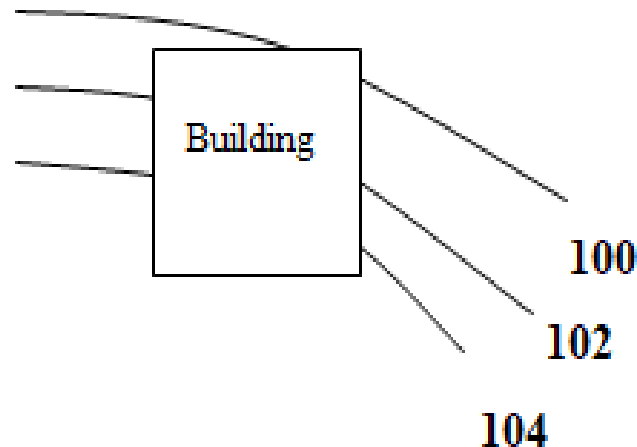


Characteristics of Contour Line(cont...):

L. A contour never splits.

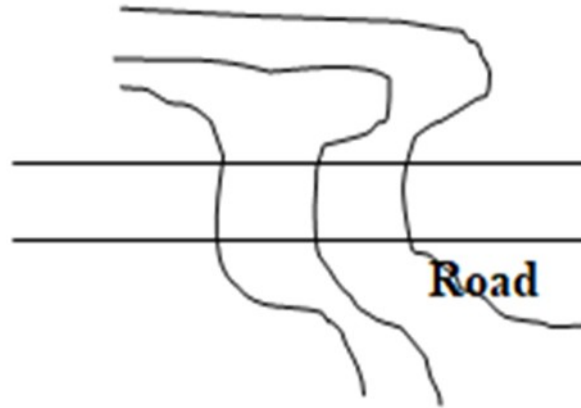


M. Contours are not shown going through buildings.



Characteristics of Contour Line(cont...):

N. Contours crossing a man made horizontal surface (roads, railway track) will be straight parallel lines as they cross the facility.

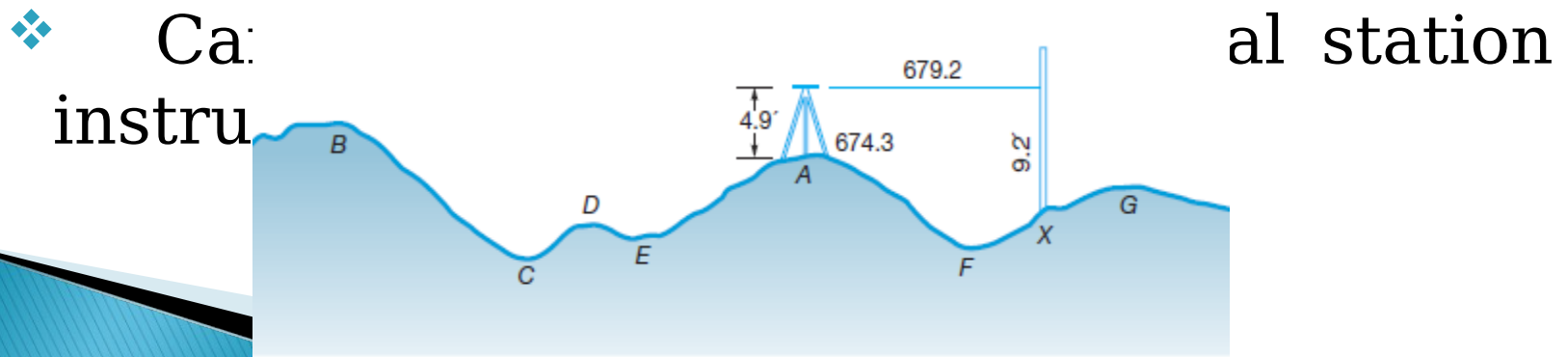


O. A single contour of a given elevation cannot exist between two equal height contours of higher or lower elevation. For example, an 820-ft contour cannot exist alone between two 810- or two 830-ft contours.

Methods of Locating Contours:

- ▶ Contours can be established by either the **direct method** (*trace-contour method*) or the **indirect method** (*controlling-point method*).
- ▶ The controlling-point method is generally more convenient and faster, and therefore it is most often selected. It is also the most frequent choice when data is entered into a computer for automated Contouring.

A, Direct Method:- the contour to be plotted is actually traced on the ground.



Methods of Locating Contours(cont...):

Steps:

- Set up the instrument, the *HI* is established, and the telescope oriented horizontally.
- For the existing *HI*, the rod reading (foresight) that must be subtracted to give a specific contour elevation is determined.
- The rod person selects trial points expected to give this minus sight and is directed uphill or downhill by the instrument operator until the required reading is actually secured.
- After the point which gives the required rod reading has been located by trial, the horizontal position of the point is determined by observing its horizontal distance and direction from the instrument.

Methods of Locating Contours(cont...):

B, Indirect Method:- the rod is set on “controlling points” that are critical to the proper definition of the topography.

- ▶ They include high and low points on the terrain, and locations where changes in ground slope occur, such as *B, C, D, E, F*, and *G* in Figure above.
- ▶ The positions of controlling points are then plotted and contours interpolated between elevations of adjacent points.
- ▶ In the indirect method of contouring one of the three adapted;

A) Cross Section Method

B) Square or Grid Method

C) Tachometric Method.

Methods of Locating Contours(cont...):

I, Cross Section Method:- is most suitable for preparing contour maps for road works, rail works, canal etc.

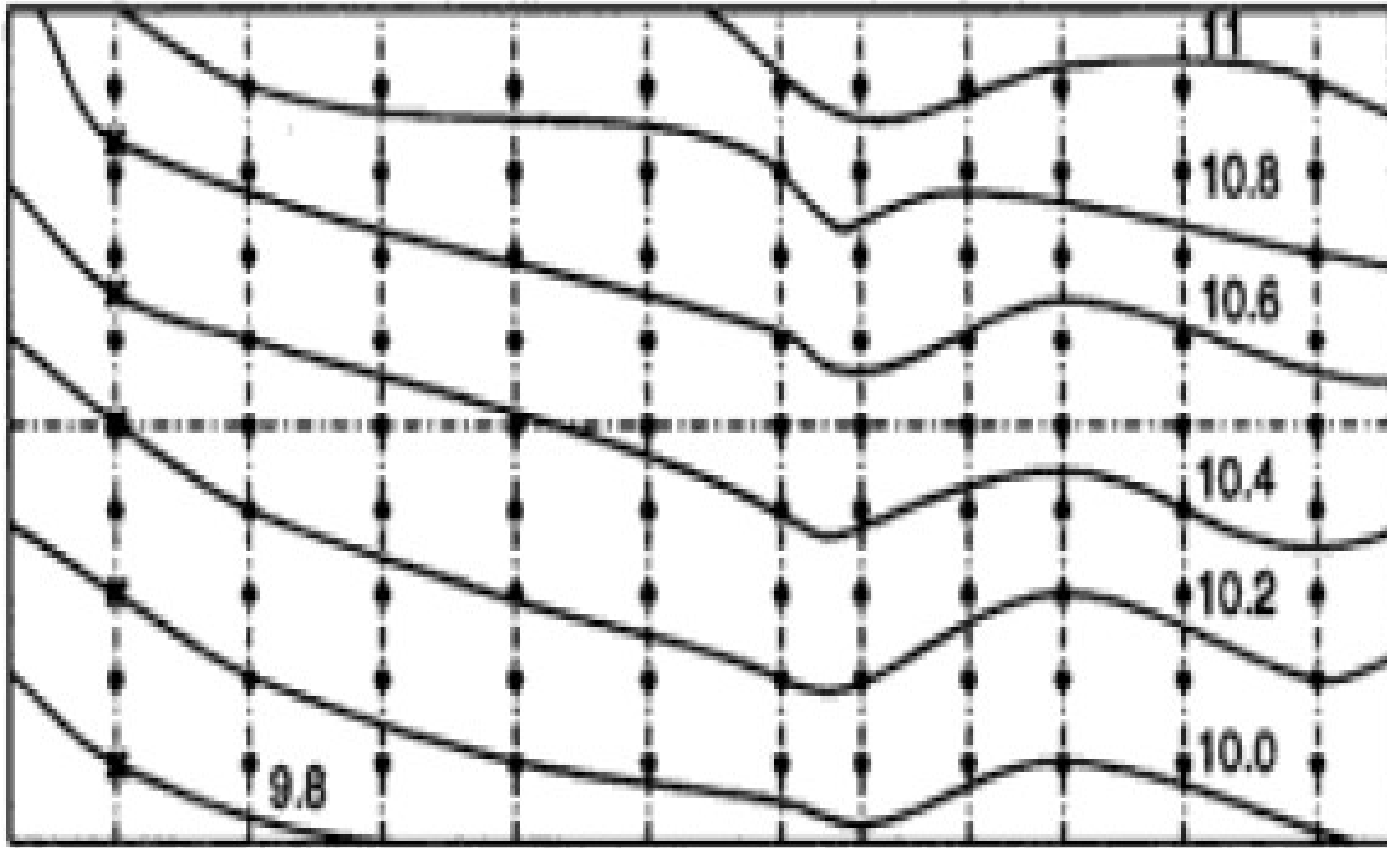
Typically, this type of land has a very long strip but narrow width.

The steps involved are as follows:

- i. The center line of the strip of land is first marked,
- ii. Lines perpendicular to the longitudinal strip are marked & dividing the strip into equal sections,
- iii. The perpendicular lines are divided into equally spaced divisions, thus forming rectangular grids,
- iv. The levels are taken at the intersection of the grid lines to obtain the cross-section profile of the strip of the land,
- v. **Contour map is plotted** in the office by interpolating points of equal elevation based on the levels taken at site.

Methods of Locating Contours(cont...):

Indirect- Cross Section Method;



Methods of Locating Contours(cont...):

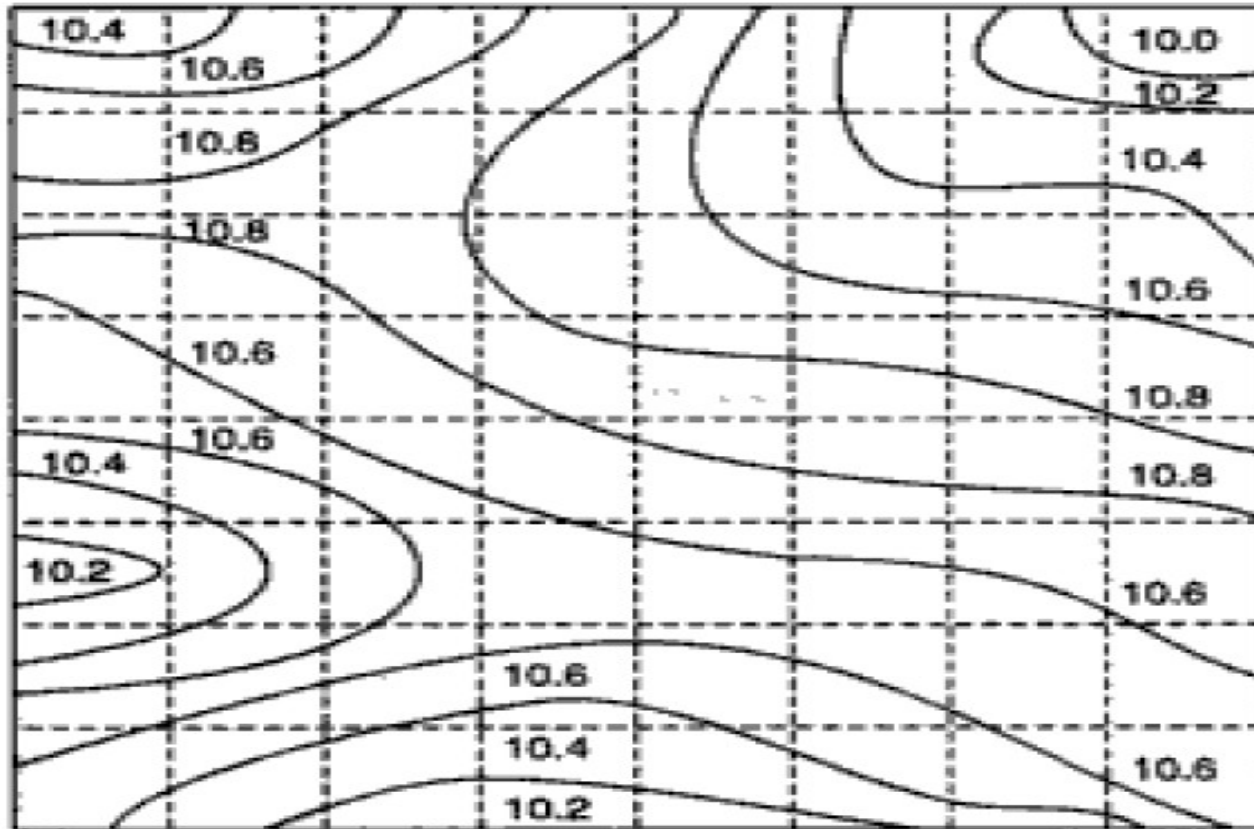
II, Square or Grid Method:- is suitable for contouring of plains or gently sloping grounds.

The steps involved are as follows:

- i. Mark square grids on the land to be surveyed. The grid size would depend on the extent of survey. Generally a 1mx1m grid is selected for small works & the larger grid size for large works,
- ii. Levels are taken at all the corners of the square & the intersection of the diagonal,
- iii. Levels taken on the intersection of the diagonal is used for verification of the interpolation,
- iv. Contour map is plotted in the office by interpolating points of equal elevation based on the levels taken on the corner of the square.

Methods of Locating Contours(cont...):

Indirect- Square or Grid Method;



***Critical high or low spots and slope changes may not occur at grid locations.

Methods of Locating Contours(cont...):

III, Tacheometric Method:- is adopted for contouring of very steep hills.

The steps involved are as follows:

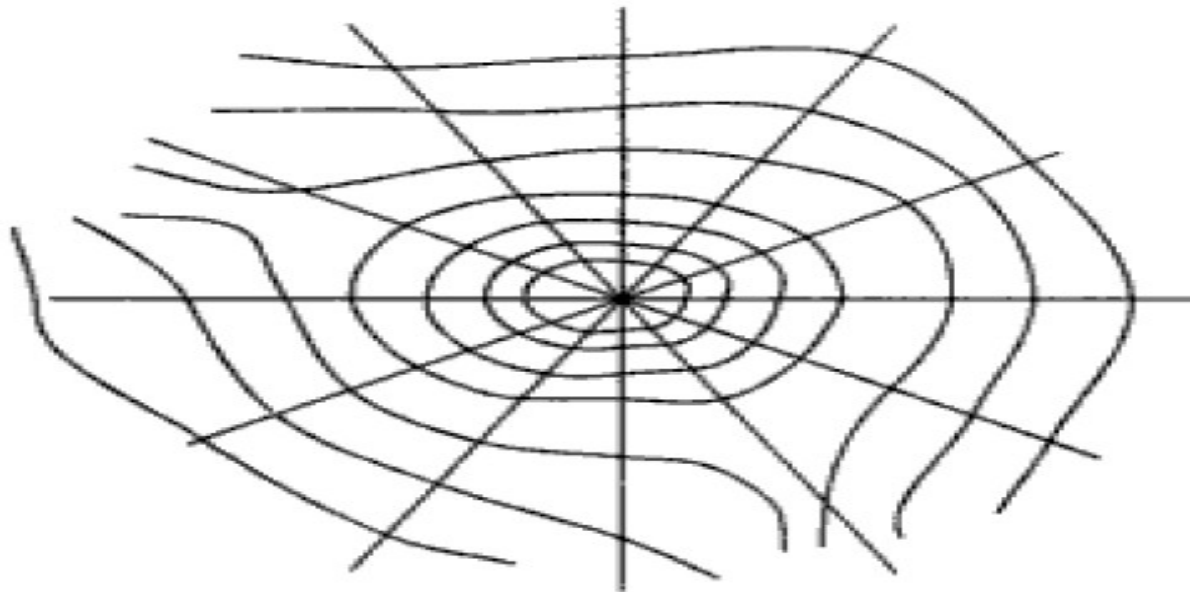
- i. Set up the tacheometer at the top of the steep hill,
- ii. With the help of tacheometer it is possible to determine the horizontal distance of the point from the telescope as well its vertical level,
- iii. The steep hill is surveyed at three levels – the base of the hill, the mid of the hill and the top level of the hill.

Methods of Locating Contours(cont...):

iv. Using the tacheometer reading are taken all around the hill

at equal angular interval on all these three levels.

vi. The radial plot thus obtained is worked in the office to in
map



***We may miss necessary data between radiating lines.

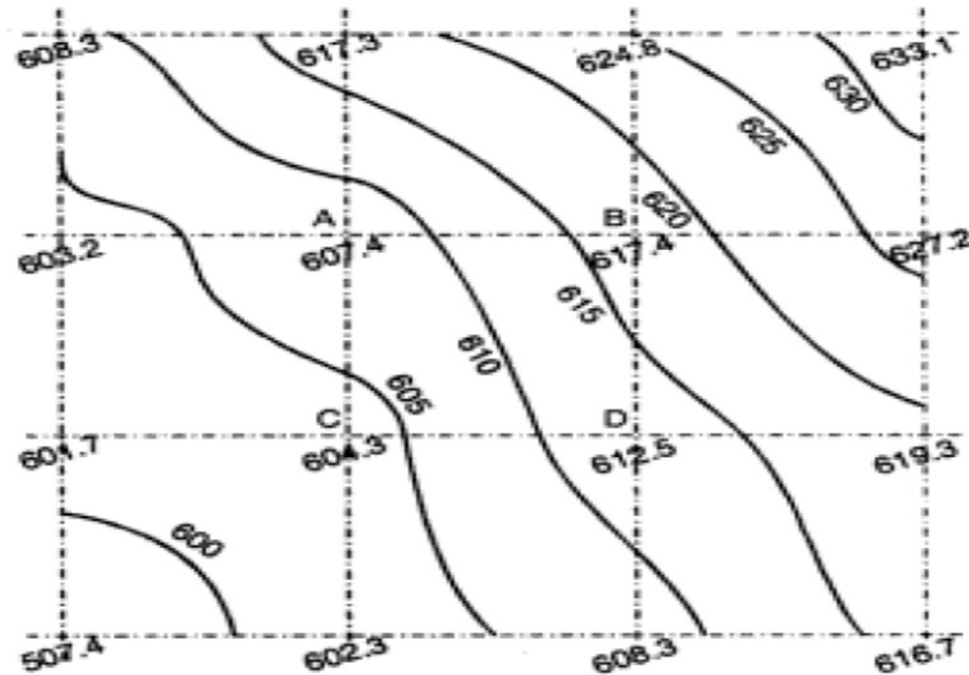
Methods of Locating Contours(cont...):

- ▶ Comparing Direct and Indirect Method of Contouring;

S N o	Direct Method	Indirect Method
1	Very tedious	Not tedious
2	Accurate	Less accurate
3	Slow	Fast
4	Requires more resources	Requires less resources
5	Suitable for contouring of small area	Suitable for contouring of large area
6	Points are physically located on the ground	Points are interpolated in the office

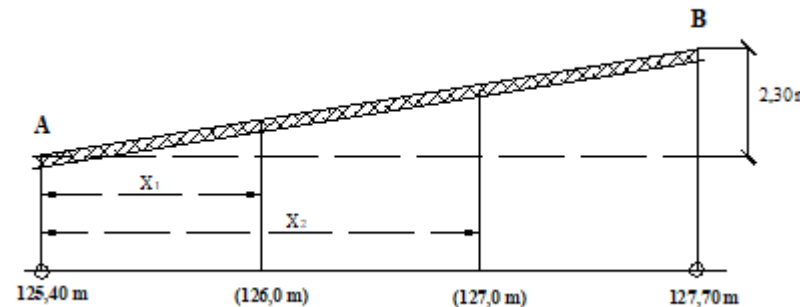
INTERPOLATION OF CONTOURS:

- a) By Estimation
- b) By Arithmetic Calculations
- c) By Graphical Method



INTERPOLATION OF CONTOURS(CONT....):

- a) **Estimation:** Here the positions of contour points between the guide points are located by estimation based on experience and judgment.
- b) **Direct/Arithmetic Calculation:** The intervening horizontal distance between the guide points is measured and contour points are located by arithmetic calculations using theory of proportion



$$X1: (126.0 - 125.4) = \frac{24.0}{2.30} \times 0.6$$

$$X1 = \underline{6.26 \text{ m}}$$

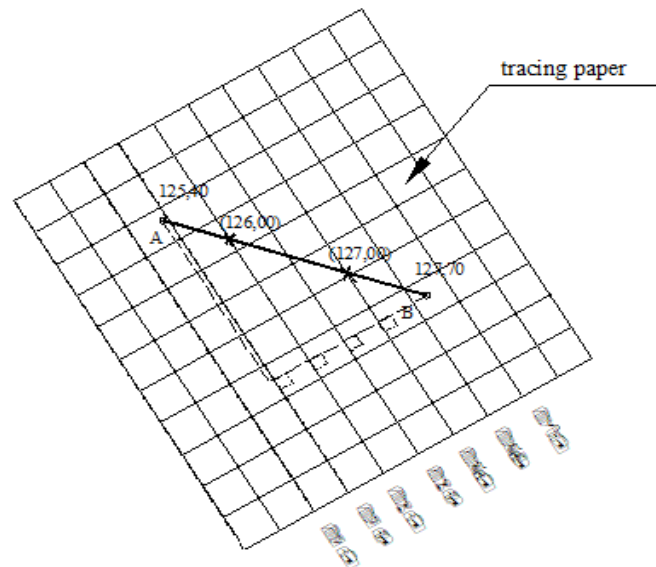
$$X2: (127.0 - 125.4) = \frac{24.0}{2.30} \times 1.6$$

$$X2 = \underline{16.70 \text{ m}}$$

INTERPOLATION OF CONTOURS(CONT....):

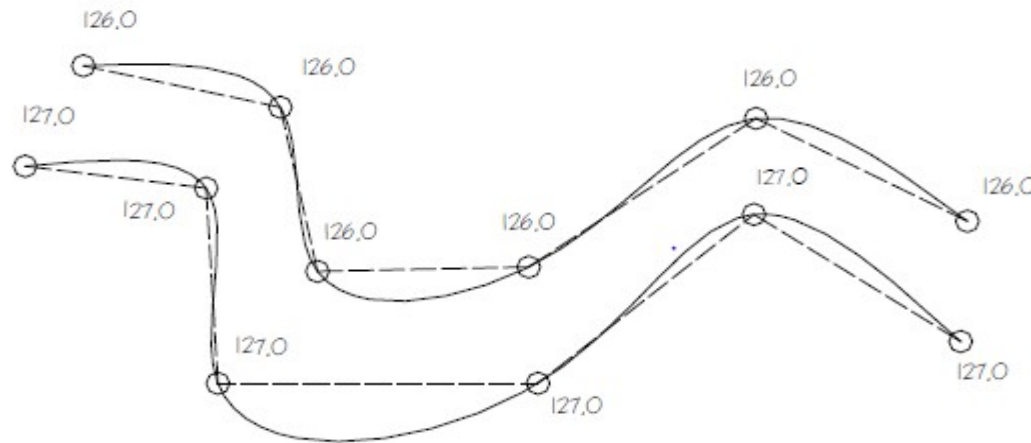
c) Graphical Method: with this interpolation method the work is done very quickly and also quite accurate, some practice provided. A sheet of tracing paper is needed on which parallel lines are drawn to represent the desired contour interval.

The distance between two parallel lines on the tracing paper must be chosen that way, that the distance, perpendicular to the parallel lines on the tracing paper, is equal to the contour interval. The distance between point A and point B is divided into equal parts, and the perpendicular distance between two parallel lines is chosen that way, that the distance, perpendicular to the parallel lines on the tracing paper, is equal to the contour interval.



Sketching of Contour Lines:

- ▶ After locating the points of various contour lines as, the contours can be sketched. To see clearly the course of each contour, the points of same elevation are joined with straight lines.
- ▶ Then, the points of same elevation are connected with a smooth curve. This is best accomplished by using *French curves*.
- ▶ It is positioned on the paper to pass through as many points as possible and a portion of the curve is drawn. The French curve is then repositioned for drawing another portion of the contour.



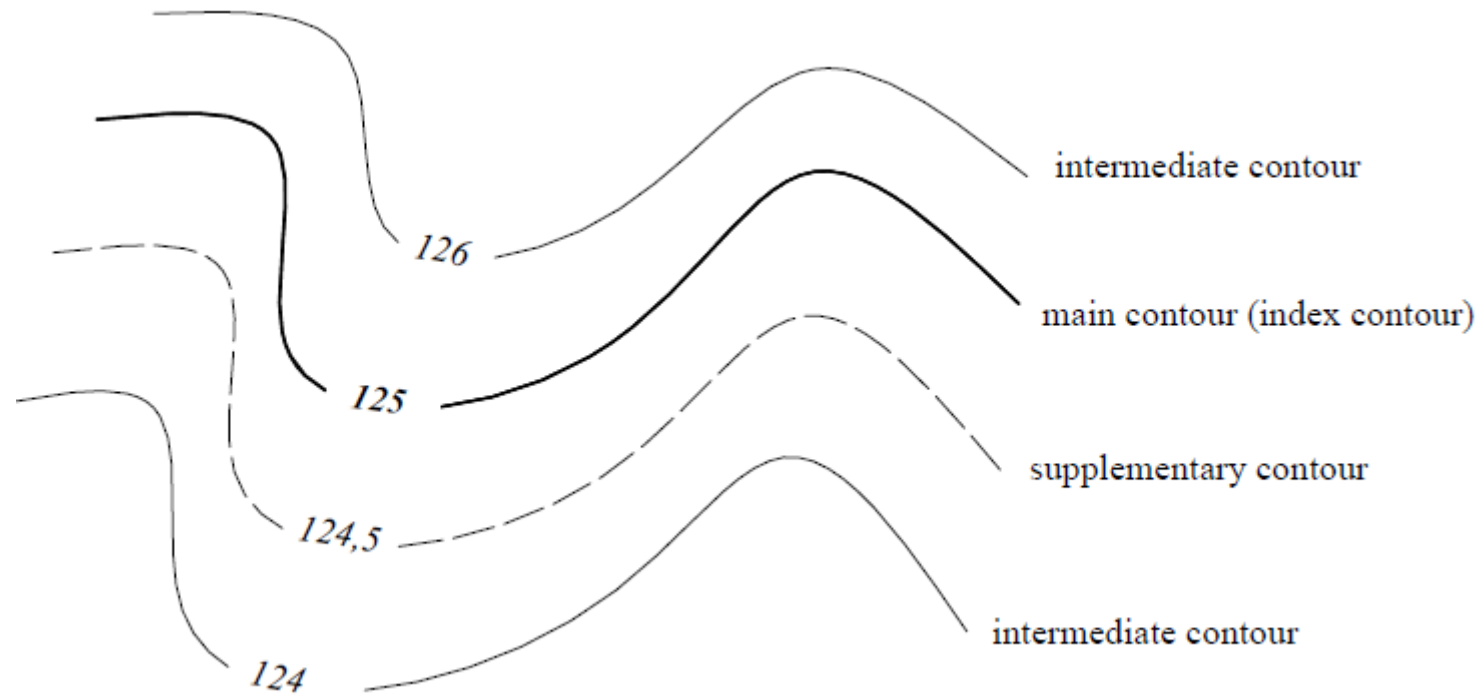
*****While sketching the contours one should always remember the characteristics of contours.**

Labeling of Contour Lines:

Some basic rules:

- Intermediate contour lines are drawn with a **continuous line**.
- An *index contour line* is a main contour line that helps the map user to quickly interpret the height situation portrayed on the map. It is drawn with a **continuous line of thicker width**.
- All other contour lines are drawn with a dashed line of the same width as the intermediate contour lines. They are called *supplementary contour lines*.
- A small gap is left for writing the elevation.
- The elevation of a contour should be so written that the foot of the text shows *towards the lowest point*.
- The amount and the location of elevation labels should be so selected, that the map will have a neat appearance.

Labeling of Contour Lines(cont...):



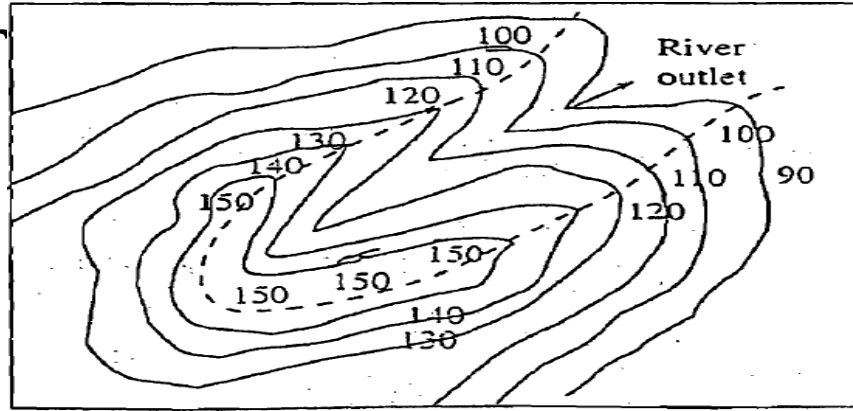
USES OF CONTOURS:

Contour maps are very useful since they provide valuable information about the terrain. Some of the uses are as follows;

- I. The nature of the ground and its slope can be estimated.
- II. Earth work can be estimated for civil engineering projects like road works, railway, canals, dams etc.
- III. It is possible to identify suitable site for any project from the contour map of the region.
- IV. Inter-visibility of points can be ascertained using contour map. This is most useful for locating communication towers.
- V. Military uses contour maps for strategic planning.

USES OF CONTOURS(cont...):

VI. *Determination of catchment area* . A study of the contour enables us to calculate the catchment area of a river.



VII. *Estimation of reservoir capacity* . From a study of a dam, the capacity of the reservoir can be estimated.

