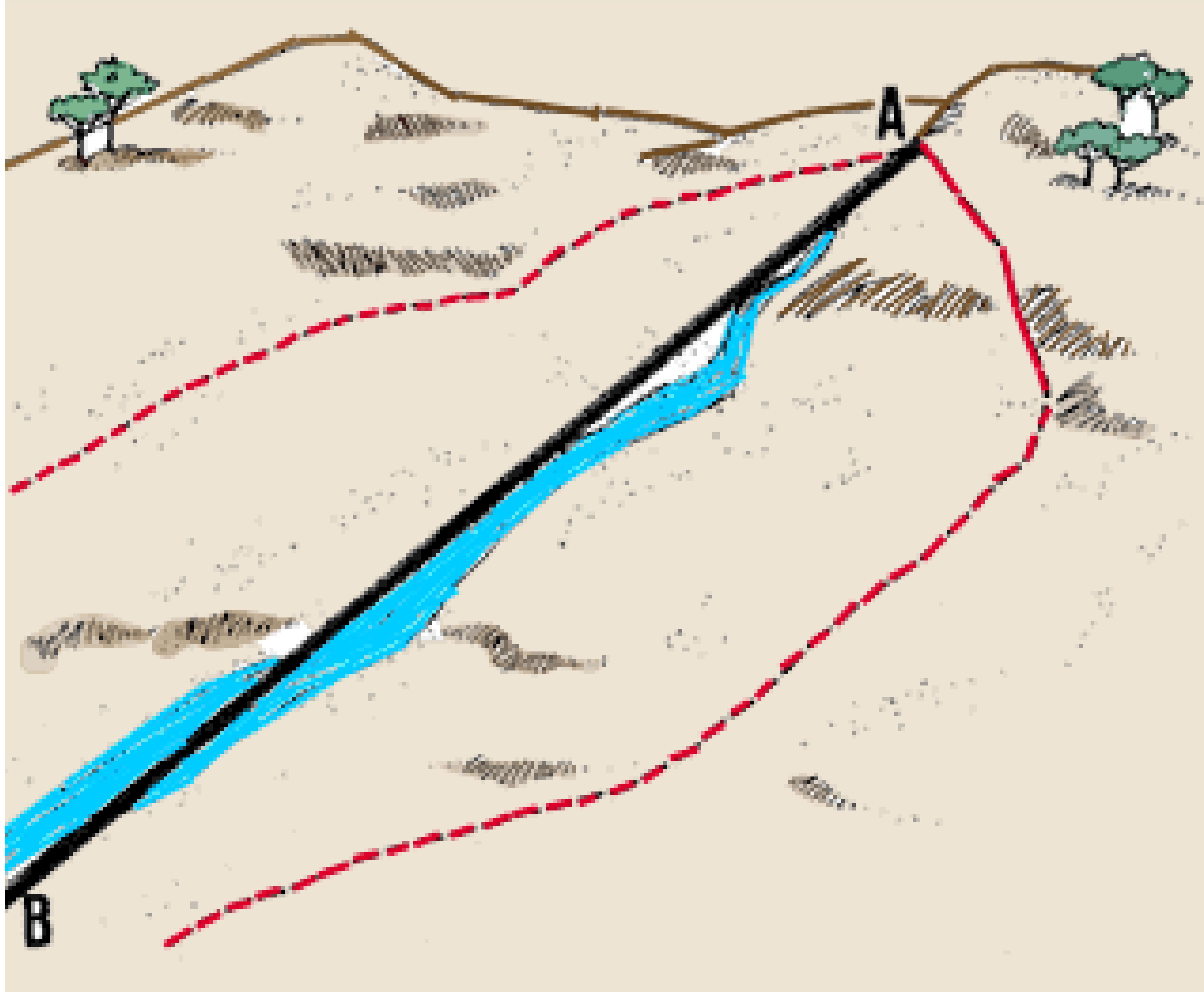
Application of Levelling

Ibrahim Almohanna, 2019

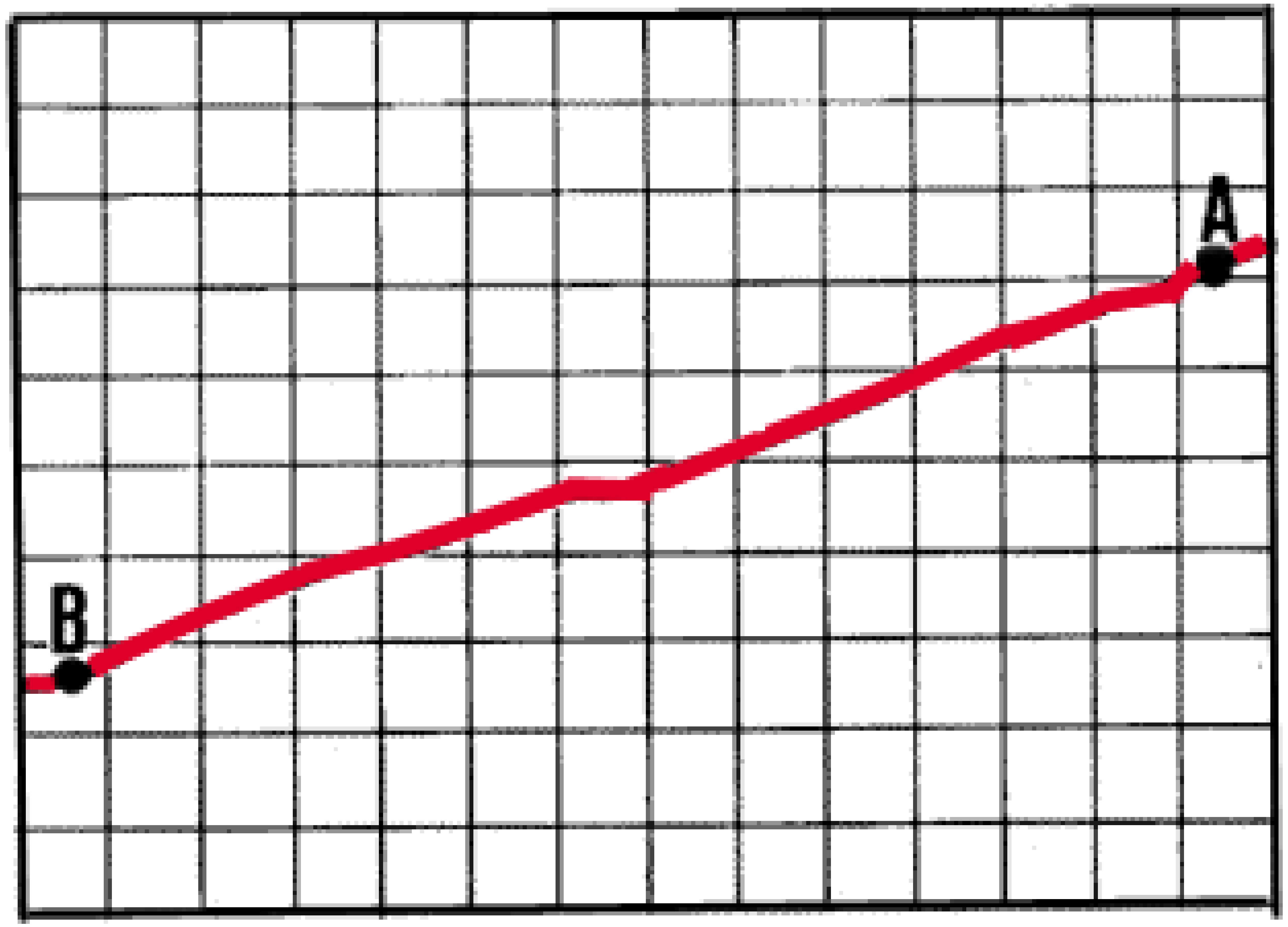
1- Profile Levelling

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 centre-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.



1- Profile Levelling

You will usually transfer the measurements you obtain during profile levelling onto paper, to make a kind of diagram or picture called a graph . This will show changes in elevation, and how they are related to horizontal distances. This kind of graph is called a **ground profile** or **Longitudinal Section**.



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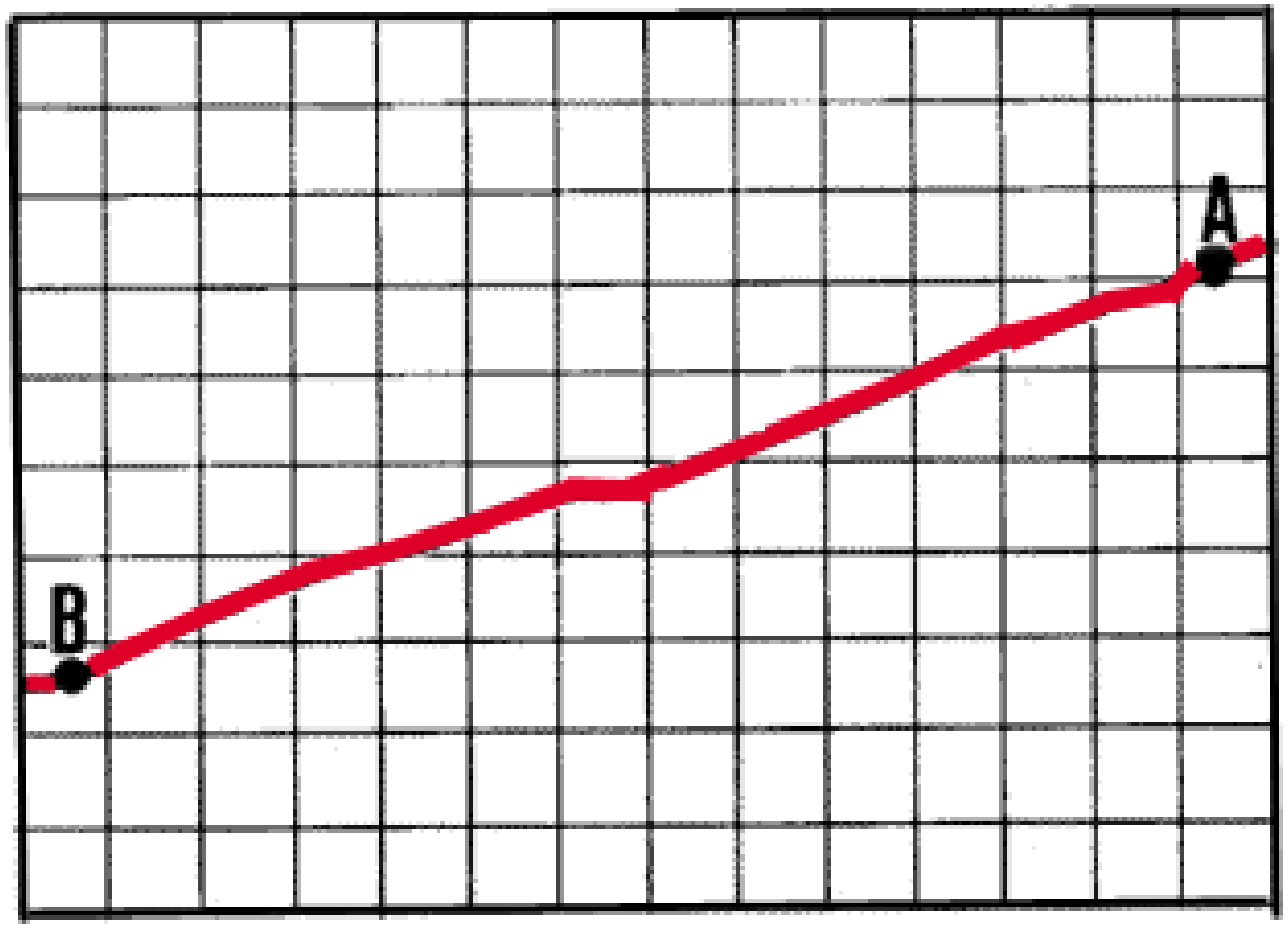
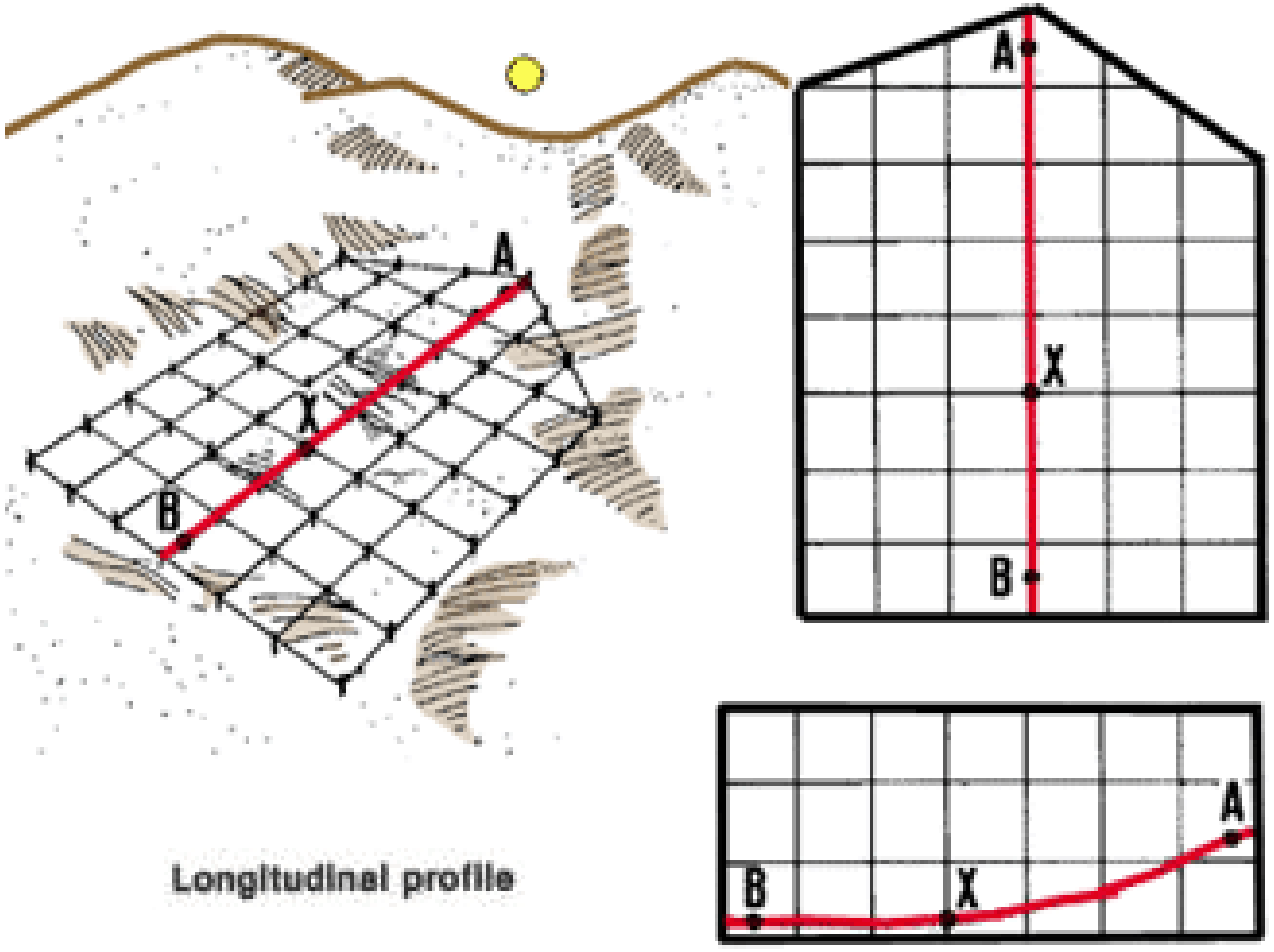
1- Profile Levelling

- When you profile level, you are determining a series of elevations of points which are located at short measured intervals along a fixed line . These elevations determine the profile of the line.



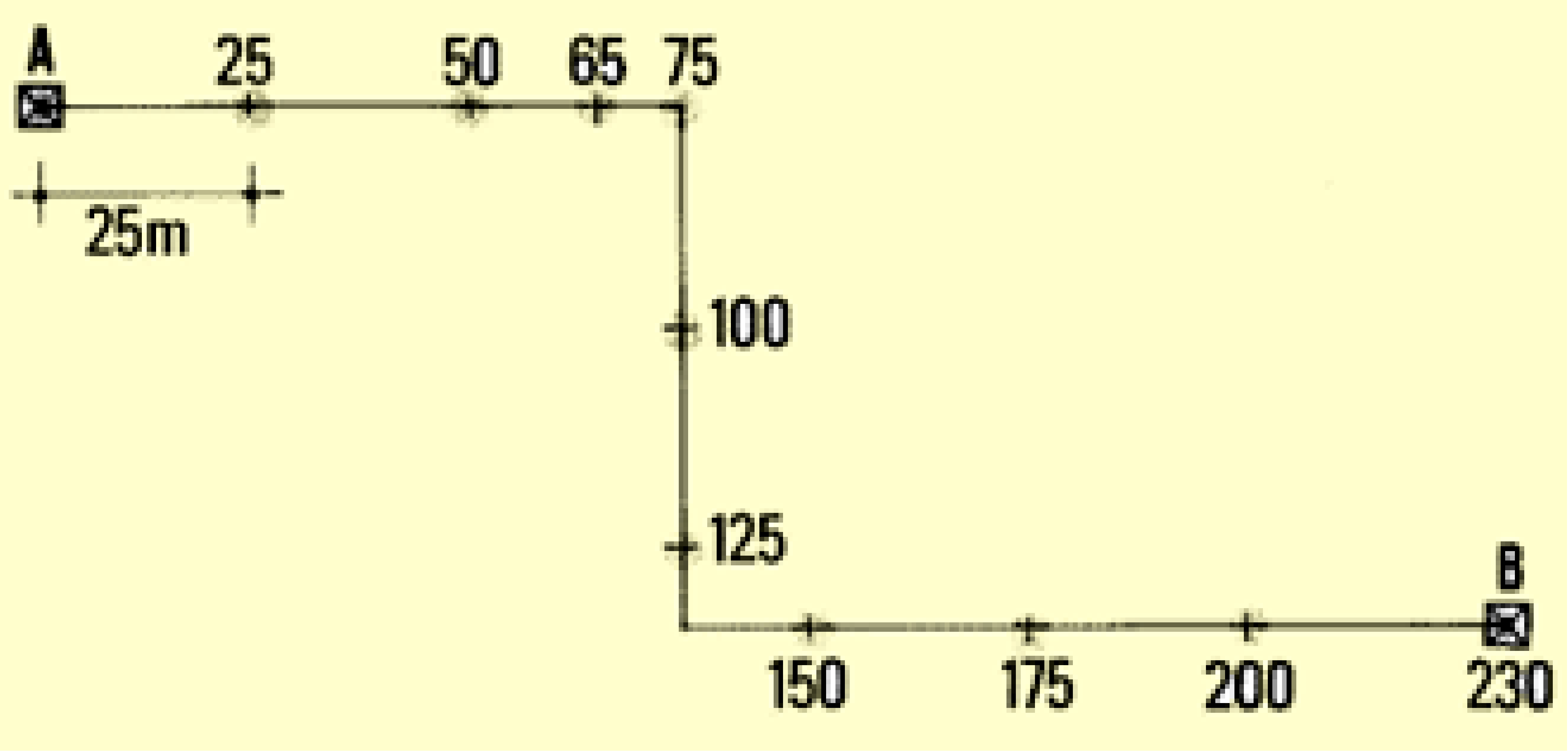
1- Profile Levelling

- You survey longitudinal profiles by profile levelling along a line which is the main axis of the survey. This can be the centre-line of a water canal or the base line of a square grid.



Longitudinal profile Levelling

- You need to survey line AB, the centre-line of a water canal. You decide to make a radiating survey using a sighting level. Measure horizontal distances and mark every 25 m of the line with a stake, from its initial to its final point. Add points between the stakes where there are marked changes of slope . On each stake, clearly indicate its distance from the initial point A, that is, the cumulated distance.



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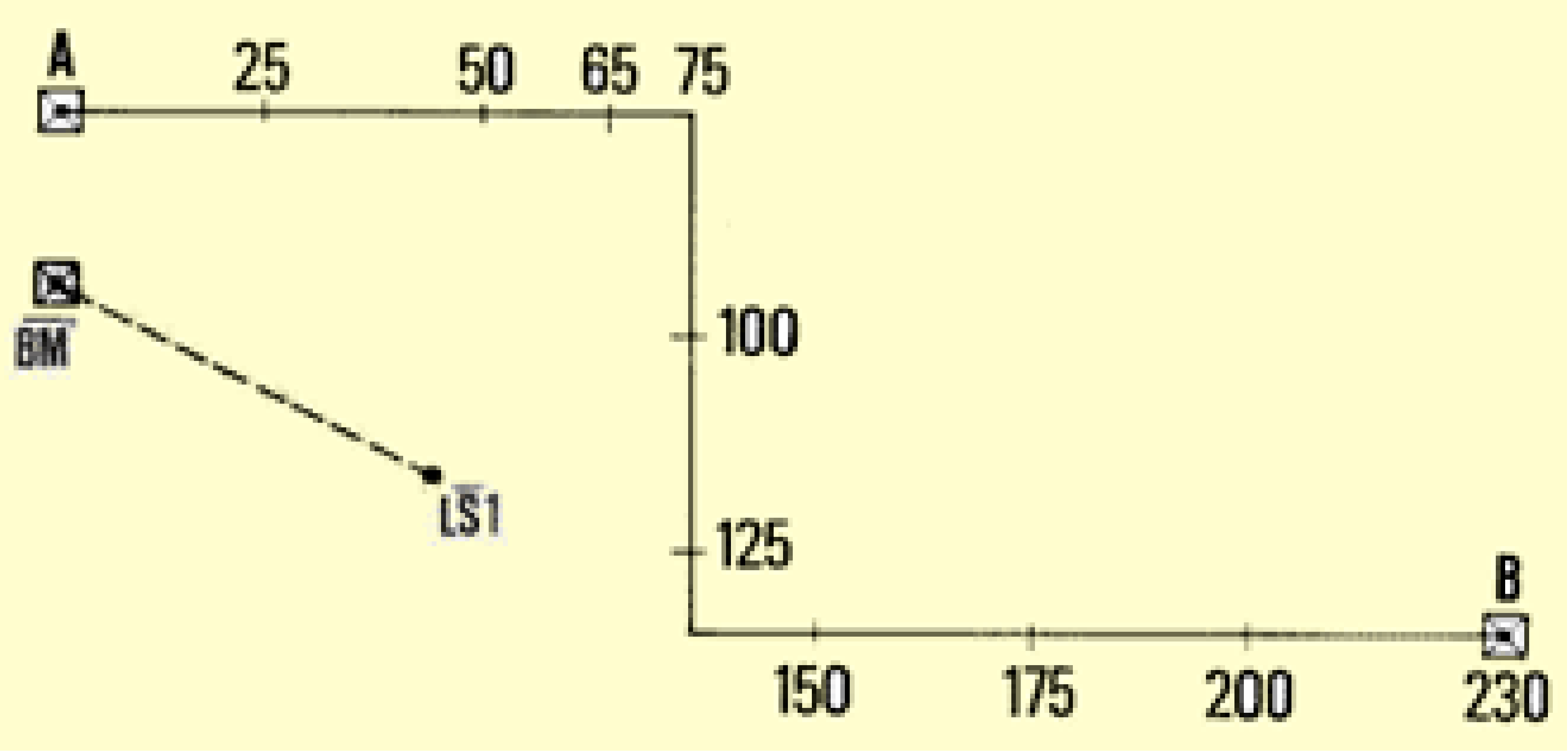
Longitudinal profile Levelling

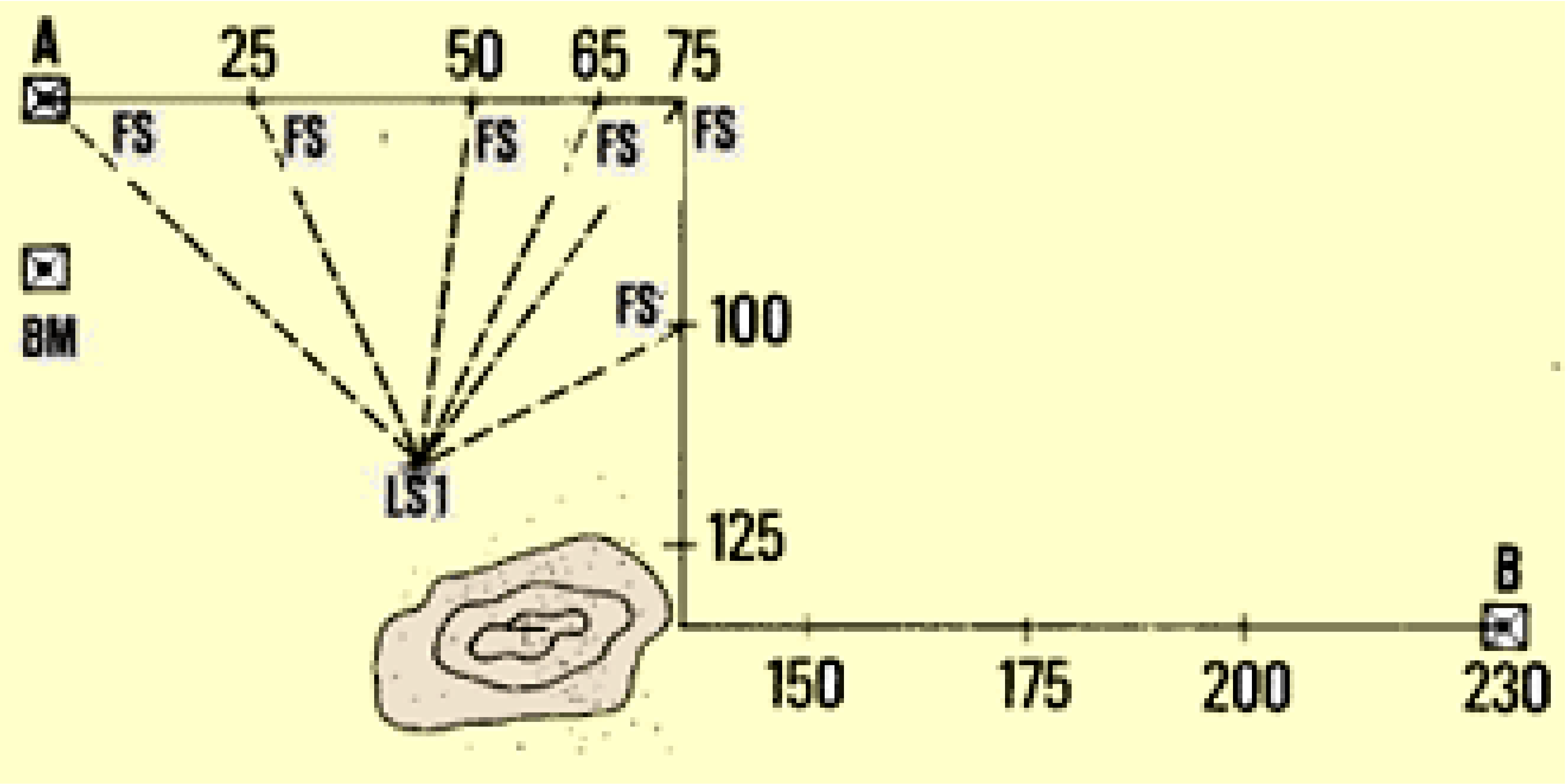
- Set up your level at LS1. Take a backsight BS on a bench-mark of elevation E(BM) to determine the height of the instrument

- HI = BS + E(BM)



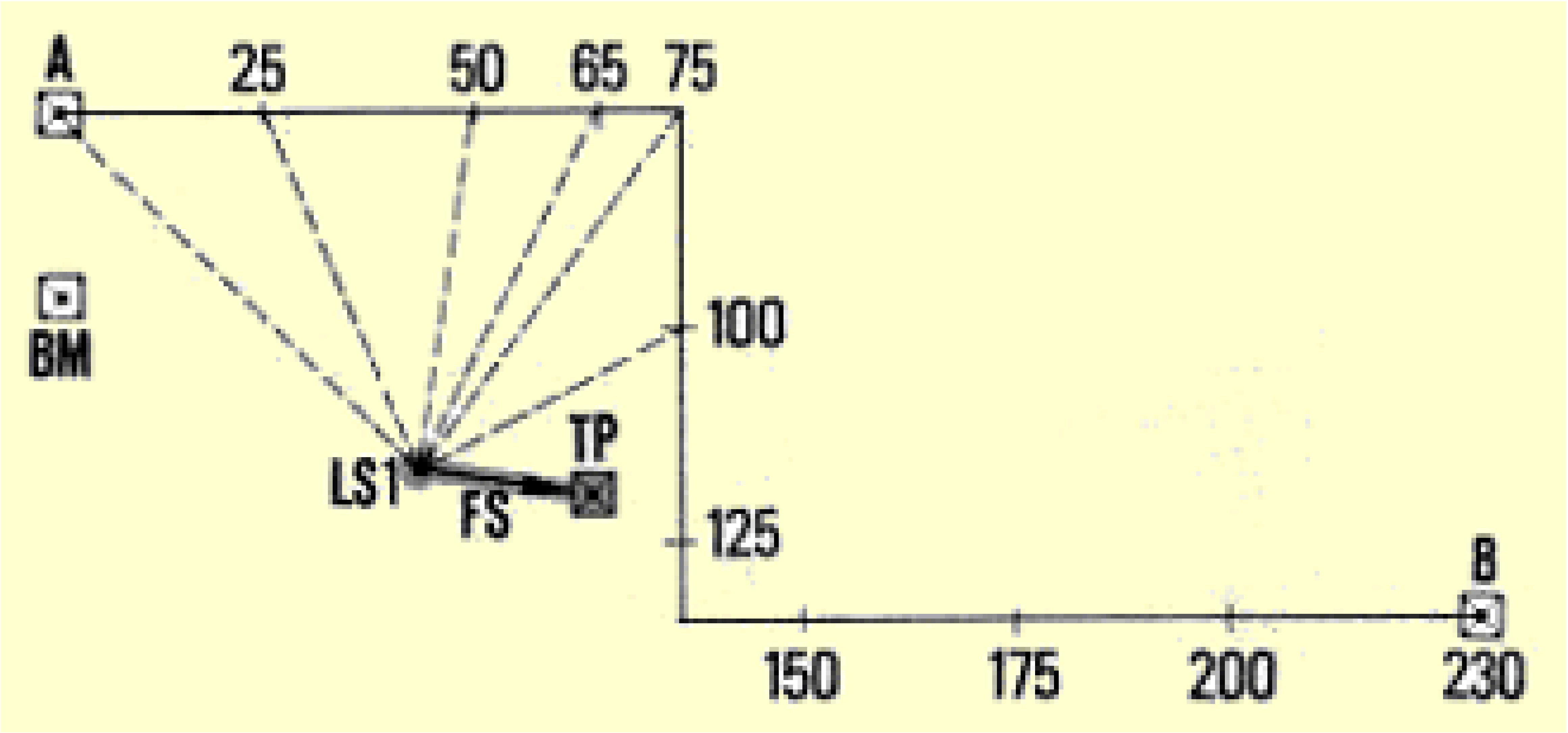
Longitudinal profile Levelling

- From levelling station LS1, read foresights FS on as many points (for example, six) of line AB as possible, starting from the initial point A.



Longitudinal profile Levelling

- 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.



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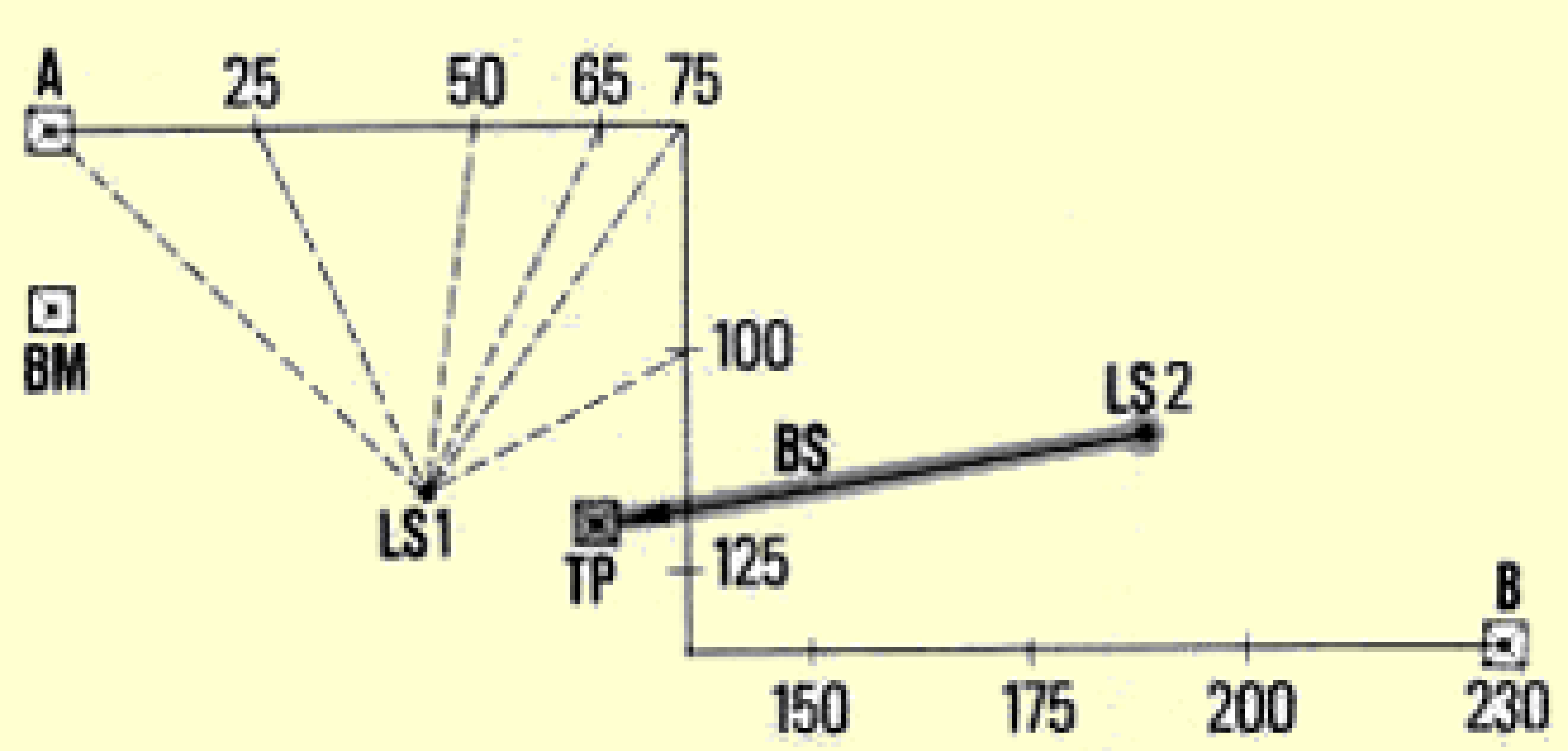
Longitudinal profile Levelling

- 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



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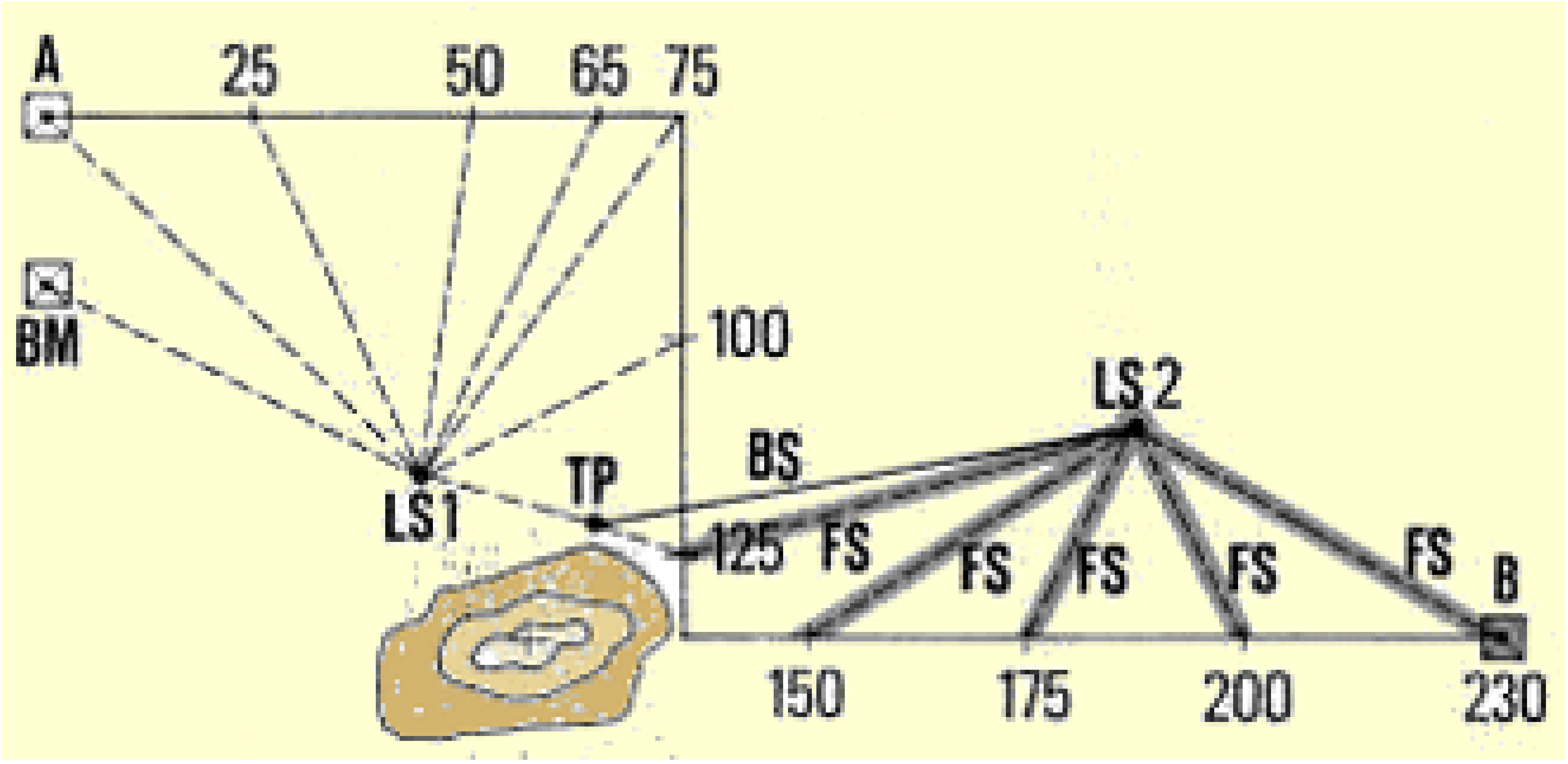
Longitudinal profile Levelling

- Note down all your measurements in a field book, using a table similar to the ones you have used with other methods. Find the elevations of the points (except for the turning point) by subtracting each FS from its corresponding HI. In the example of the table shown here, cumulated horizontal distances (in metres) appear as point numbers 00, 25, 50, 65,etc. in the first column.



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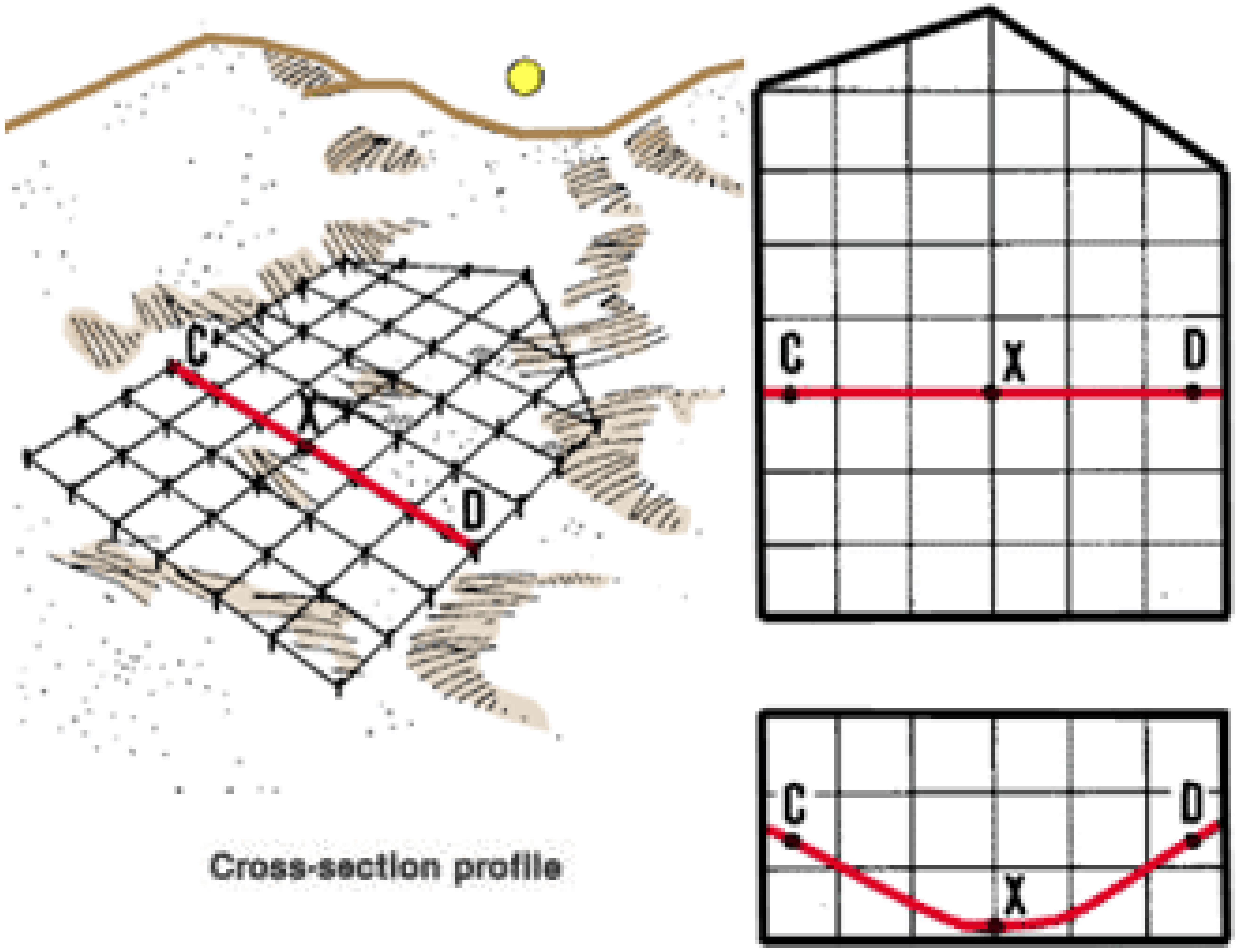
Example

Longitudinal profile levelling with a sighting level in a radiating survey

Points(m)	BS	HI	FS	Elevation(m)	Remarks
BM	**1.37**	**2.87**	-	**1.50**	**Nail at foot of tree stump**
00	-	**2.87**	**1.53**	**1.34**	**Beginning of canal**
25	-	**2.87**	**1.67**	**1.20**	
50	-	**2.87**	**1.73**	**1.14**	
65	-	**2.87**	**1.90**	**0.97**	**Marked change of slope**
75	-	**2.87**	**2.05**	**0.82**	
100	-	**2.87**	**2.22**	**0.65**	
TP	**1.80**	**3.07**	**1.60**	**1.27**	**On stone**
125	-	**3.07**	**2.27**	**0.80**	
150	-	**3.07**	**2.37**	**0.70**	
175	-	**3.07**	**2.57**	**0.50**	
200	-	**3.07**	**2.77**	**0.30**	
230	-	**3.07**	**3.00**	**0.07**	**End of canal**

2-Cross-Section Levelling

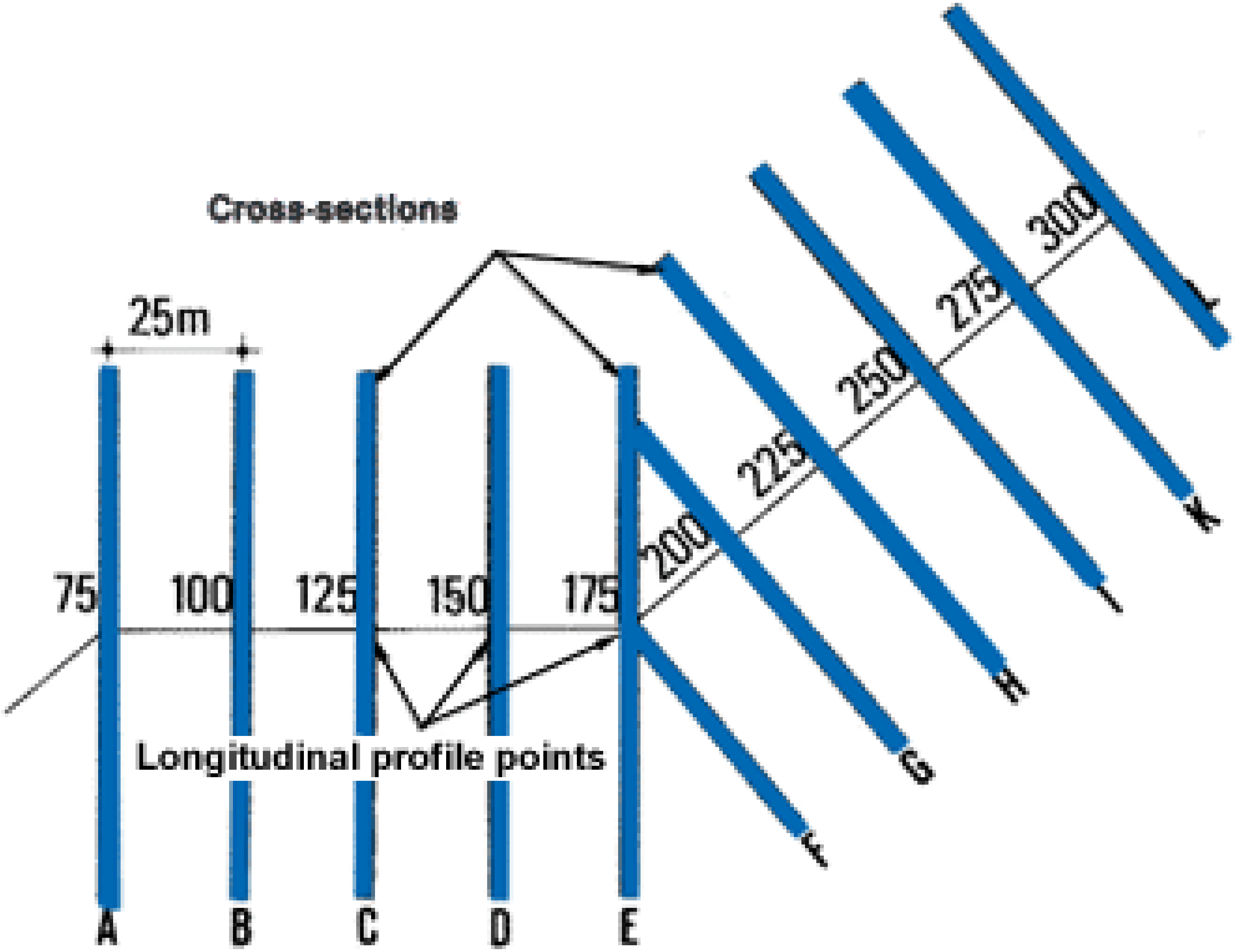
•You usually survey cross-section profiles along a line which is perpendicular to a surveyed longitudinal profile, using its points of known elevation as bench-marks. Cross-sections of valleys are useful in helping you locate a good fish-farm site. On a smaller scale, you can also survey cross-sections for water-supply canals, for dam construction, and for pond construction



Cross-section profile

2-Cross-Section Levelling

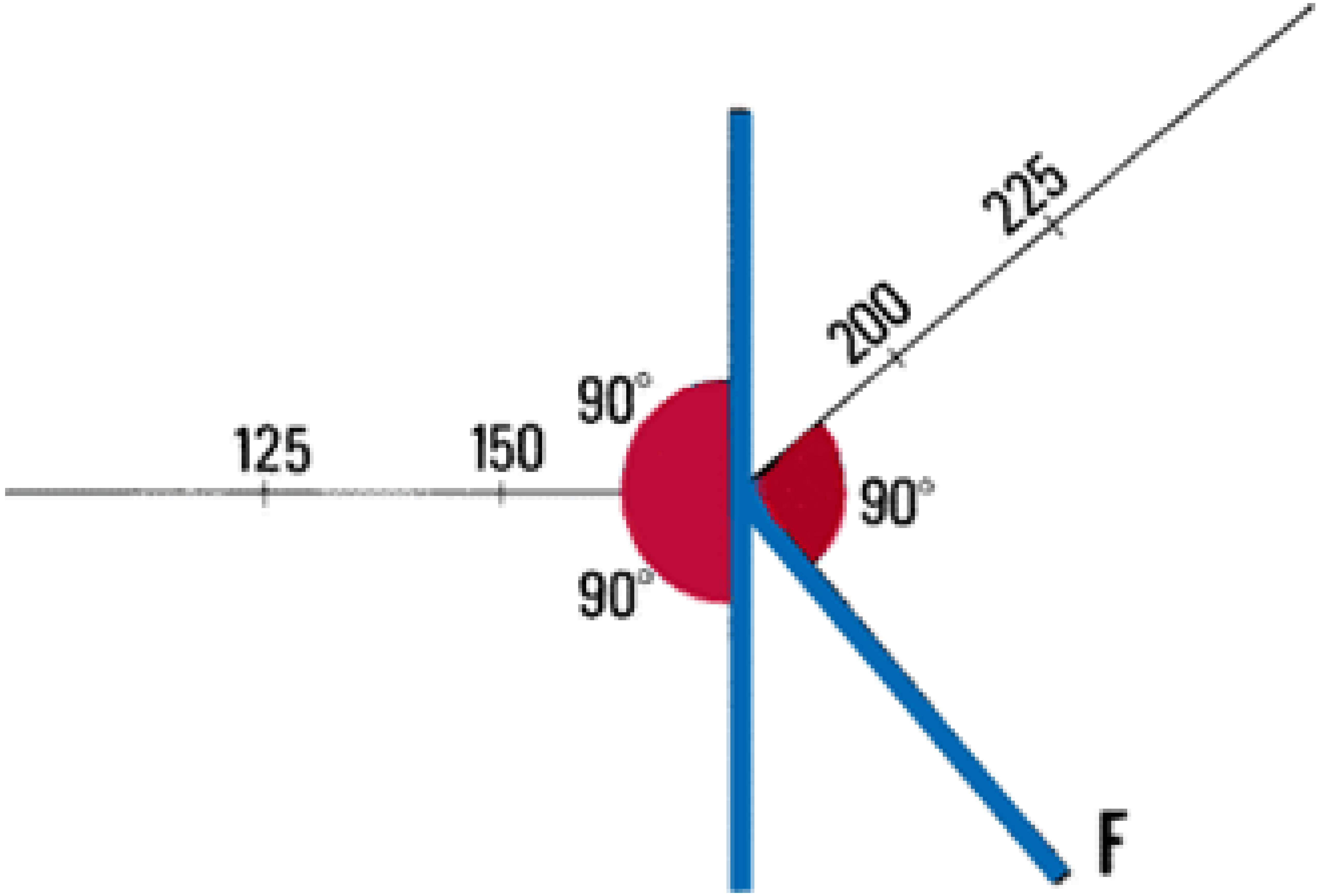
After you have found the elevations of points along a longitudinal profile, you can proceed with the survey of perpendicular cross-sections . These cross-sections can pass through as many of the points as necessary. Cross-sections are commonly used for contouring long, narrow stretches of land



2-Cross-Section Levelling

- You will need to have more information on some of the longitudinal profile points. Choose these points and mark them. Then, set out and mark perpendicular lines at these points ,and extend these perpendiculars on both sides of the traverse as far as you need to. In this type of levelling, such perpendiculars are called the cross-section lines.

- at points where the traverse changes direction (for example, at point 175 in the drawing), you should set out two perpendicular lines E and F; each line will be perpendicular to one of the traverse sections



2-Cross-Section Levelling

- You identify each cross-section line by the number of the traverse point of known elevation. To do this, identify the surveyed points along each cross-section line according to whether hey are to the left or the right of the traverse . Also use their distance (in metres) from the traverse points as identification. The following example is of field notes and calculations for a radiating survey, where each cross-section was surveyed from a single levelling station

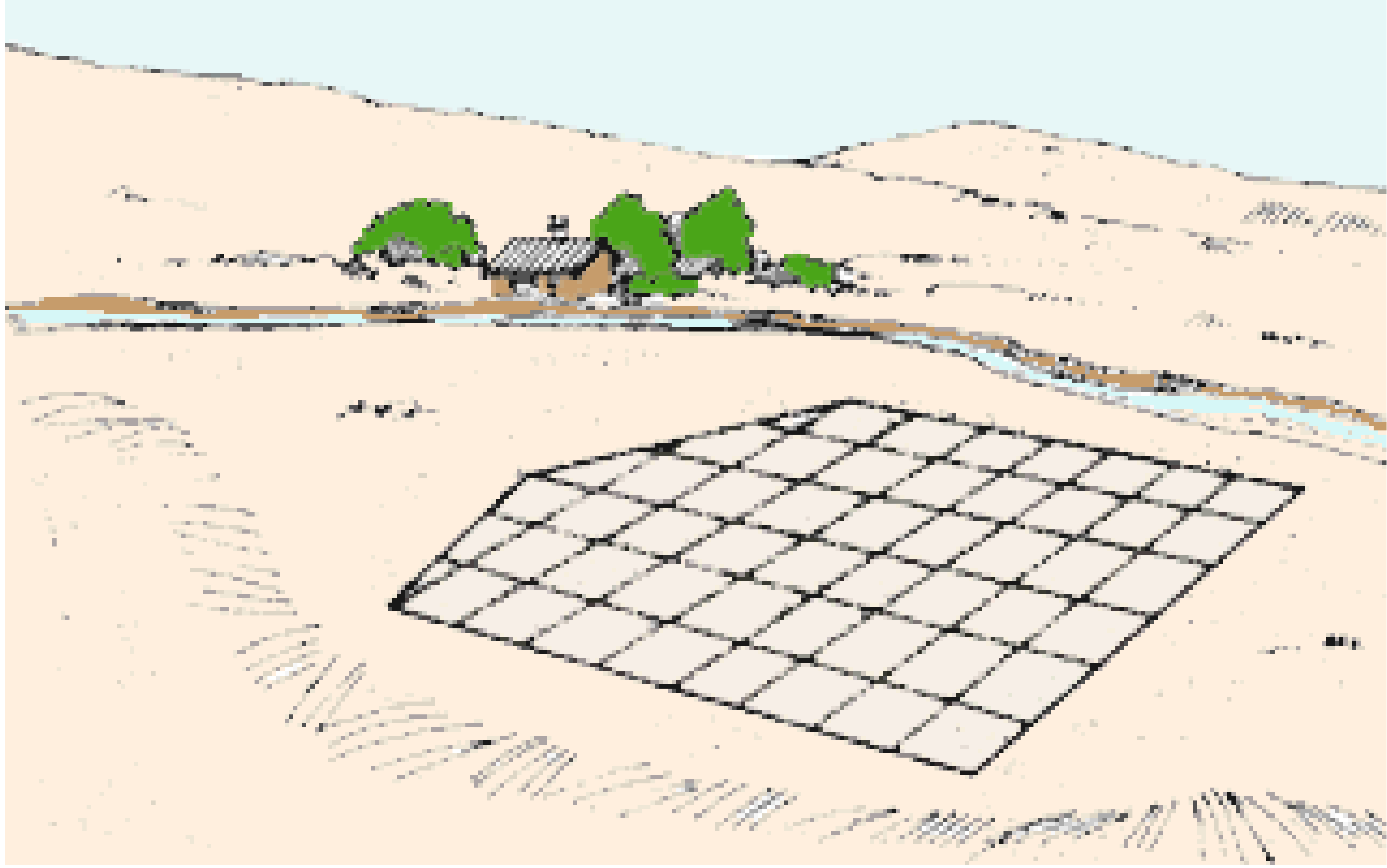
Cross-section profile leveling by radiating

Traverse Point	Point		BS(m)	HI(m)	FS(m)	Elevation(m)	Remarks
	Left	Right					
50	...	...	...	...	...	...	
75	-	-	0.54	40.94	-	40.40	Edge of existing path
	10	-		40.94	1.09	39.85	
	18	-		40.94	1.15	39.79	
	-	9		40.94	0.85	40.09	
	-	16		40.94	0.68	40.26	
100	-	-	1.15	38.96	-	37.81	Edge of maize field
	8	-		38.96	1.23	37.73	
	-	4		38.96	1.11	37.85	
	-	16		38.96	0.78	38.18	
125	-	-	0.97	36.64	-	35.67	Edge of small forest
	5	-		36.64	1.12	35.52	
	20	-		36.64	1.55	35.09	
	-	14		36.64	1.03	35.61	
		25		36.64	0.89	35.75	
150	...	...	...	...	...	...	

3- Square Grid Levelling

- The square-grid method is particularly useful for surveying small land areas with little vegetation. In large areas with high vegetation or forests, the method is not as easy or practical. To use the method, you will lay out squares in the area you are surveying, and determine the elevation of each square corner.

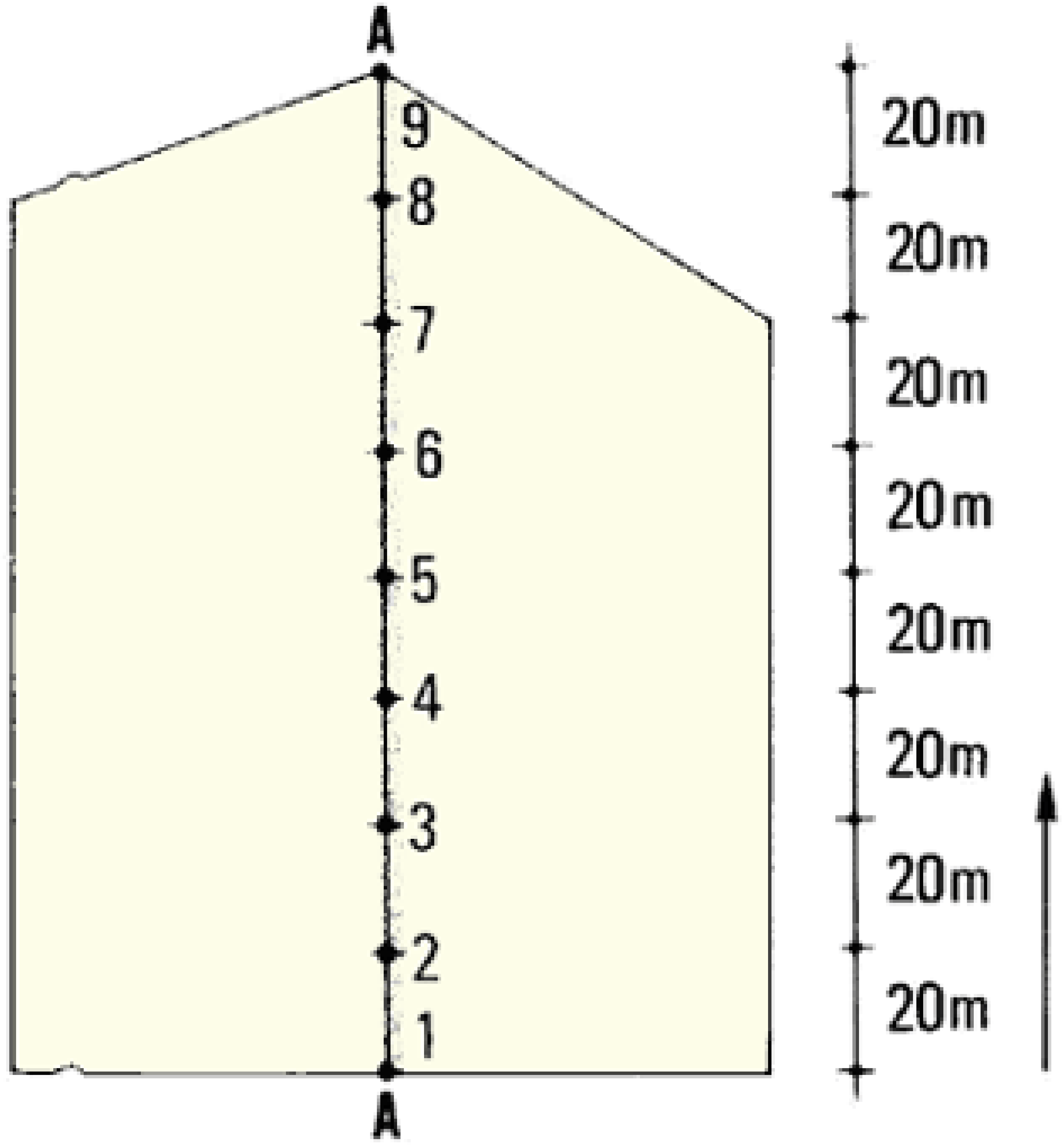
- The size of the squares you lay out depends on the accuracy you need. For greater accuracy, the sides of the squares should be 10 to 20 m long. For reconnaissance surveys, where you do not need to be as accurate, the sides of the squares can be 30 to 50 m long.



3- Square Grid Levelling

- In the field choose base line AA and clearly mark it with ranging poles. This base line should preferably be located at the centre of the site, and it should be parallel to the longest side of the site. When you work with a compass, you may find that it helps to orient this base line following the north-south direction.

- Working uphill, chain along this baseline from the perimeter of the area, and set stakes at intervals equal to the size you have chosen for the squares, such as 20 m. Clearly number these stakes 1, 2,3, . . . n.



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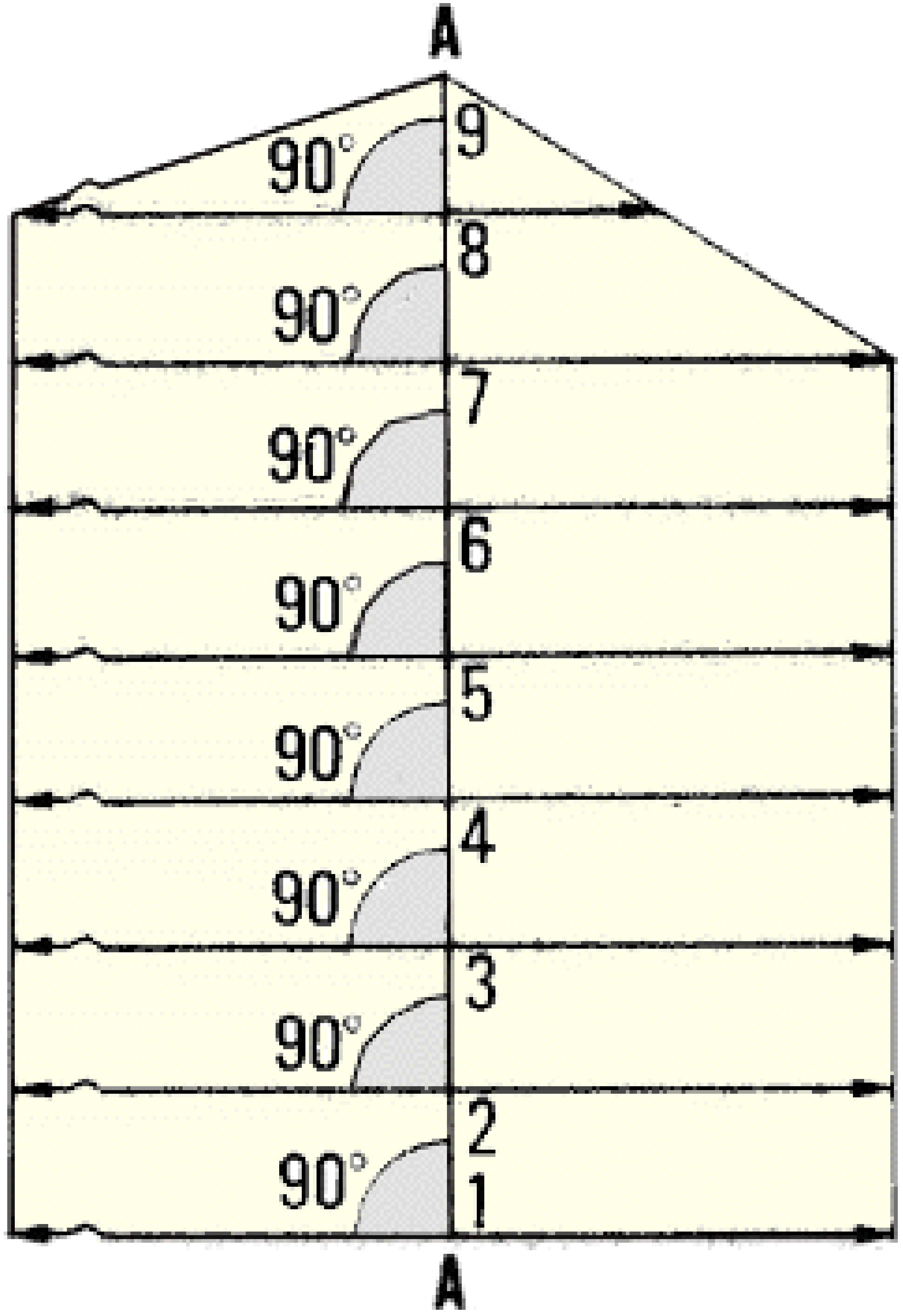
3- Square Grid Levelling

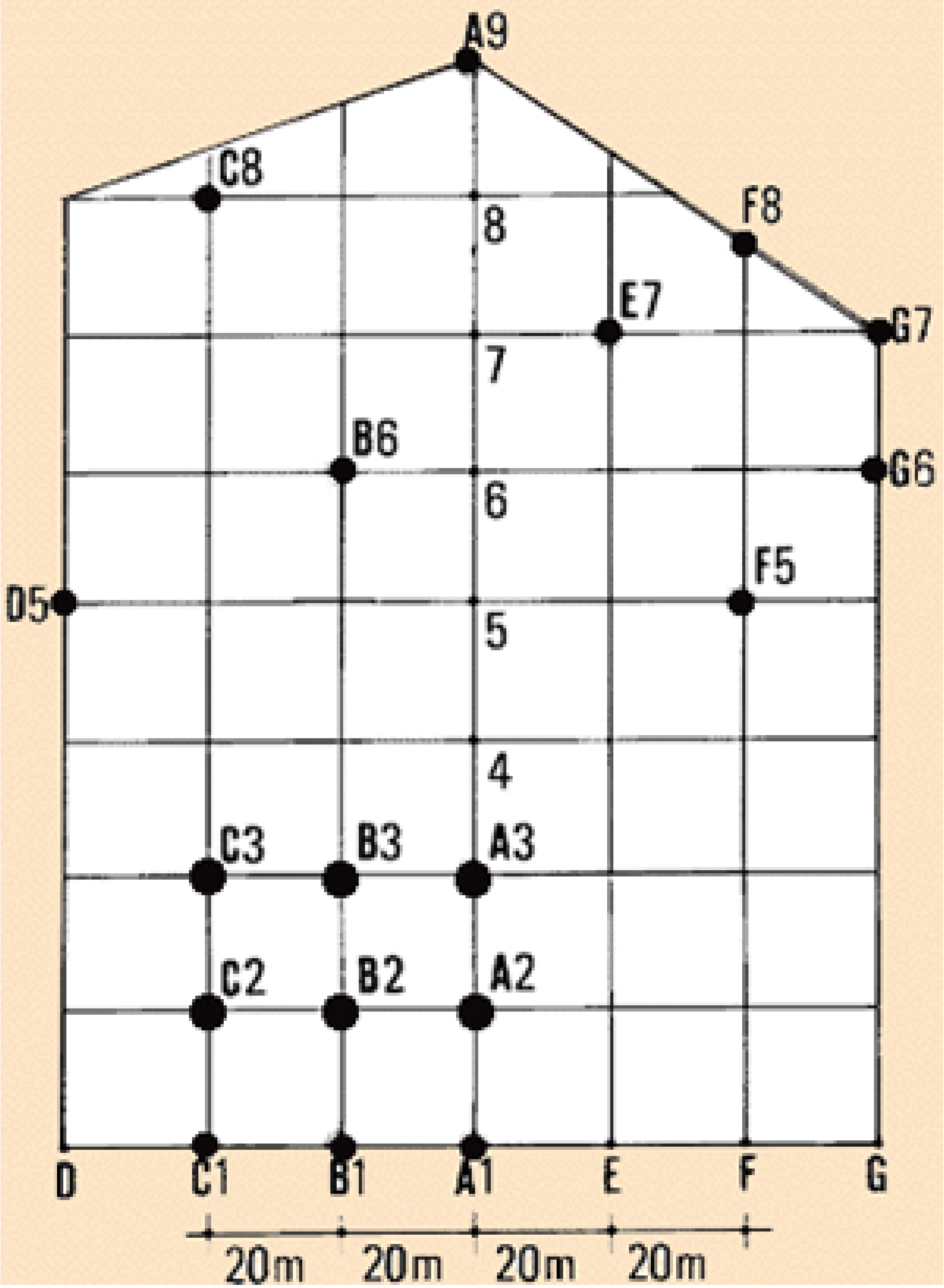
- From each of these stakes, lay out a line, perpendicular to the base line , that runs all the way across the site.



3- Square Grid Levelling

- Proceed by chaining along the entire length of each of these perpendiculars, on either side of the base line . Set a stake every 20 m (the selected square size).Identify each of these stakes by:

- •a letter (A, B, C, etc.) which refers to the line, running parallel to the base line, to which the point belongs;
- •a number (1, 2, 3.... n) which refers to the perpendicular, laid out from the base line, to which the point belongs.



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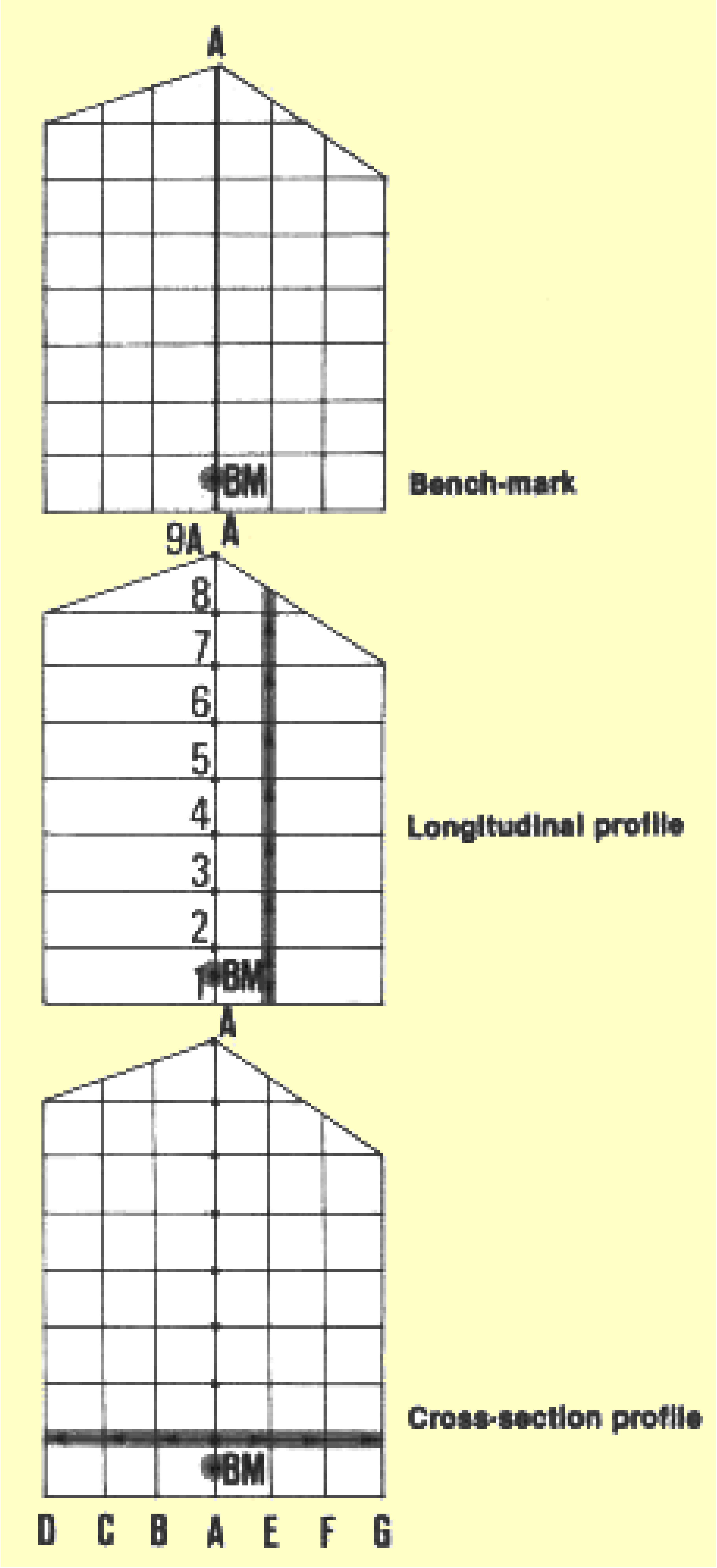
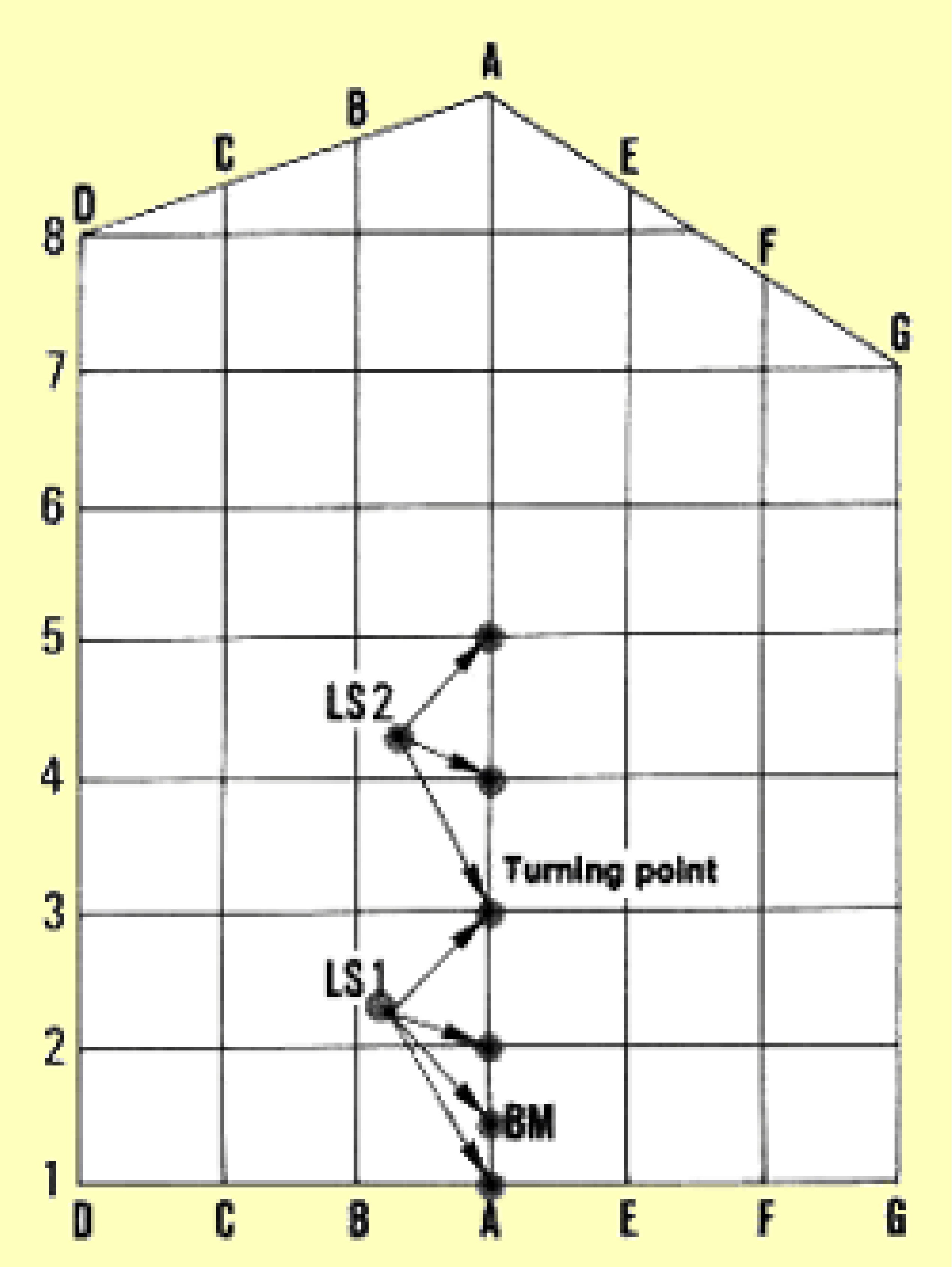
3- Square Grid Levelling

- Now that you have laid out the square grid on the ground, you need to find the elevation of each corner of the squares, which you have marked with stakes. First establish a bench-mark (BM) on base line AA near the boundary of the area and preferably in the part with the lowest elevation. This bench-mark can be either at a known elevation (such as one point on a previously surveyed traverse), or at an assumed elevation (such as 100 m).
- Starting from the bench-mark, measure the differences in elevation for all the base points A1, A2, A3, ... An. This is called **longitudinal profile levelling**.
- Then, starting at these base-line points with known elevations, measure the differences in elevation for all points of each of the perpendiculars, on each side of the base line (for example, B2, C2 and D2 followed by E2, F2 and G2). This is called **cross-section levelling**.



3- Square Grid Levelling



Leveling station	Point	BS	HI	FS	Elevation	Remarks
1	BM	1.53	101.53	-	100.00	Assumed elevation
	A1	-	101.53	1.25	100.28	
	A2	-	101.53	1.20	100.33	
	A3	-	101.53	1.15	100.38	
2	A3	1.48	101.86	-	100.38	Turning point
	A4	-	101.86	1.41	100.45	
	...	...	...	...	...	
	A9	...	...	...	...	
5	A1	1.20	101.48	-	100.28	Known from A1 above
	B1	-	101.48	0.23	100.25	
	C1	-	101.48	0.25	100.23	
	D1	-	101.48	0.28	100.20	
6	D1	1.30	101.50	-	100.20	Turning point
	E1	-	101.50	0.35	100.15	
	...	...	...	...	...	
	G1	-	101.50	0.47	100.03	
9	A2	1.35	101.68	-	100.33	Known from A2 above
	B2	...	...	-	...	
	...	...	...	...	...	
12	F2	...	...	-	...	
	G2	...	...	-	...	
13	A3	...	...	-	100.38	Known from A3 above

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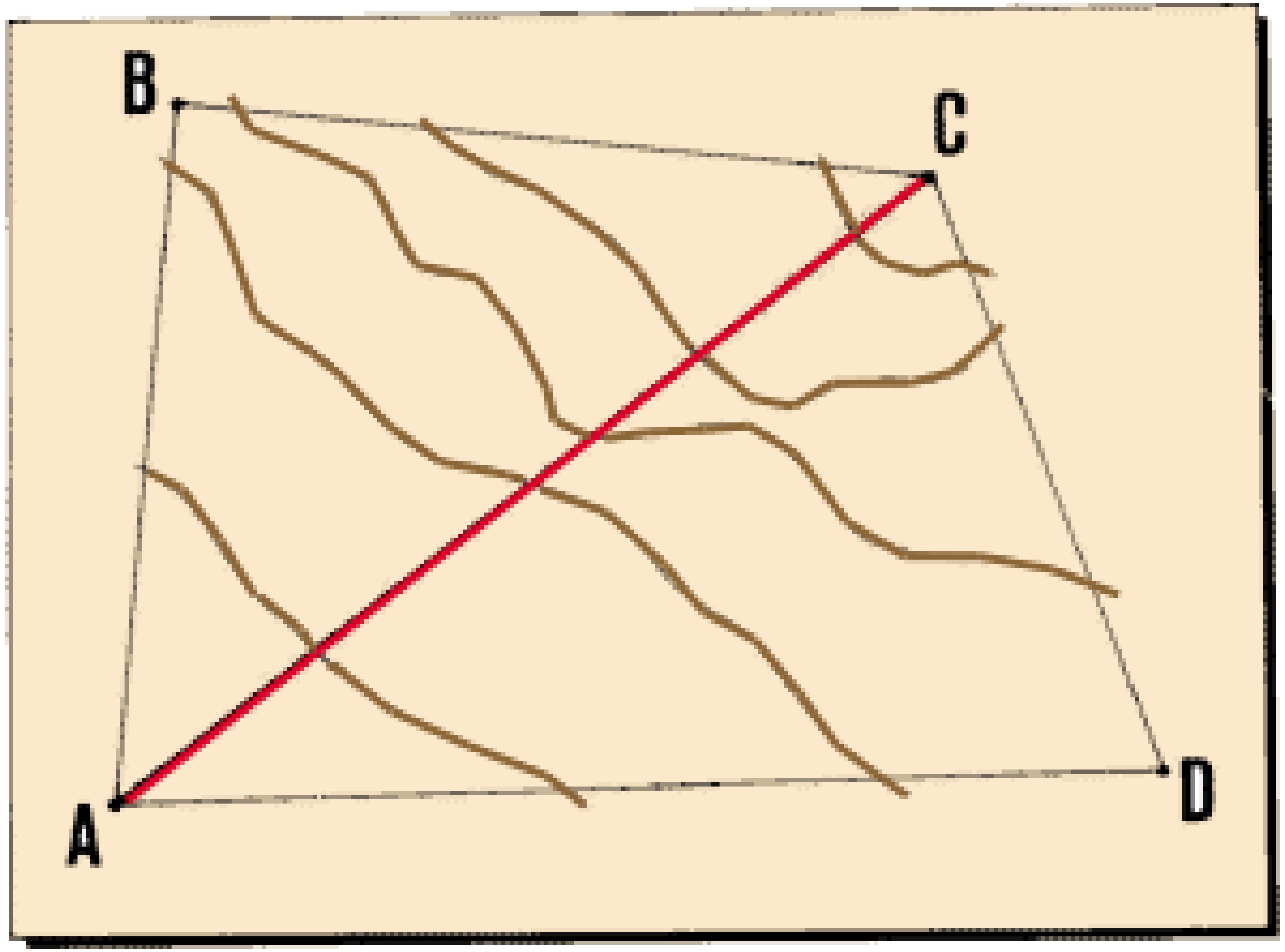
How to plot longitudinal profiles

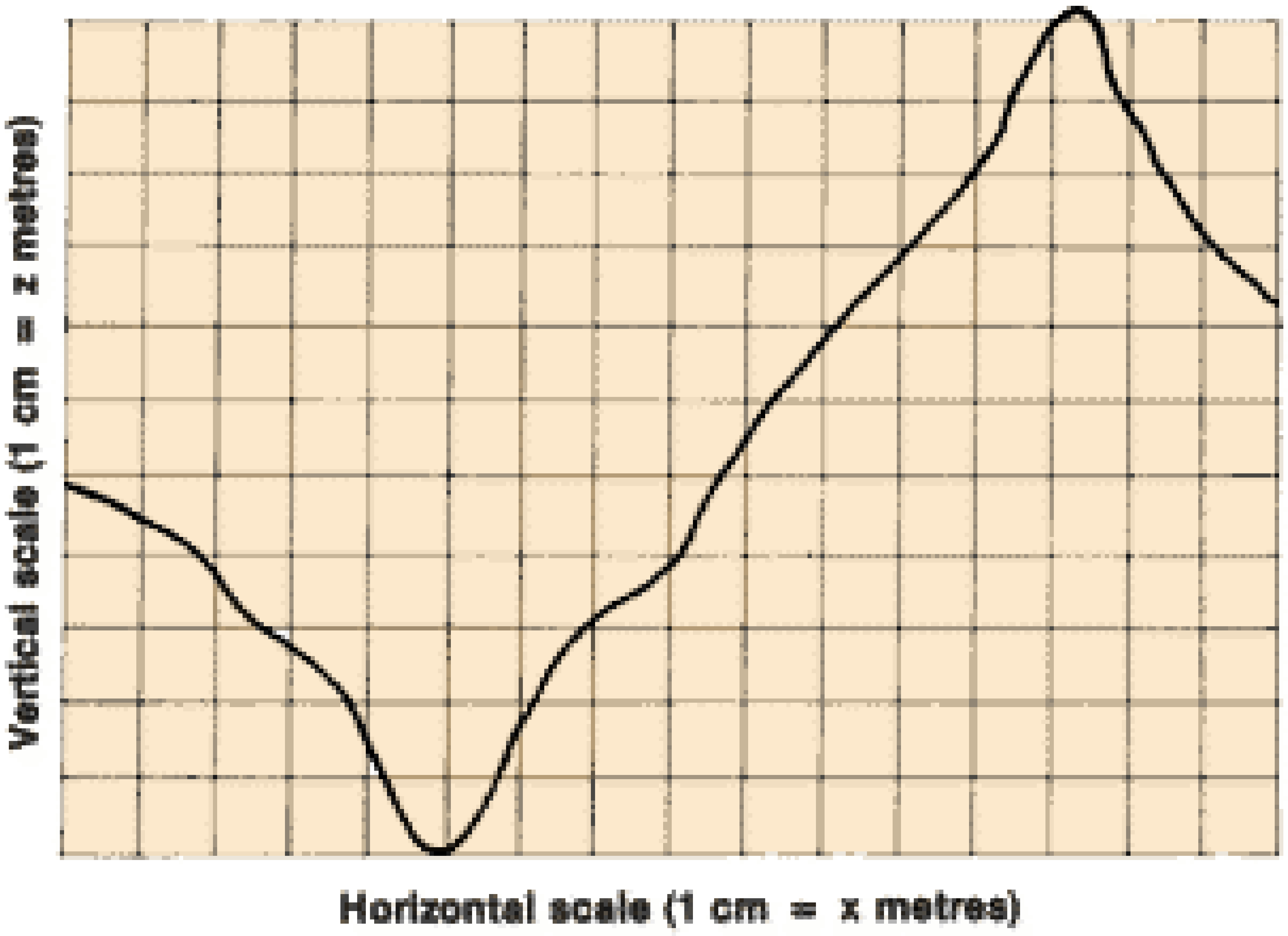
- Longitudinal profiles are plotted to show relative elevations on a plan. When you design a fish-farm, longitudinal profiles help you to determine the route and the bottom slope of such works as water-supply and drainage canals. They are also useful when you need to estimate the amounts of earth you need to dig out or build up on a site (called the volumes of earthwork), and when you choose sites for the construction of reservoir dams and river barrages (small dams that channel the water into ditches or canals).

- You plot a longitudinal profile as a continuous line drawn through points of known elevations. The information you use for this can be:
- •ground elevations, which are separated by known distances, along several lines; or
- •a contour map.

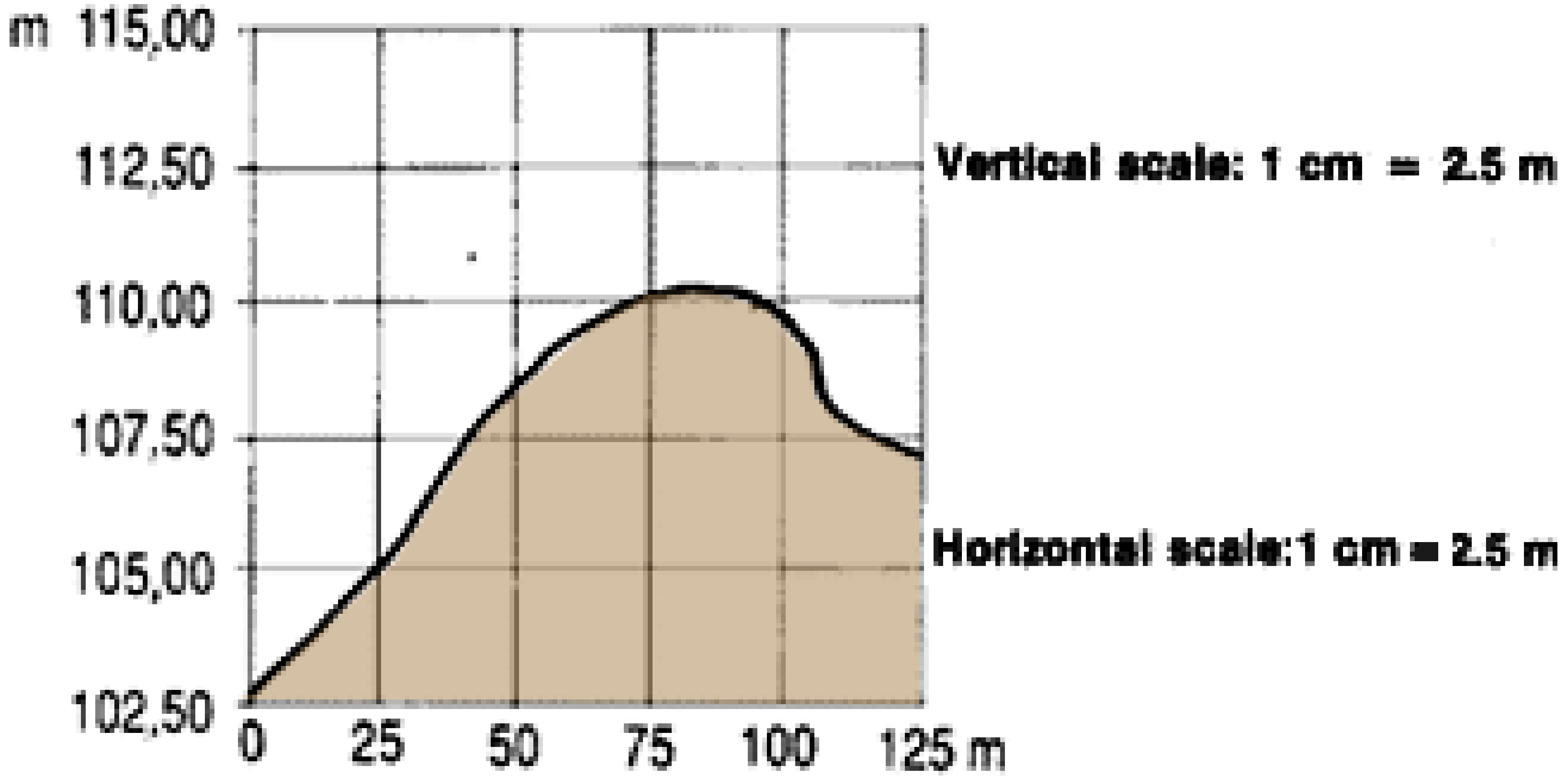


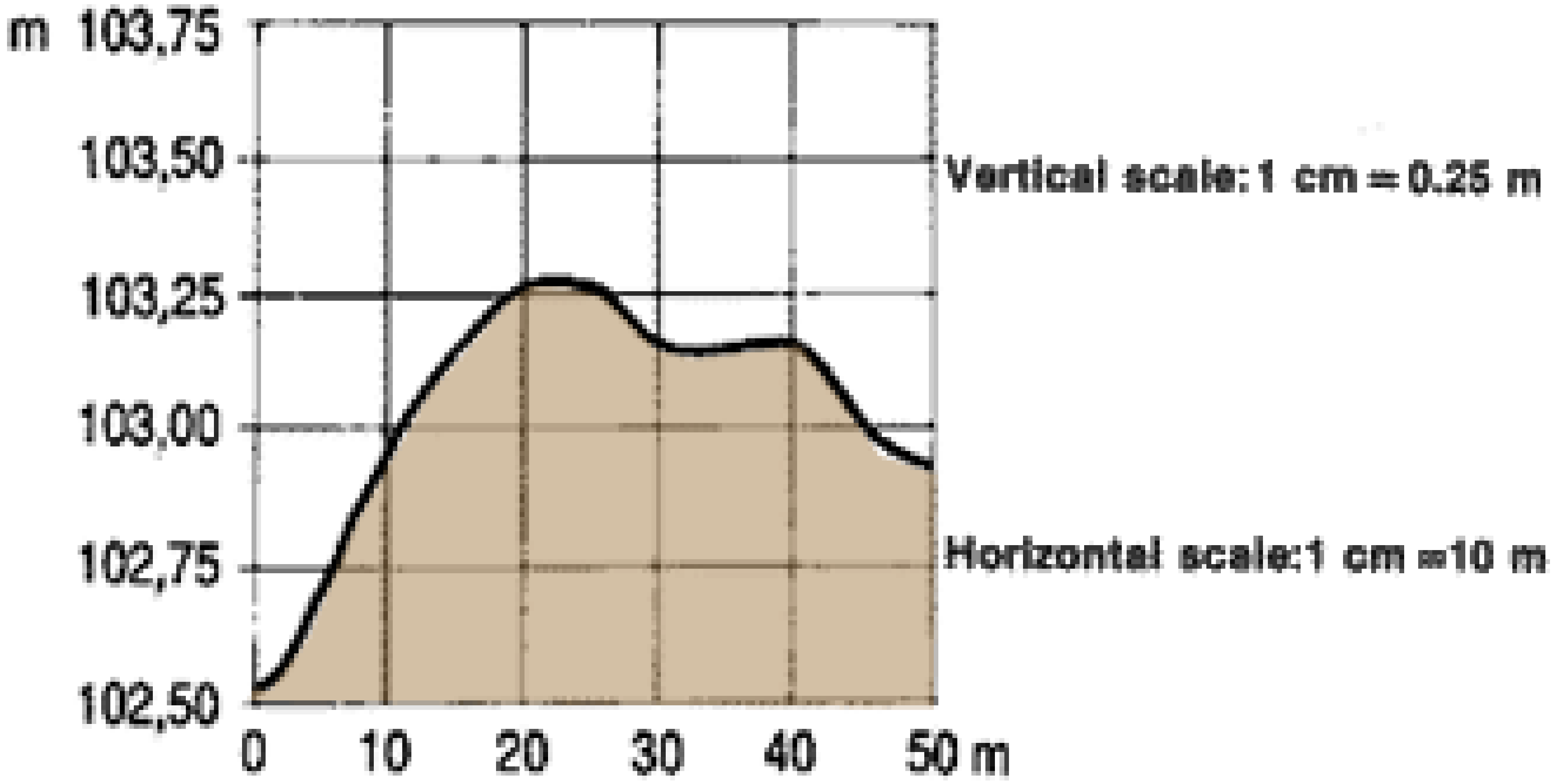
Scales for profiles

- You need two different scales to be able to plot longitudinal profiles:
- •a horizontal scale, for horizontal ground distances;
- •a vertical scale, for vertical elevations.
- Both scales should use the same unit of length. This is usually the metre.
- The horizontal scale of the profile should preferably be the same as the scale of the plan or map. The vertical scale will be larger to show the relief change.



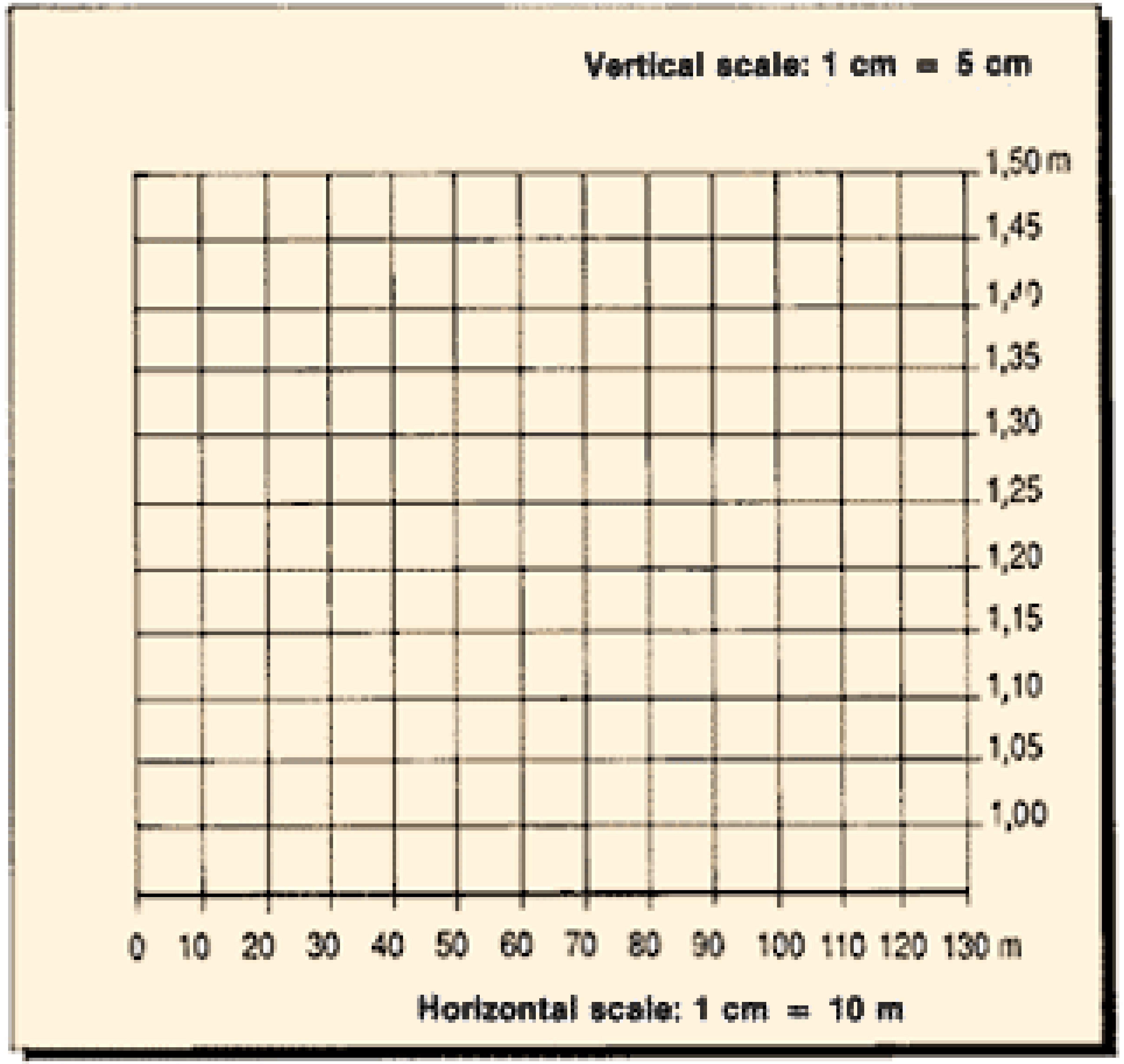
Scales for profiles





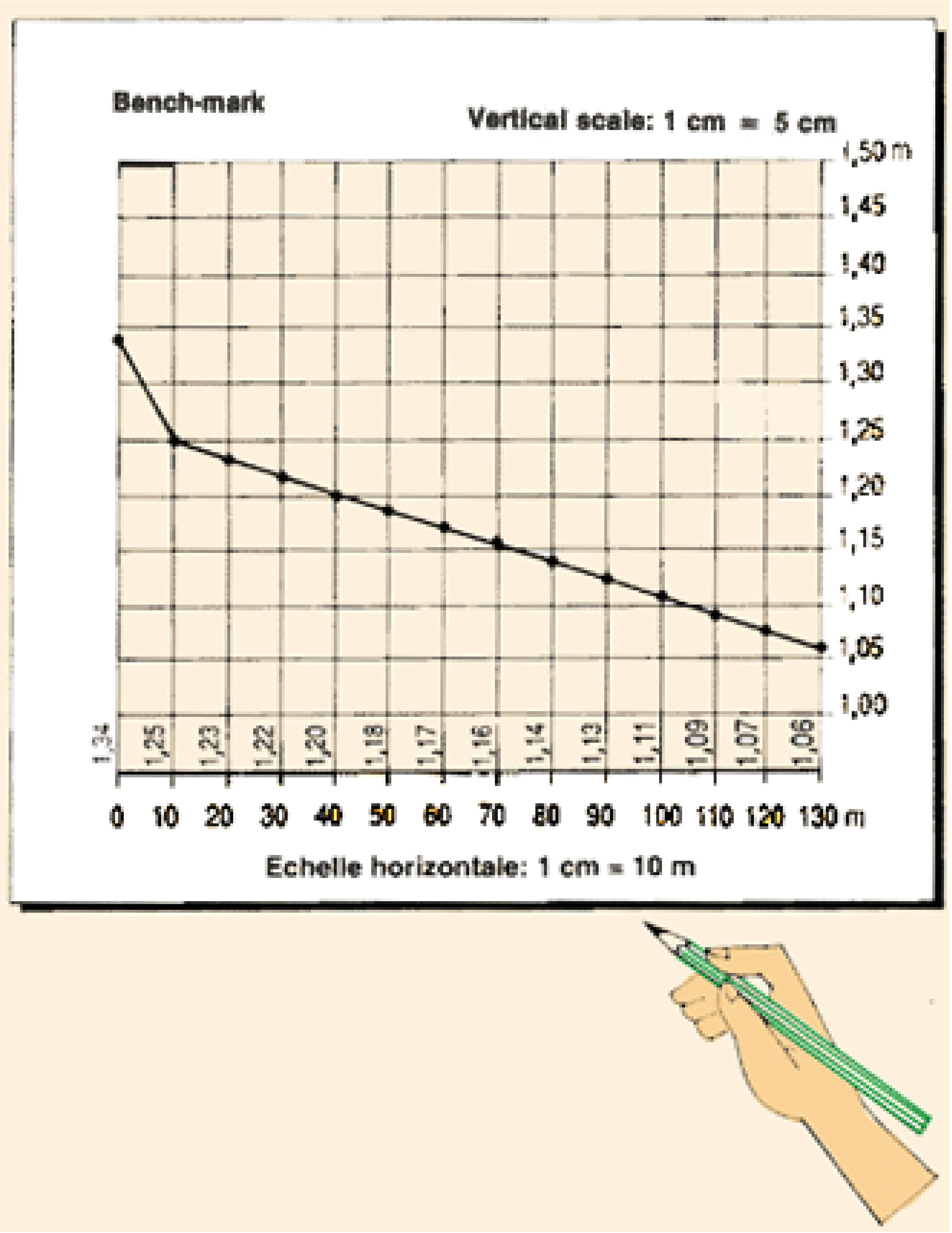
Plotting Profiles from Field Survey

- You can use measurements of distances and elevations from a field survey to plot profiles. Along the horizontal axis, first plot the positions of the survey stations which you have located, for example at regular intervals along a centre-line using the horizontal scale (here 1 cm = 10 m) as a basis. Next to each of these points, mark its distance from the starting point of the profile, the cumulative distance* (in m).



Plotting Profiles from Field Survey

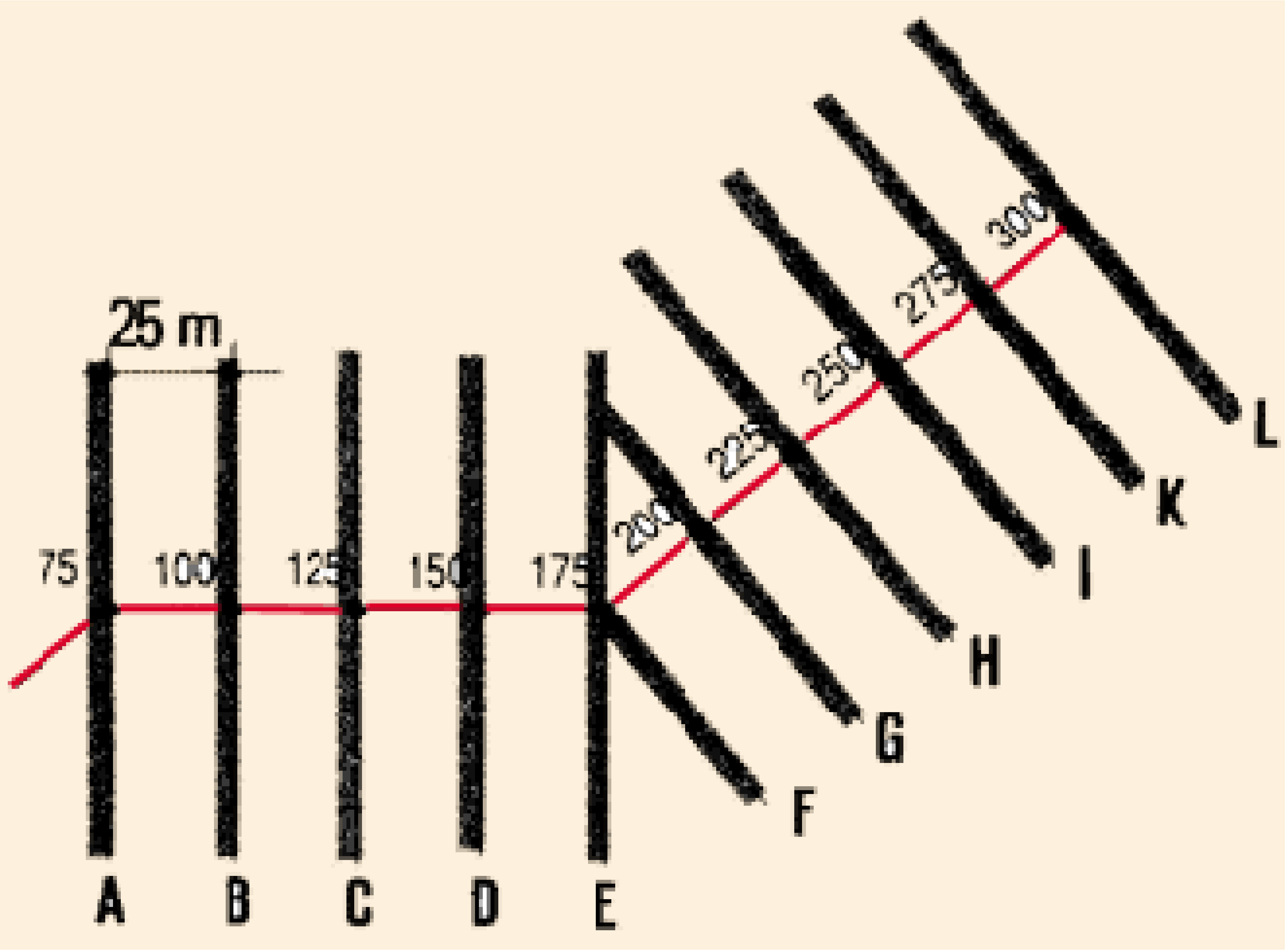
- For each of these points, plot the elevations on vertical lines, using the vertical scale (1 cm = 5 cm) and the two extreme elevations (1.34 m and 1.06 m) as bases.
- Join these points with a continuous line, which represents the profile of the ground along the centre-line.
- Add more information, such as the elevations of the bench-mark (BM) and of any turning point (TP). If you also plot the proposed canal slope (0.15 cm/m = 7.5 cm/ 50 m), you can use the drawing to easily locate areas where you need to raise the land to a required level (called a fill*), or places where you need to dig a channel (called a cut*). Then you can use the drawing to estimate the amount of earthwork these will require.



How to plot cross-section profiles

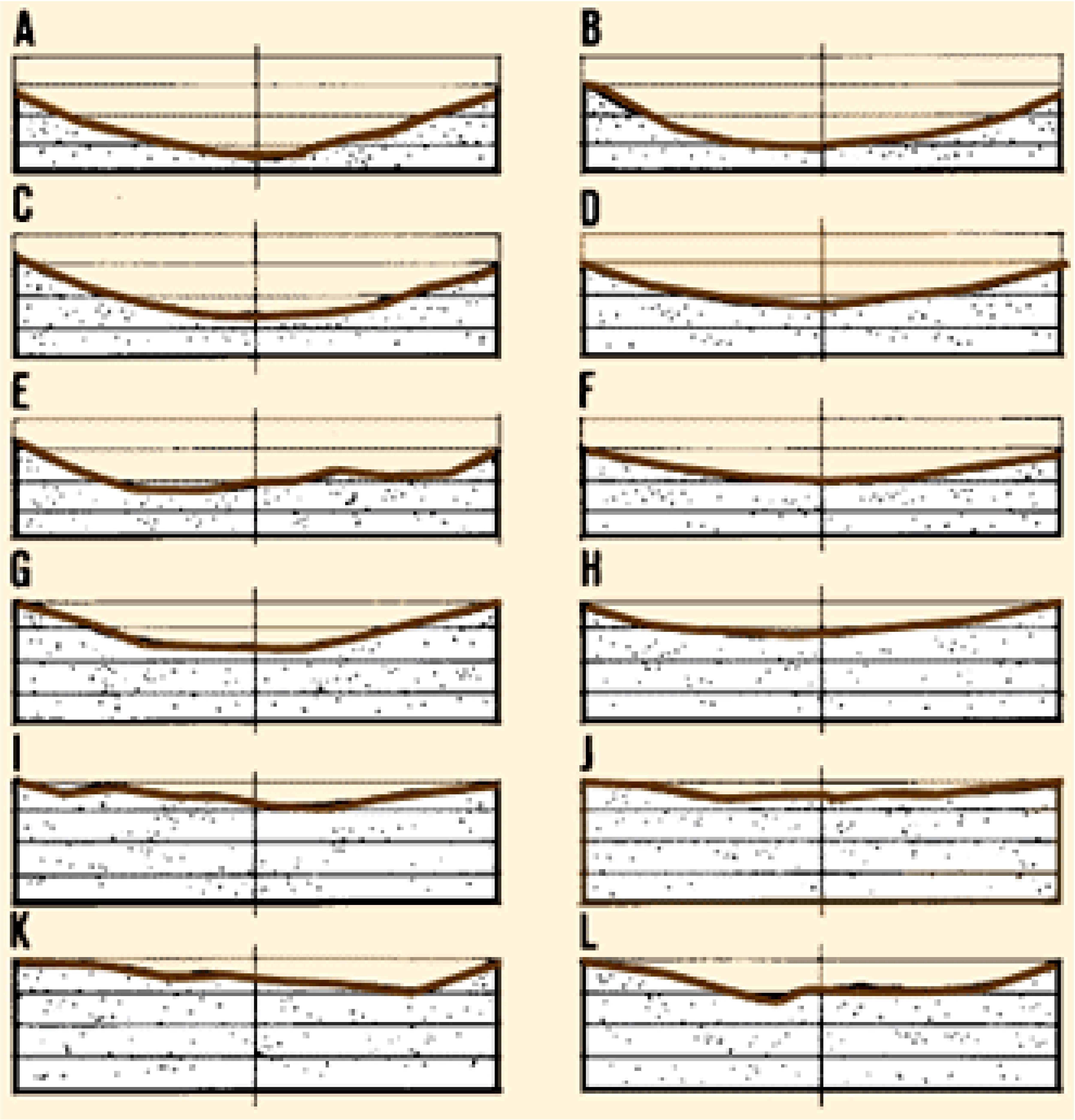
- You can plot cross-section profiles either from contour maps or from levelling-survey information.

- A good example of when to use a cross-section profile plotted from a contour map is for a study of a river valley when you want to create a water reservoir, or build a small barrage that will raise the water level and fill the fish-ponds by gravity.



How to plot cross-section profiles

- If you use the information from a levelling survey, you can plot cross-section profiles to calculate volumes of earthwork when you are building water canals and fish-ponds, for example

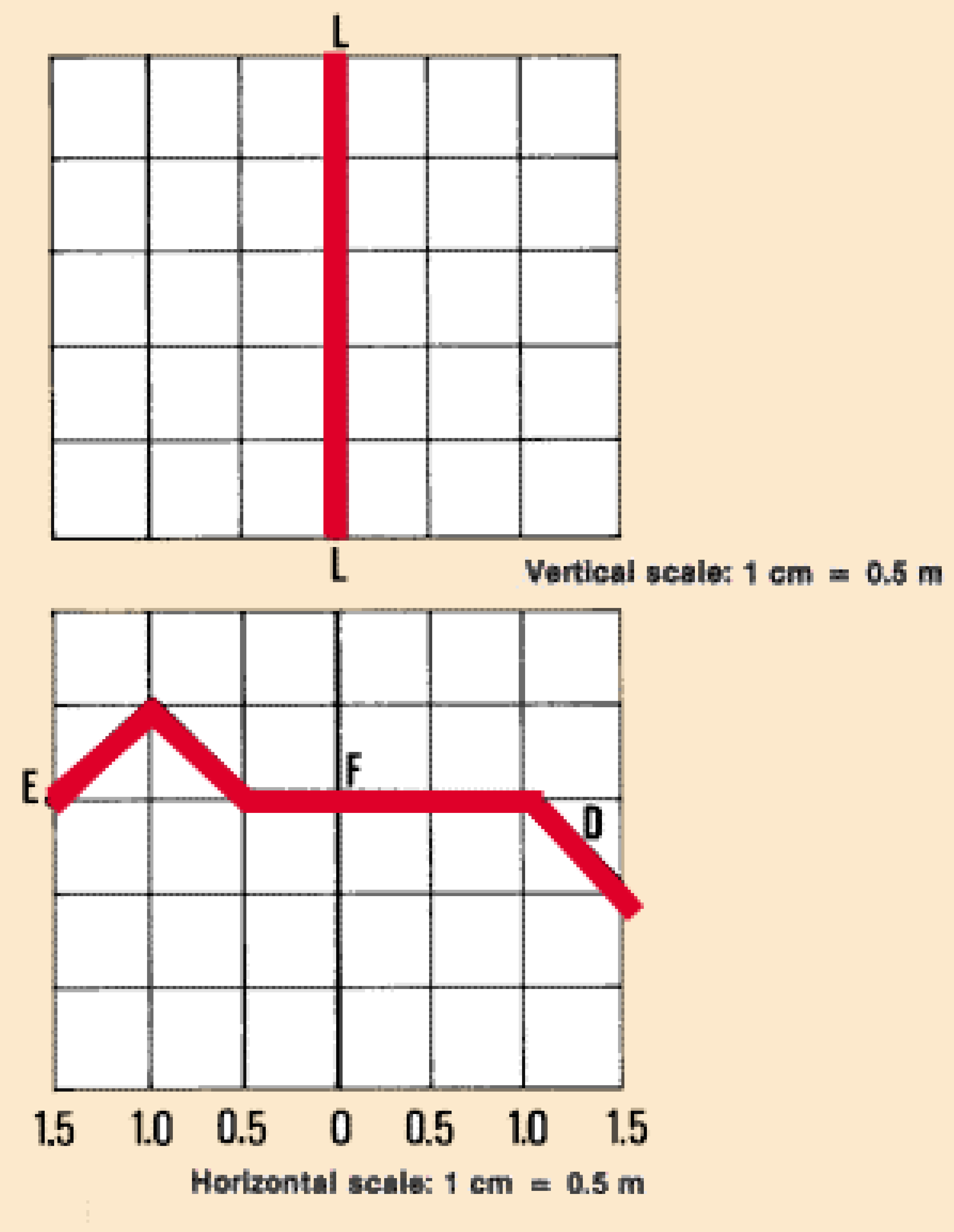


Plotting cross-section profiles for earthwork estimates

- To estimate how much earthwork you need to do, you can usually plot cross-sections to a scale of either 1 cm per metre or 1cm per 0.5 m. Use the larger scale when the amount of a cut or fill is small. Horizontal scales and vertical scales should be identical, so that you can obtain a true surface area from the scaled dimensions.

Plotting cross-section profiles for earthwork estimates

- You can plot best on square-ruled millimetric paper or use one sheet of such paper as a guide placed under a sheet of transparent tracing paper.
- Draw a vertical centre-line (LL) representing the centre-line of the cross-section profile. LL should follow one of the heavier lines of the squared-ruled paper.
- On both sides of this centre-line, draw the ground profile EFD on the basis of your levelling data, using the horizontal scale for distances and the vertical scale for elevations.



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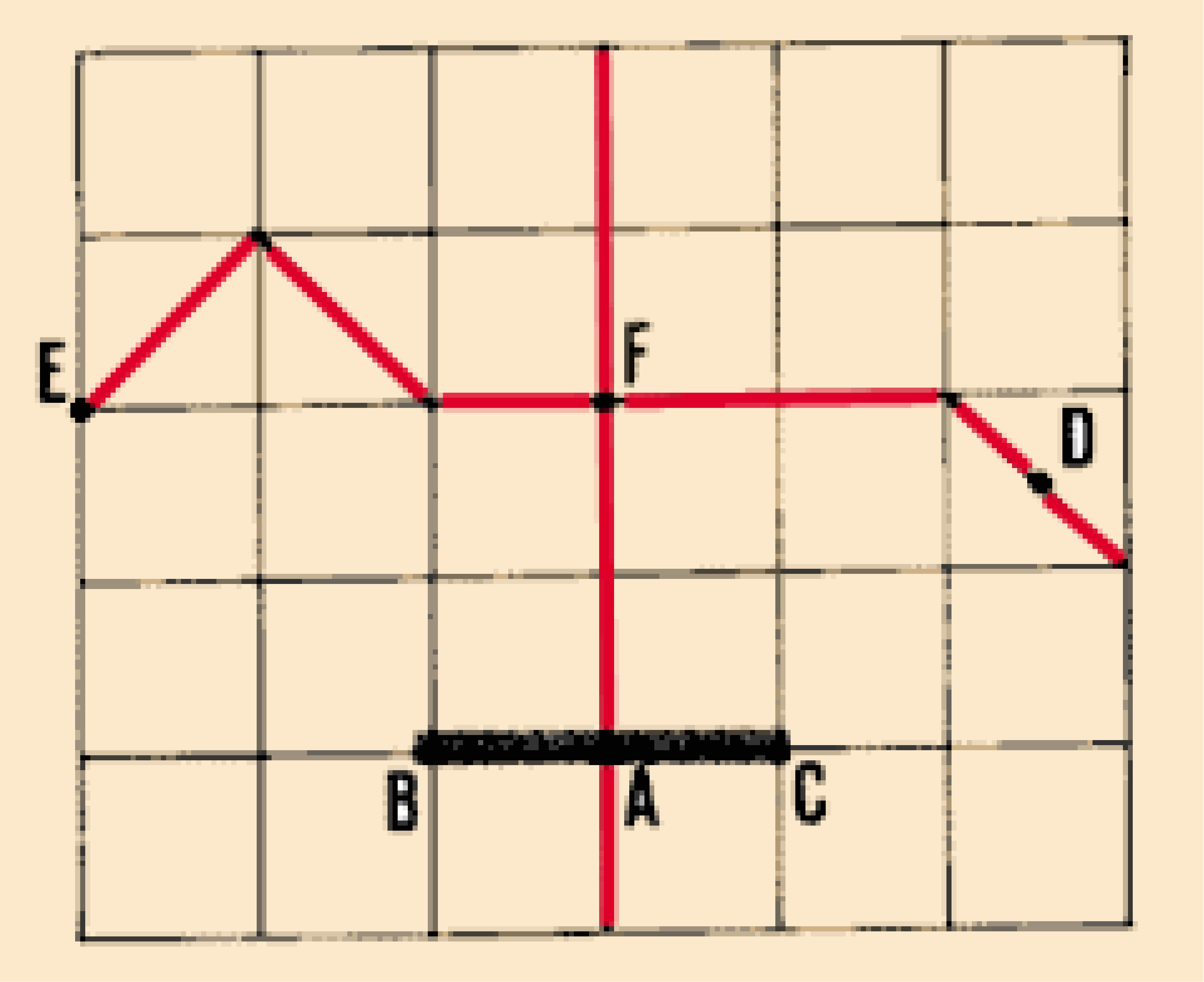
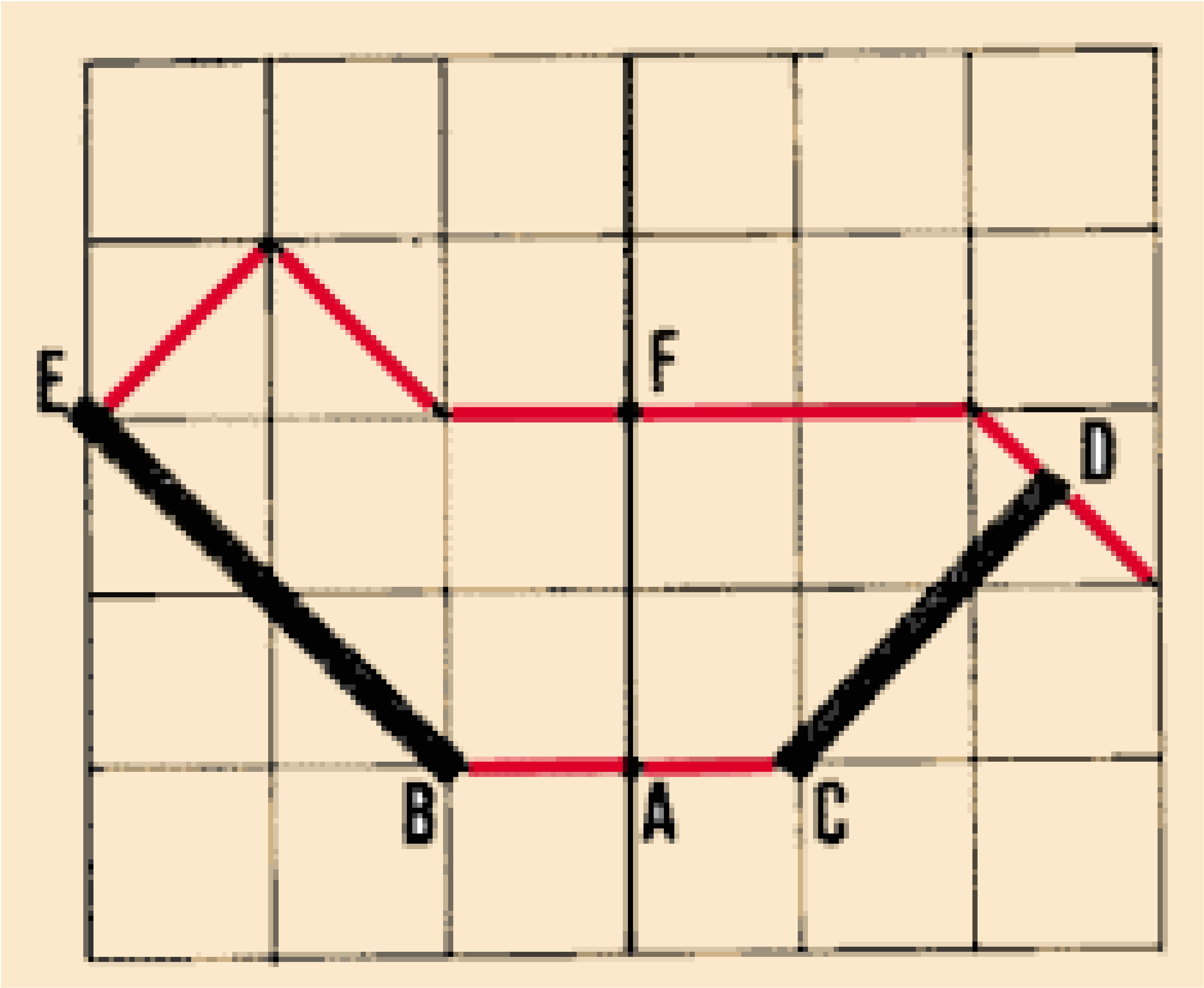
Plotting cross-section profiles for earthwork estimates

- From your longitudinal profile, locate point A on line LL. In the example, it represents the elevation of the bottom of the canal at this particular levelling station.
- Through point A, draw a horizontal line BAC to show the canal bottom. Make sure that AB = AC, and each is half the width of the canal bottom.



Plotting cross-section profiles for earthwork estimates

- Through B and C, draw lines BE and CD representing the sides of the canal .These two lines intersect the ground surface at points E and D.



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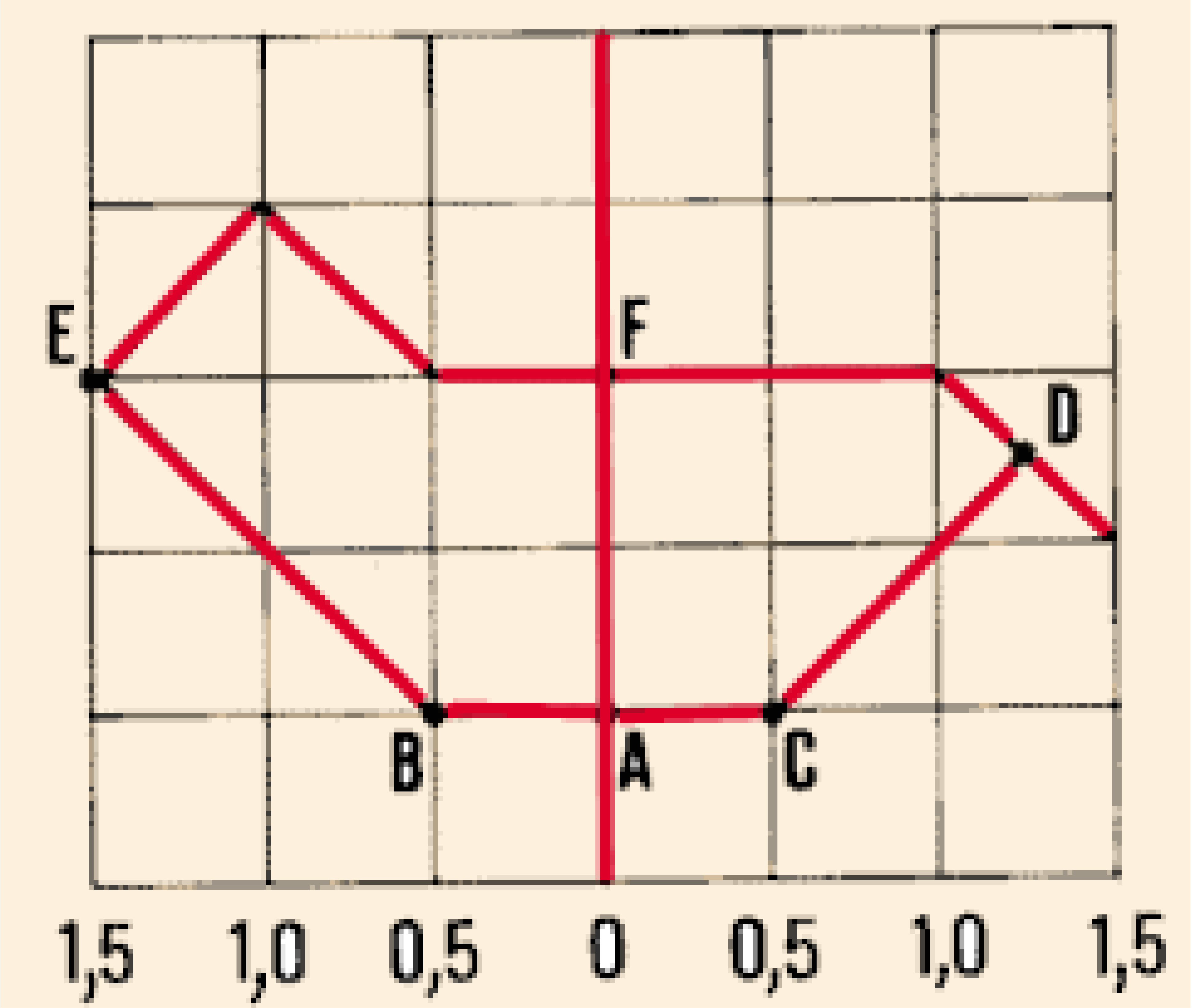
Plotting cross-section profiles for earthwork estimates

- The cross-section EBACDFE represents a vertical section of the earth. You can then easily calculate the area of this cross-section. Using this area as a basis, you can estimate the volume of earth you need to remove from this location along the centre-line of the canal.

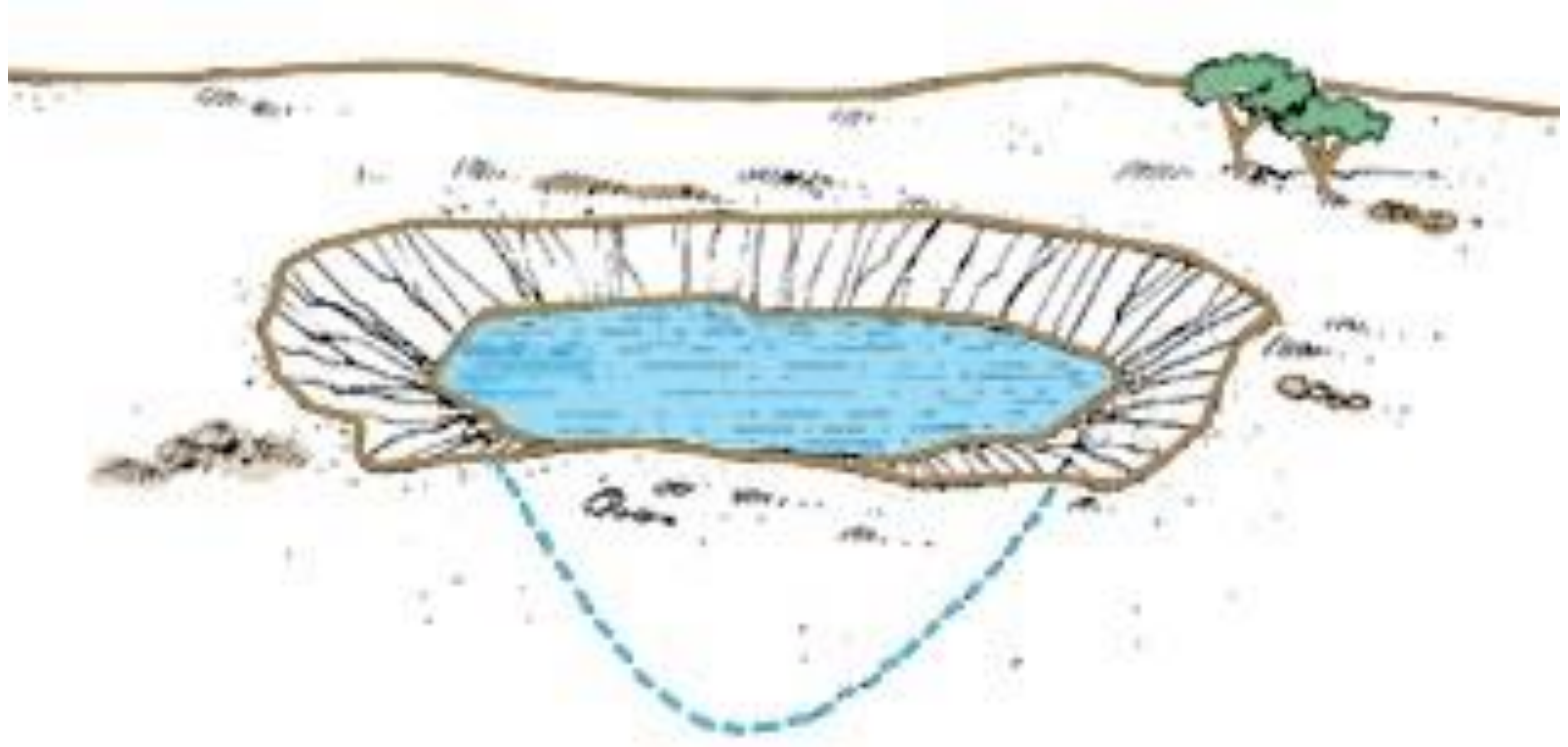


4- Contouring

- A contour is an imaginary continuous line or curve which joins ground points of an equal elevation. The elevation of the ground points must be measured from the same reference plane (Horizontal Datum, for example MSL).
- Contour lines are lines drawn to join points of equal elevation. On a plan or map, they represent the contours you found and marked in the field. Contour lines show the three-dimensional ground topography of a site on a two-dimensional map or plan

4- Contouring

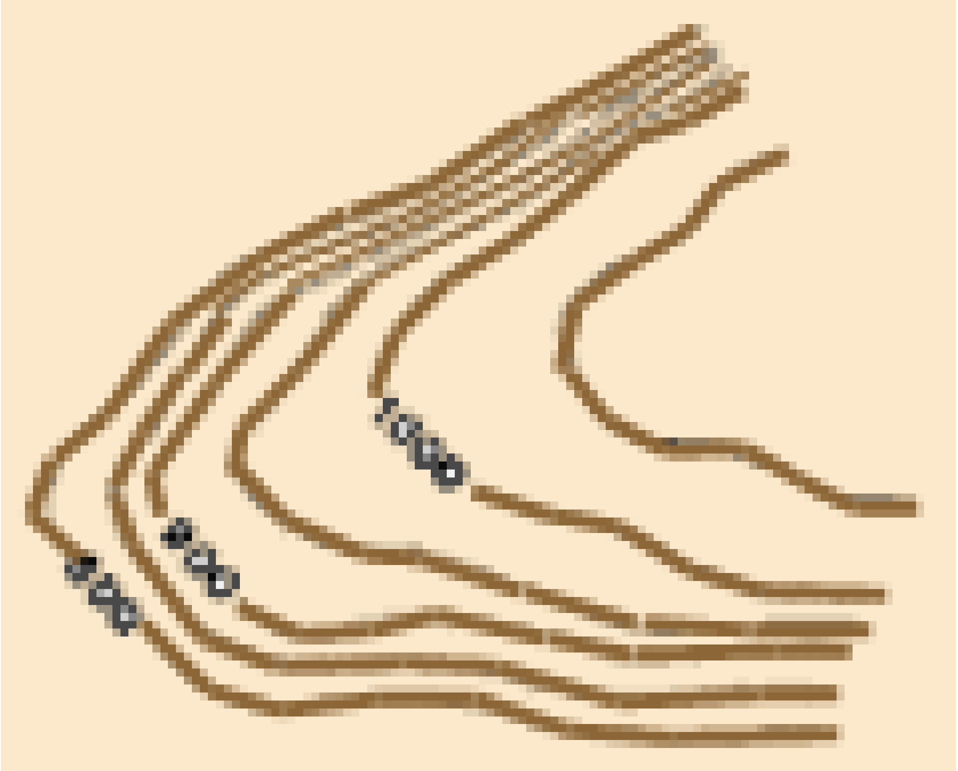
- When you pour water into a hole in the ground, you will see that the surface of the water forms a continuous line made up of the water's points of contact with the sides of the hole. This line shows one contour for this particular water depth in the hole. A lake or a reservoir also has a surface contour which depends on its water level



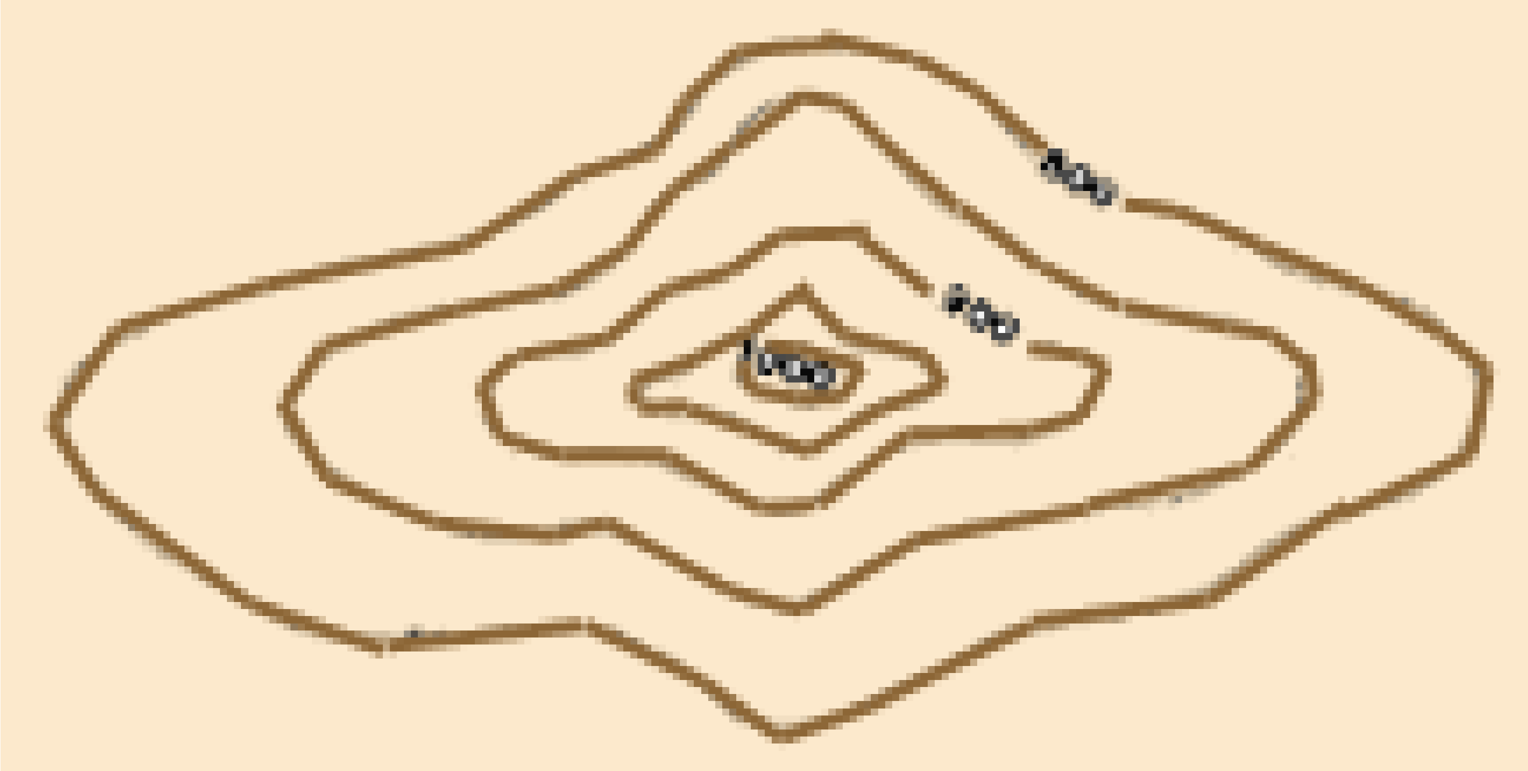
characteristics of contour lines

1. all points on a contour line are at the same elevation;
2. contour lines cannot cross each other or divide in any way (such as branching or splitting off);
3. contour lines always close on themselves, either within or outside the limits of the map. When they close within the map's limits, they indicate either a summit (such as a hill) or a depression (such as a valley);
4. straight, parallel contour lines indicate horizontal ground;

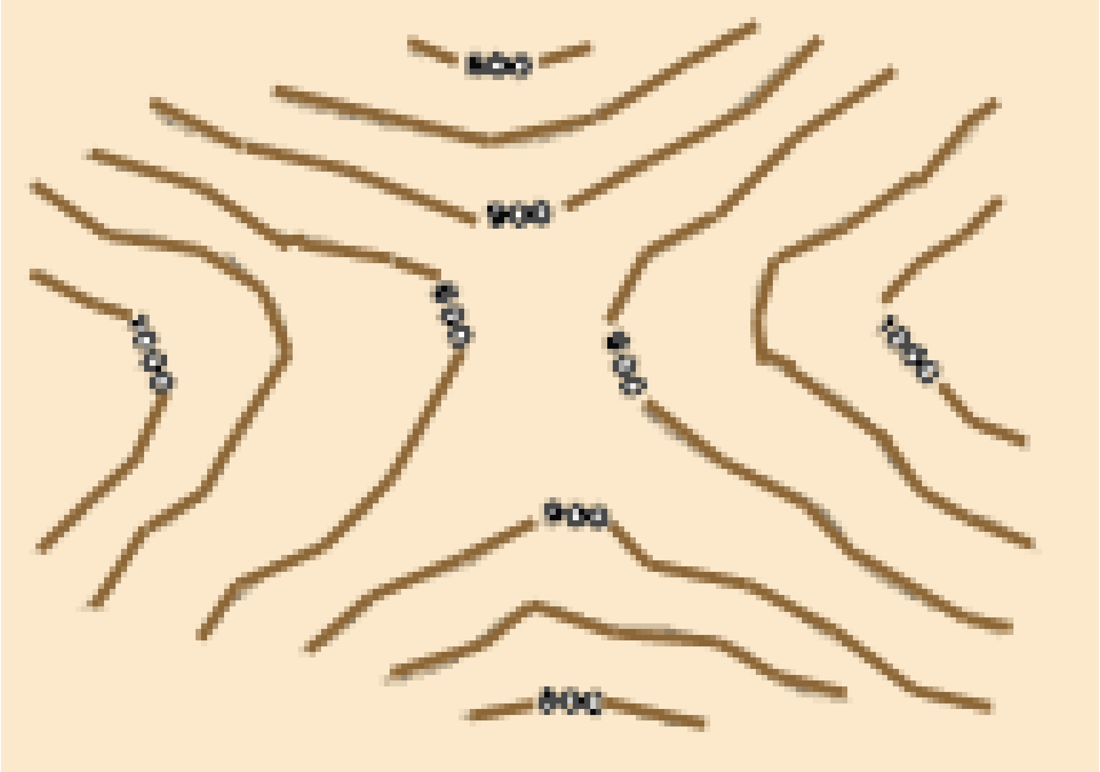
Hill



Peak



Two hills

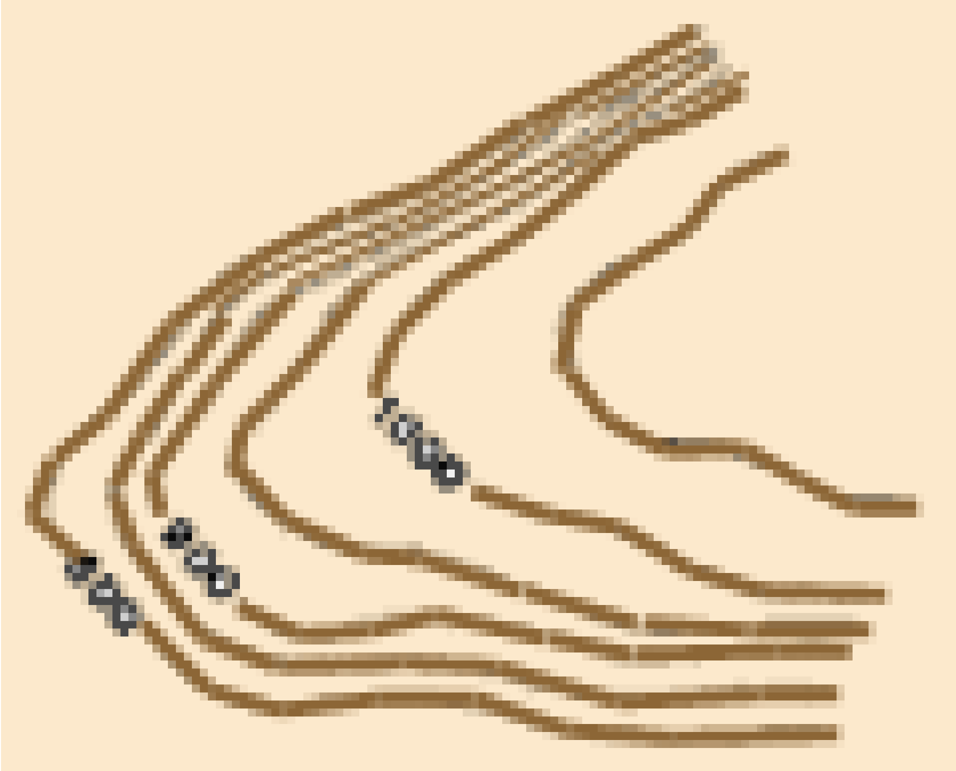


Valley

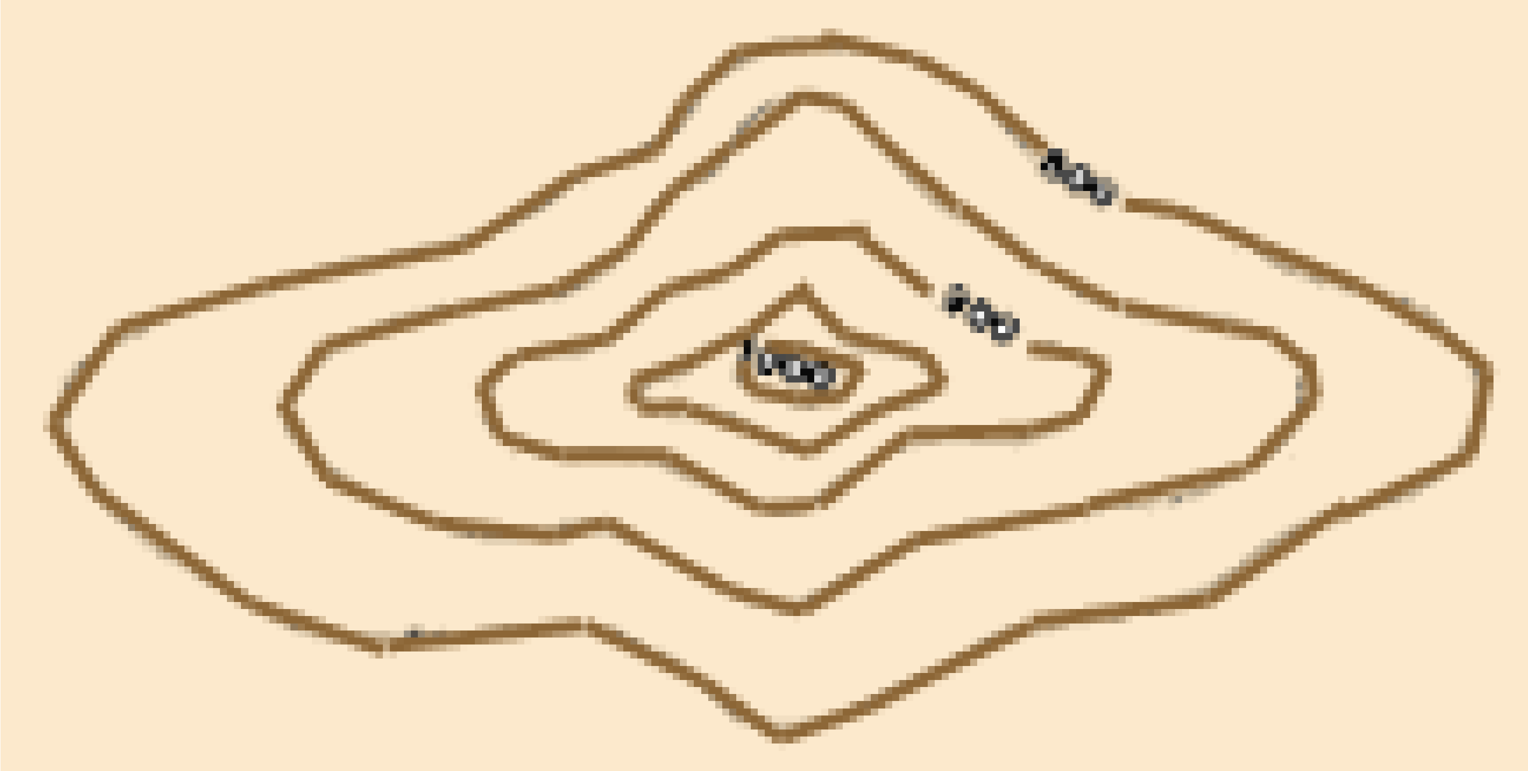
characteristics of contour lines

5. evenly spaced contour lines indicate a uniform, or regular, ground slope;
6. the closer the contour lines, the steeper the slope
7. widely spaced contour lines indicate a gentle slope;
8. closely spaced contour lines indicate a steep slope;
9. the steepest slope is always at right angles to the contour lines;
10. contour lines cross ridges perpendicularly;
11. contour lines cross river valleys following a U- or V- shaped path.

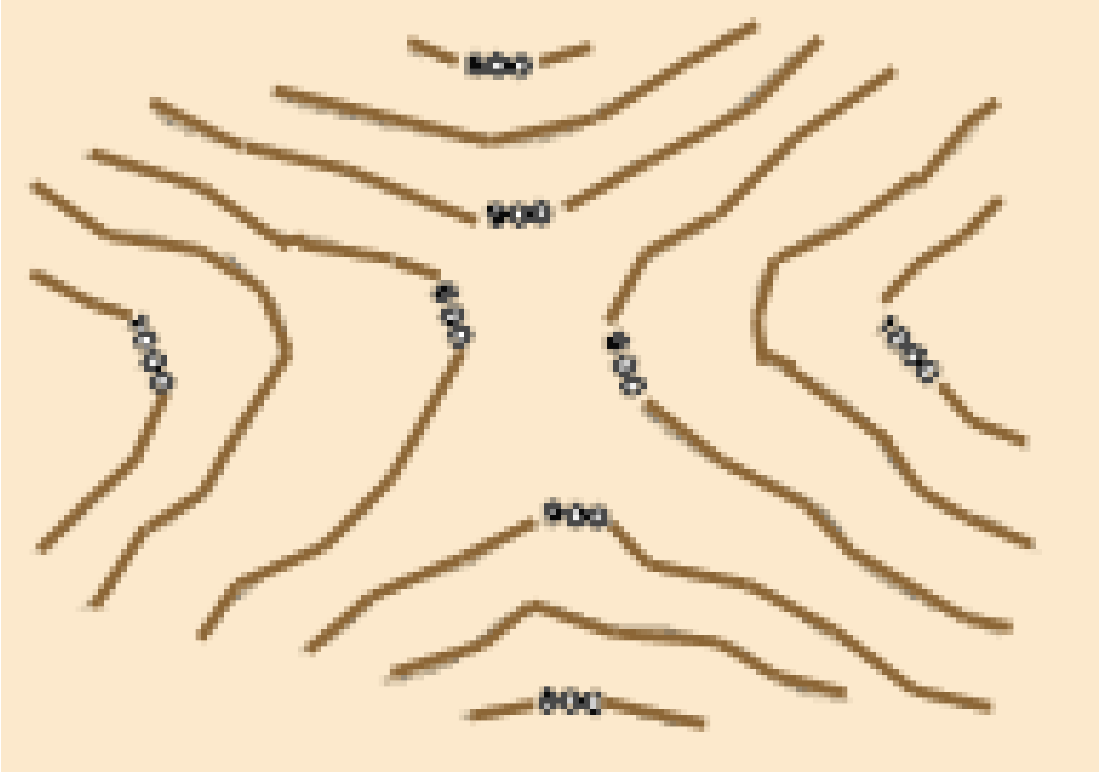
Hill



Peak



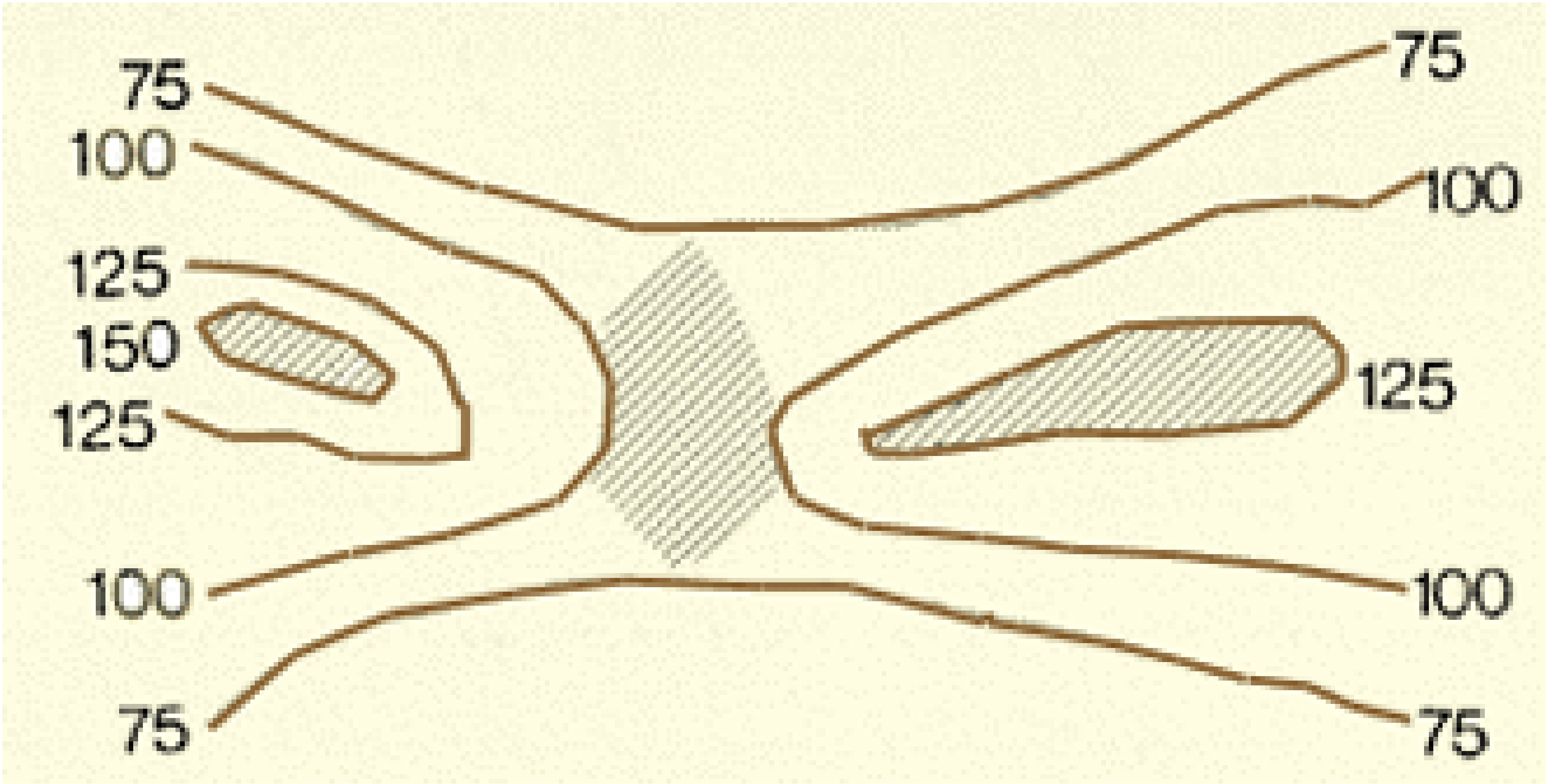
Two hills



Valley

Indeterminate Slope

- when two contour lines of equal elevation are near each other, the land between them is often flatter than the general trend of slope but its slope is indeterminate (unknown).



Indeterminate Slope

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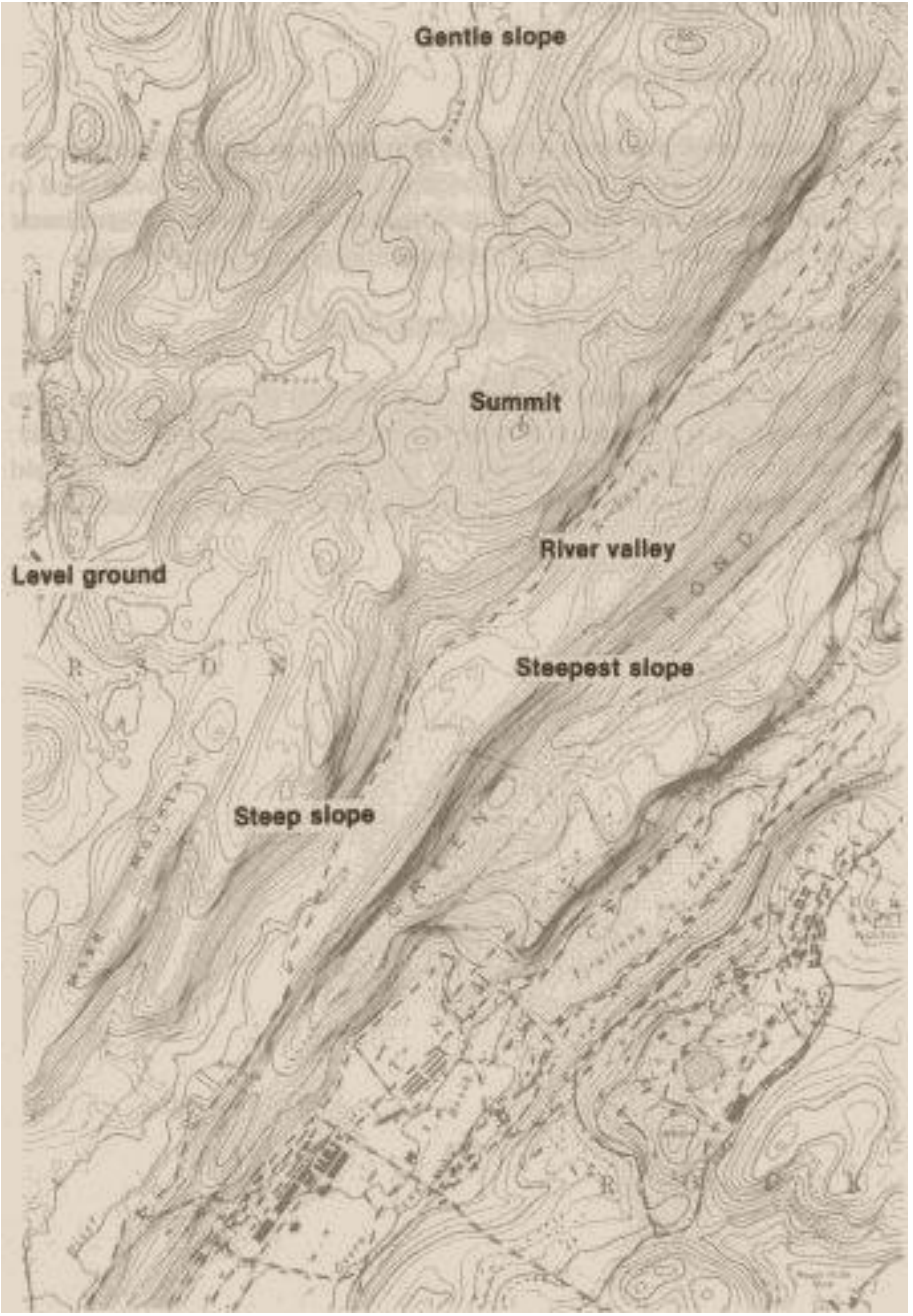
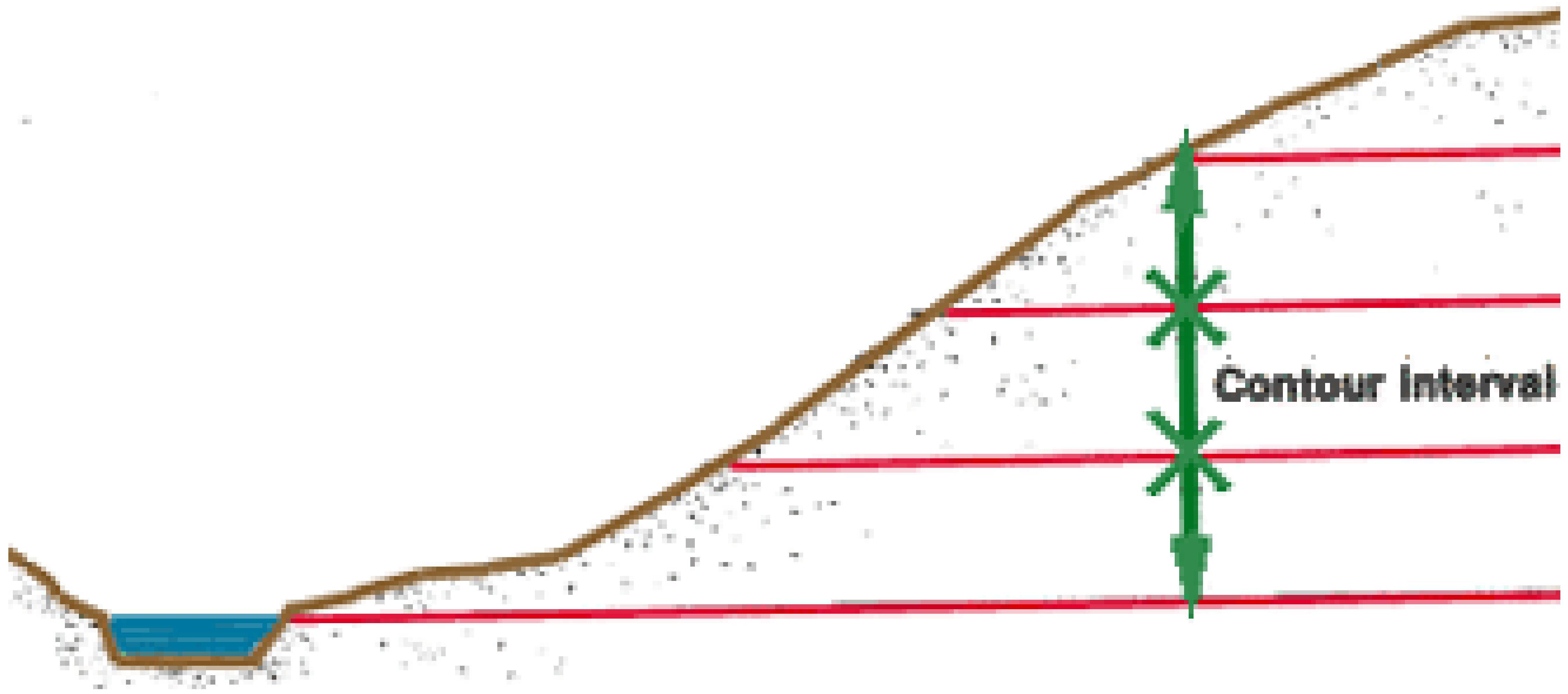


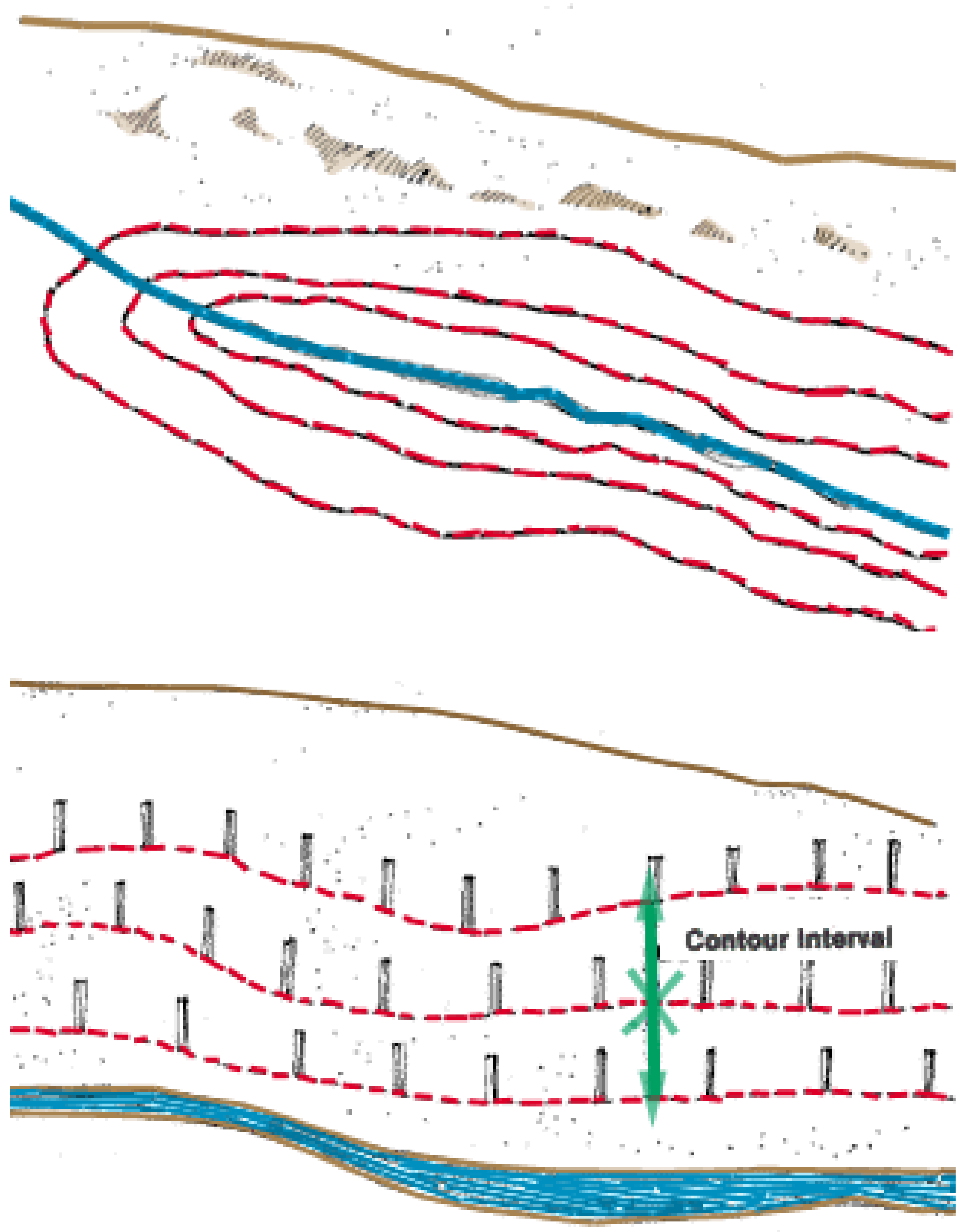
Contour Interval

- It would be an impossible task to identify all the contours in one area. Therefore, you will have to decide how many contours you need to identity in each area. You will have to fix the difference in elevation between contours which are next to each other. This is called the contour interval .



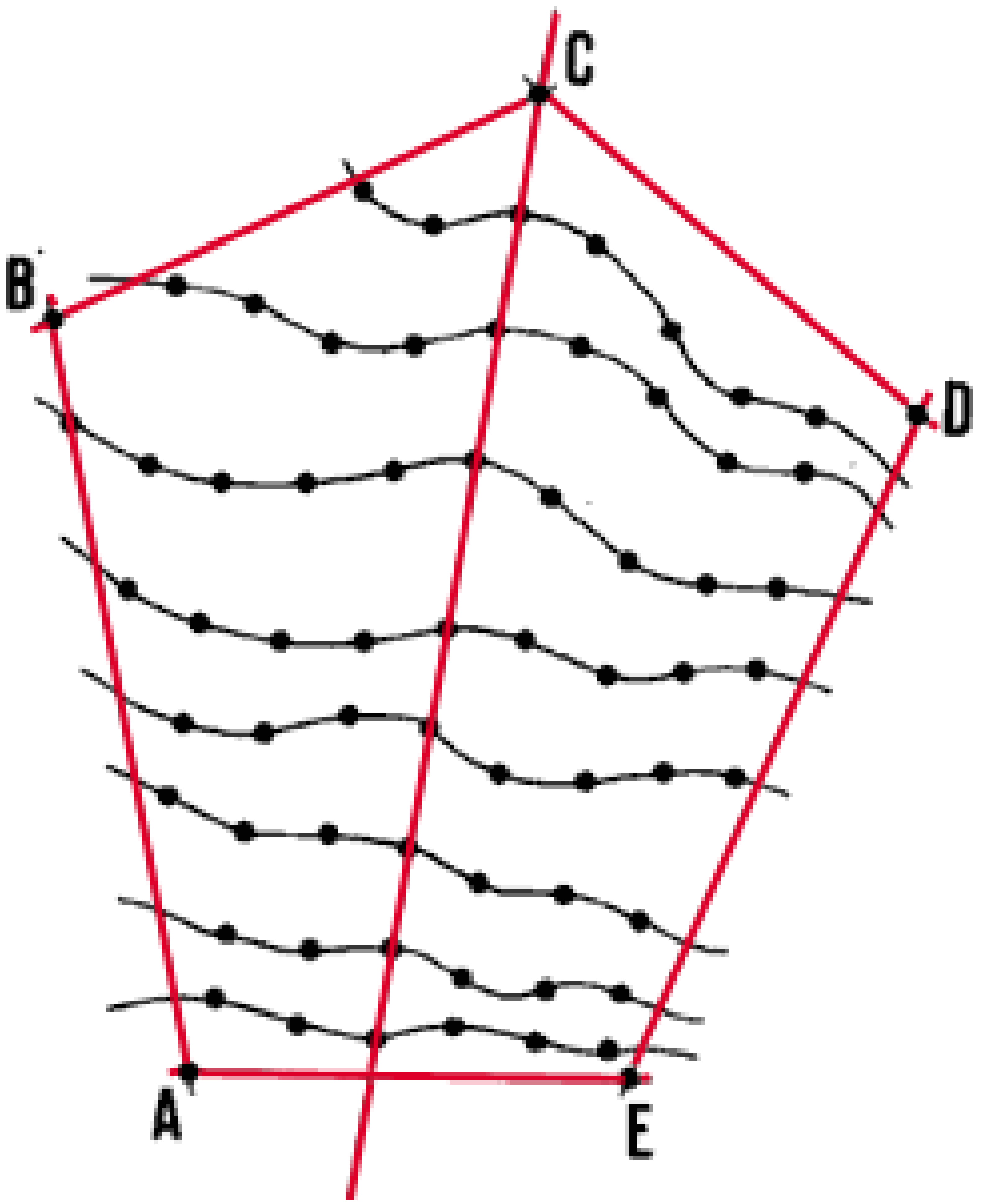
Contour Interval

- Choosing which contour interval to use depends mainly on the accuracy you need, on the scale of the map you will prepare and on the kind of terrain you are surveying. Contour intervals usually vary from 0.25 m to 1 m . This range of intervals allows good accuracy, and makes it possible to produce large-scale topographical maps for flat or slightly sloping ground.



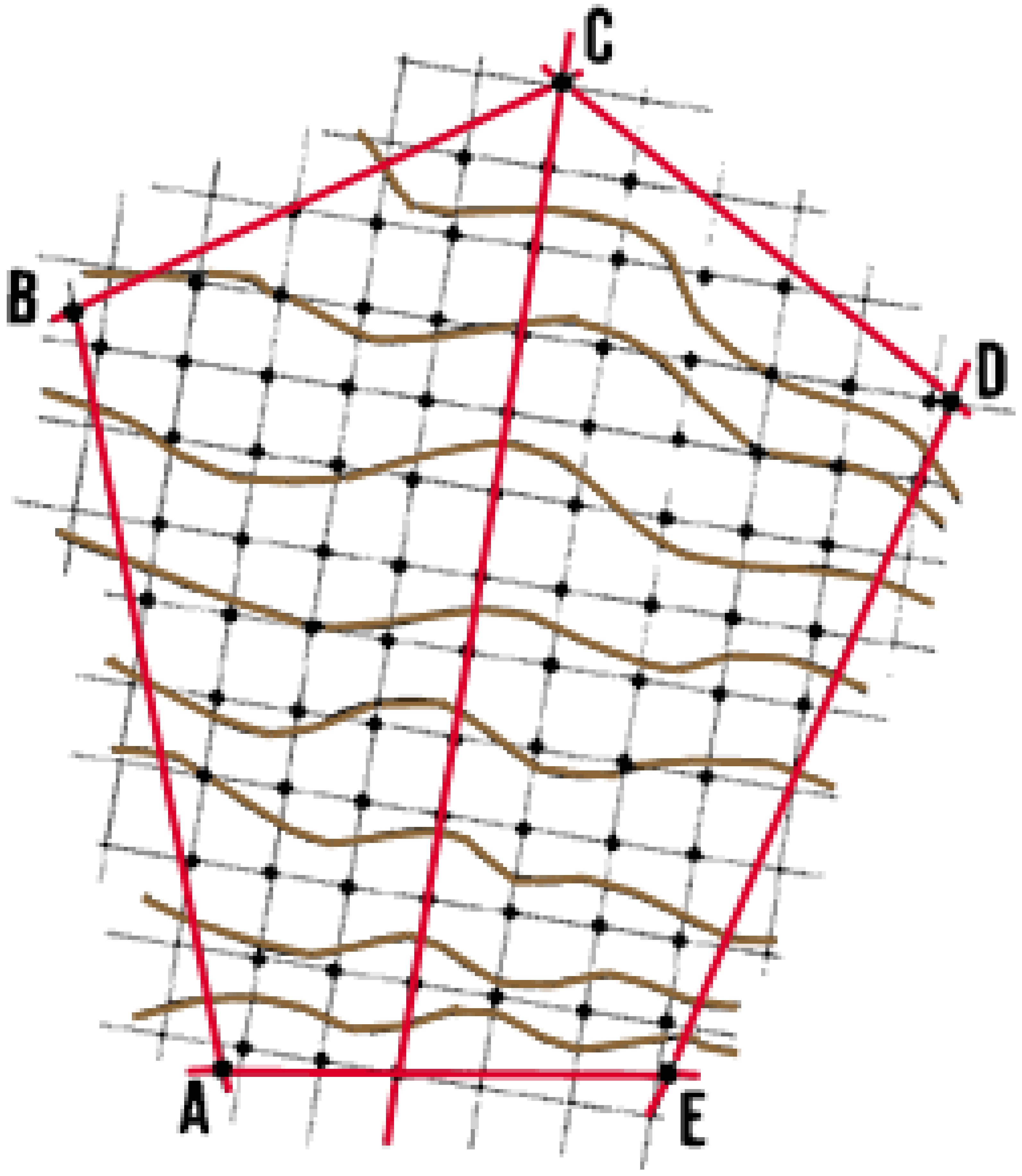
methods of surveying contours

- **direct method**; in which you trace and mark the line of each contour on the ground, and then plan survey these lines so that they can be mapped,



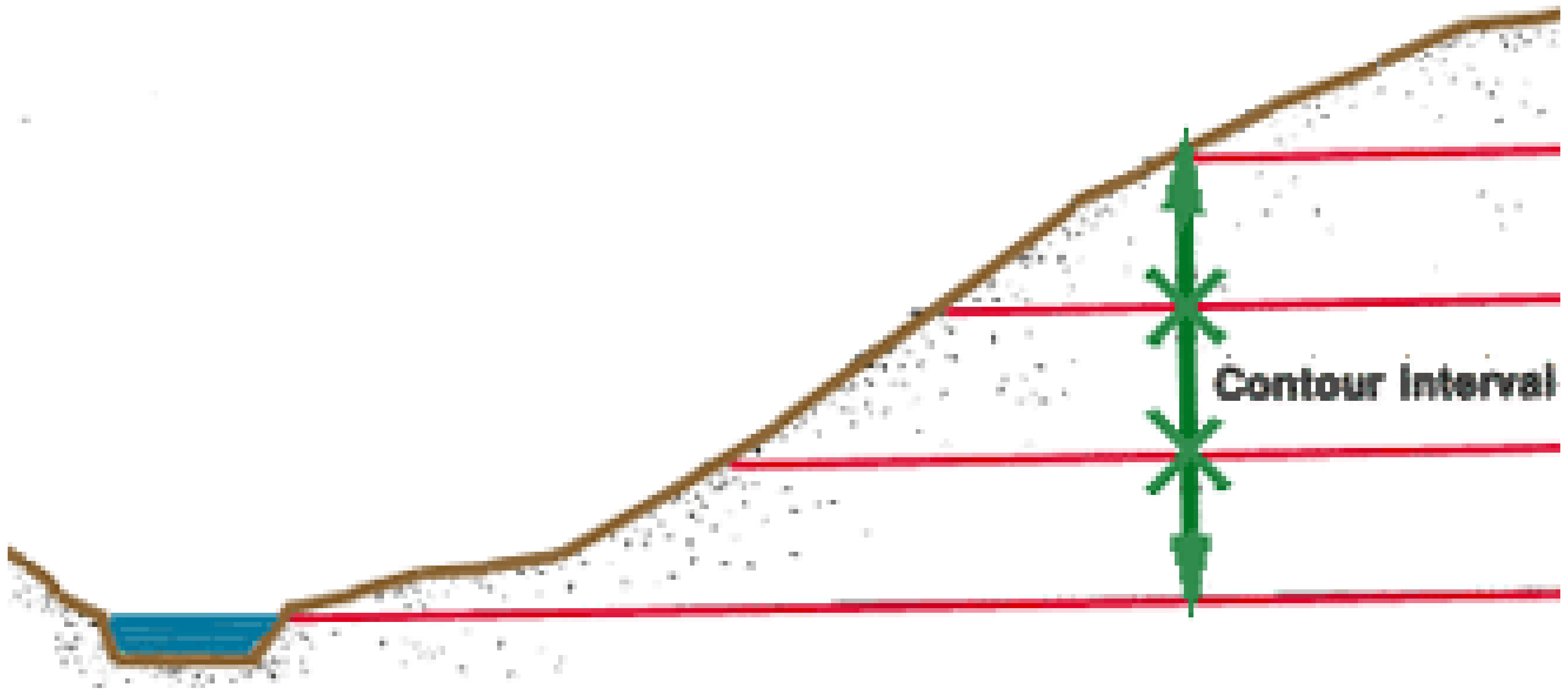
methods of surveying contours

- **indirect method**; in which you make a topographical survey of the area to find a series of points of known elevation. Then you enter them on a map and determine the contours from this map.



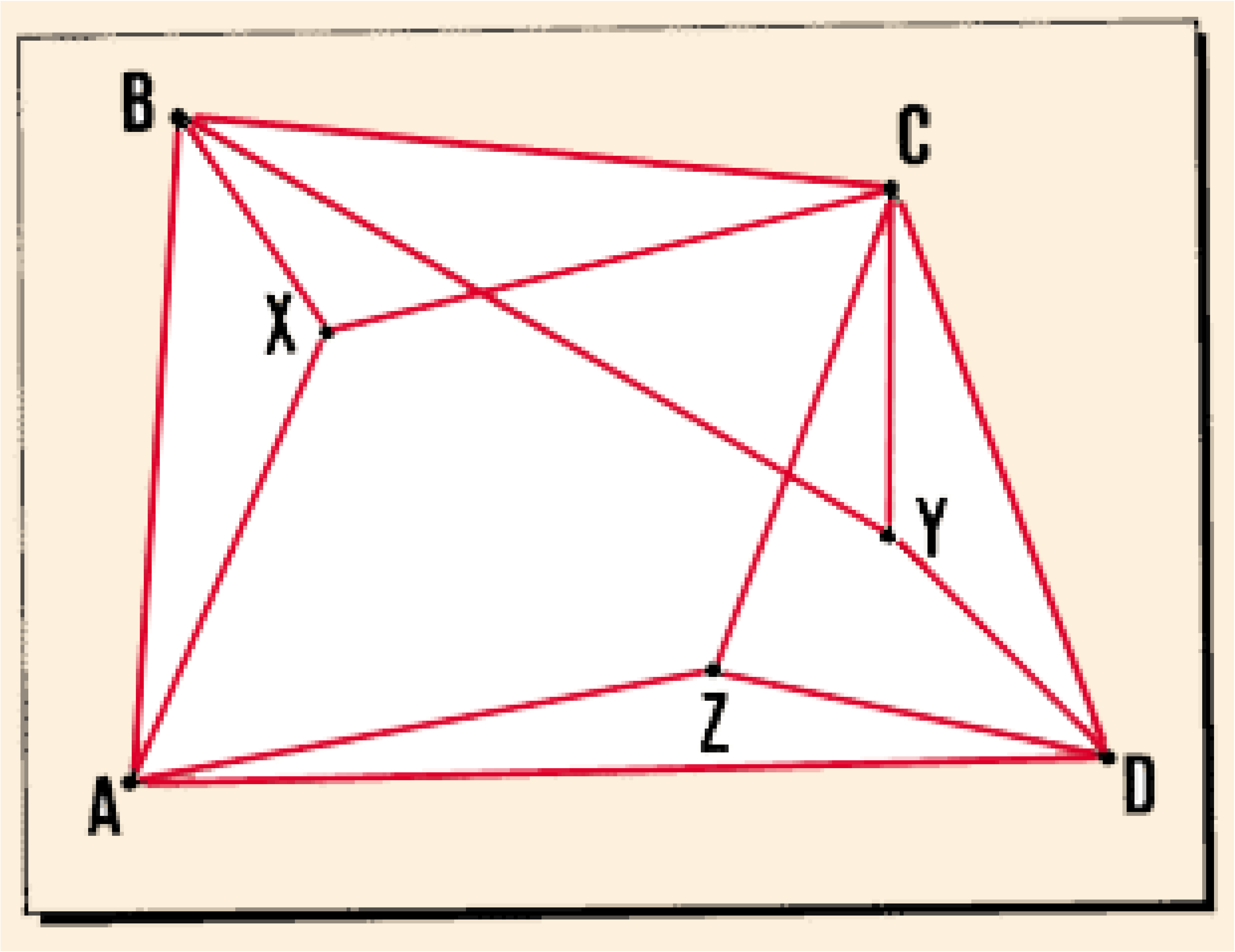
Making a contour map

- Before drawing the contour lines on a plan or map, you must choose the contour interval you will use. The contour interval depends on the accuracy or scale you need, and on the topography of the area. A smaller contour interval, such as 0.15 m, 0.25 m or 0.5 m, is generally used for flat or gently sloping areas.
- First prepare a planimetric map of the area. This is a map showing the boundaries of the land, the surveying stations, the major physical features and all available details.



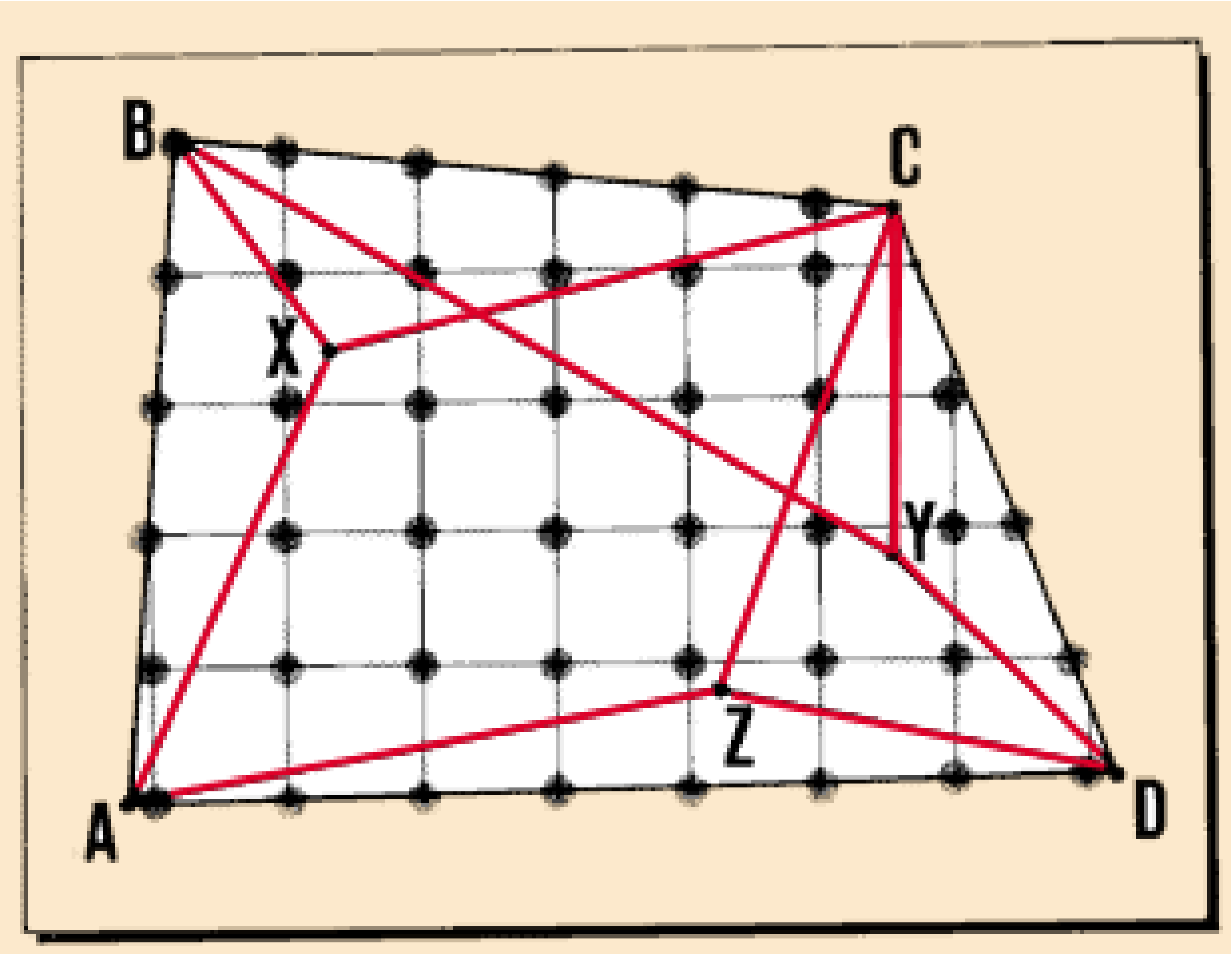
Making a contour map

- Add the points of known ground elevation to the map. To locate these points on the map, use a distance scale and, if necessary, a protractor for determining any angles. Write the elevations next to the points.



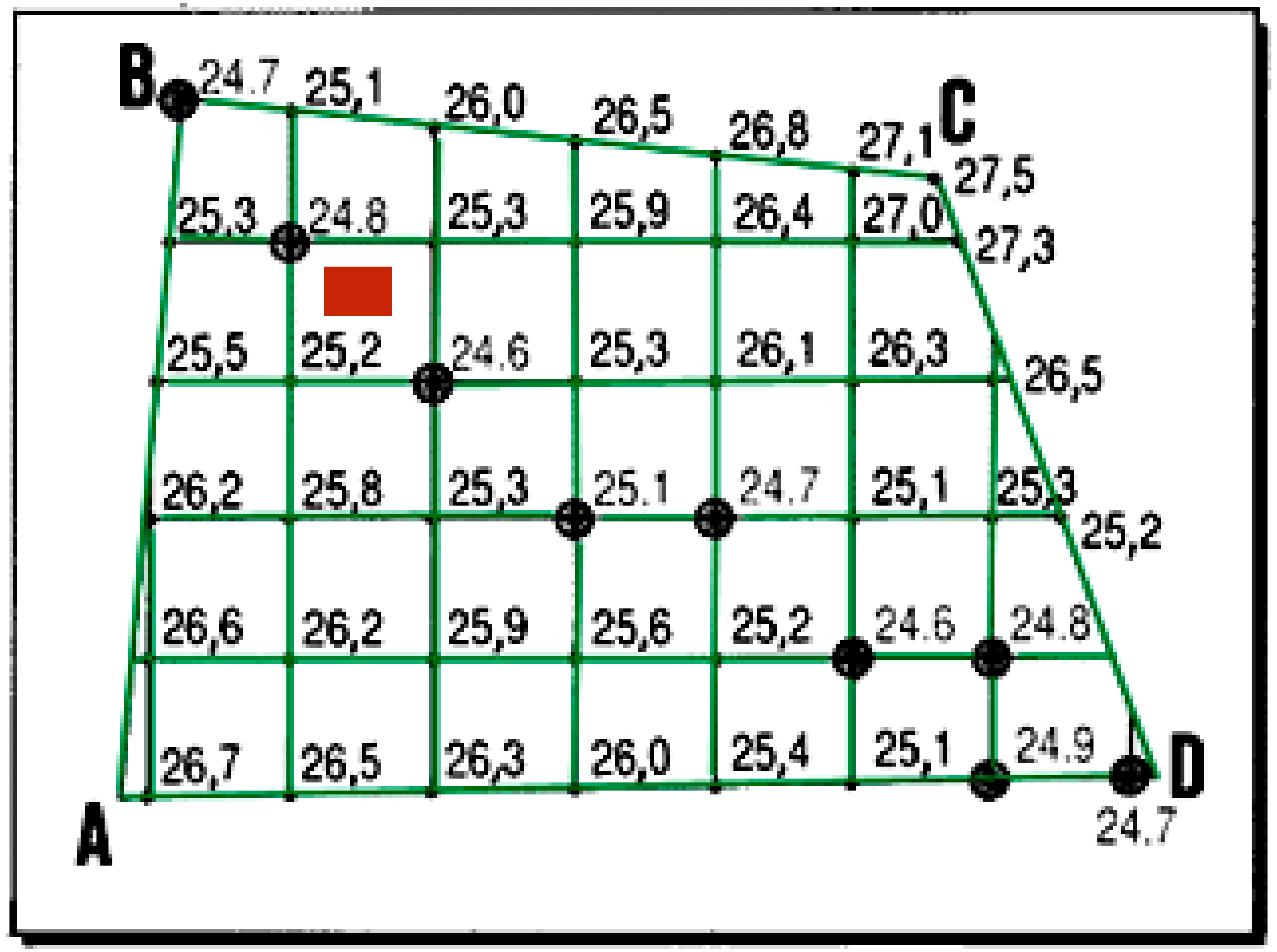
Making a contour map

- Find the points of lower ground elevation. Then, according to the contour interval you have chosen, determine which elevation represents the first contour line you need to draw.

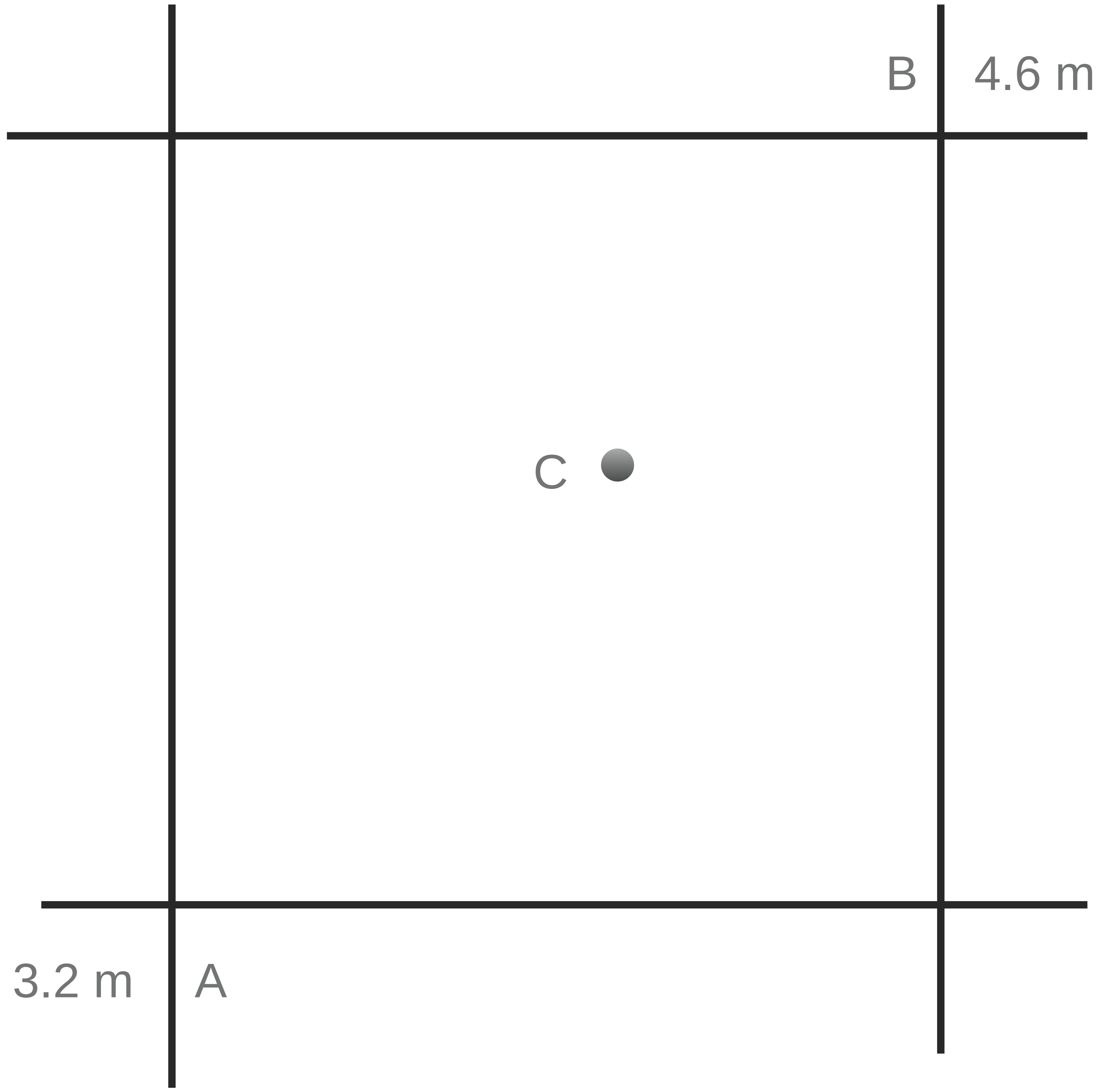


Making a contour map

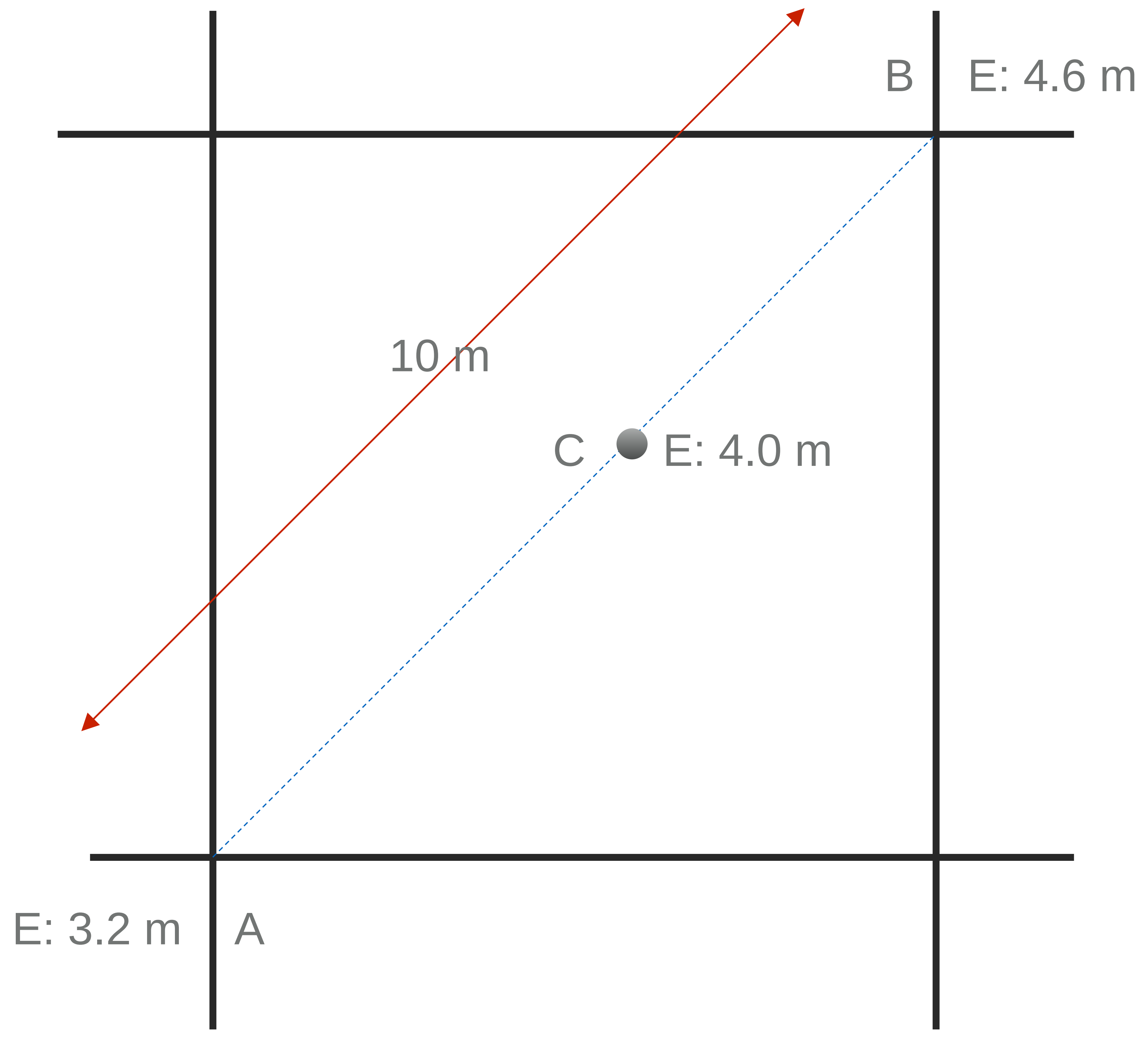
- The first contour line will pass between ground points with elevations which are lower and higher than the elevation of the contour points. Carefully locate the path of the contour line between these higher and lower points, as you draw.
- Note that contour lines are usually curved, not straight. You should draw them free-hand, rather than using a ruler to connect the points.



Making a contour map



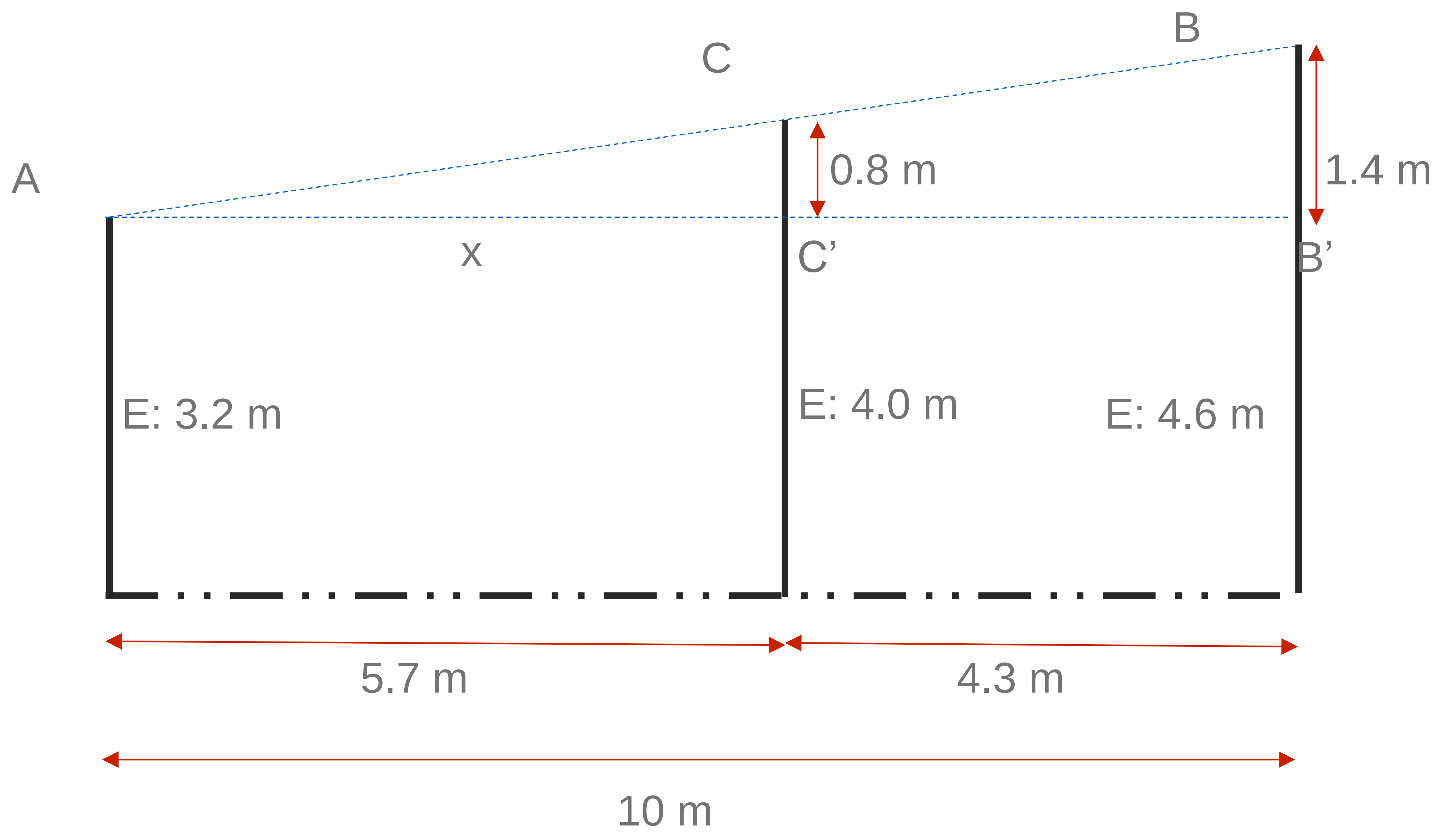
The ground slope between any two grid corners is assumed to be constant. The position of the contour point on the line between the two corners is determined by ratio method.



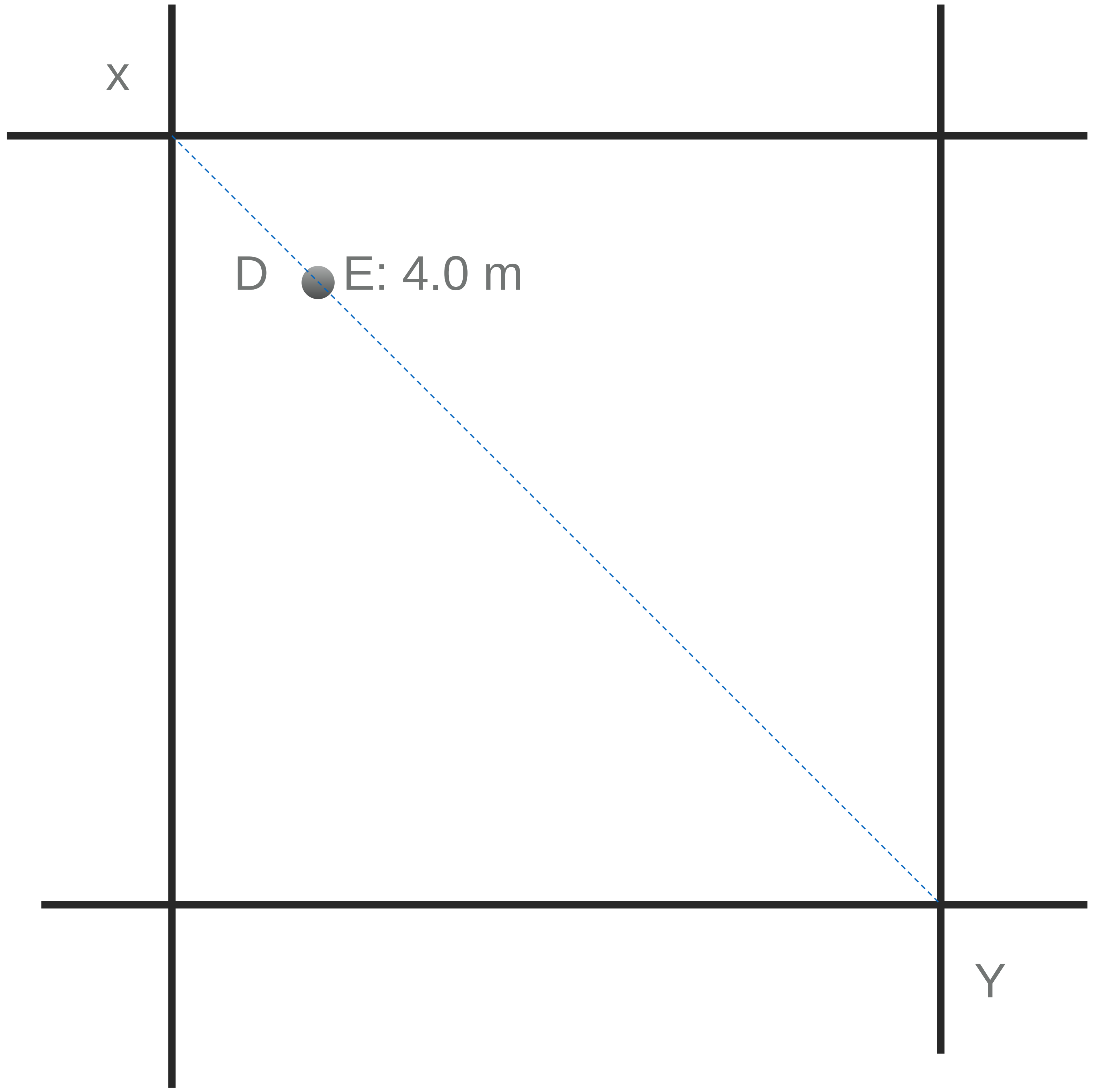
Making a contour map

- Assume two neighbouring grid corners, A and B of levels 3.2m and 4.6m respectively. Horizontal ground distance between A and B is 10m.

Making a contour map

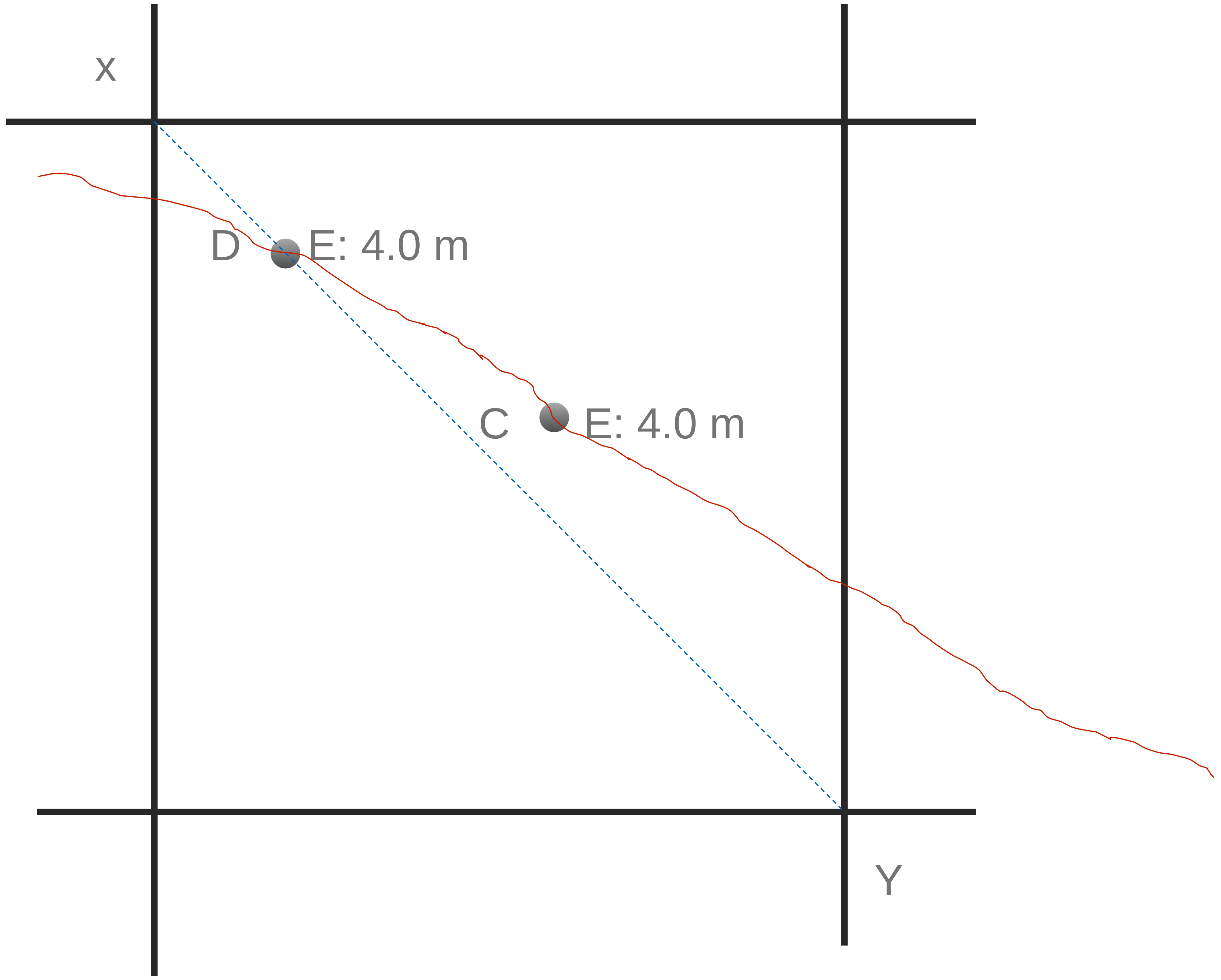


- To locate position of point C of level 4.0m:
- 1) level B – level A= 4.6 -3.2 = 1.4m.
- 2) Level C – level A = 4.0 – 3.2 = 0.8m.
- From similar triangles ACC' and ABB',
- 3) x/0.8 = 10/1.4 ➔ x = 0.8*10/1.4 = 5.7m.



Making a contour map

- Next step is to search for the point of elevation 4.0m on the neighbouring grid side.



Making a contour map

- Locate this point and join it with point C. This forms contour line 4.0m in this first grid cell.

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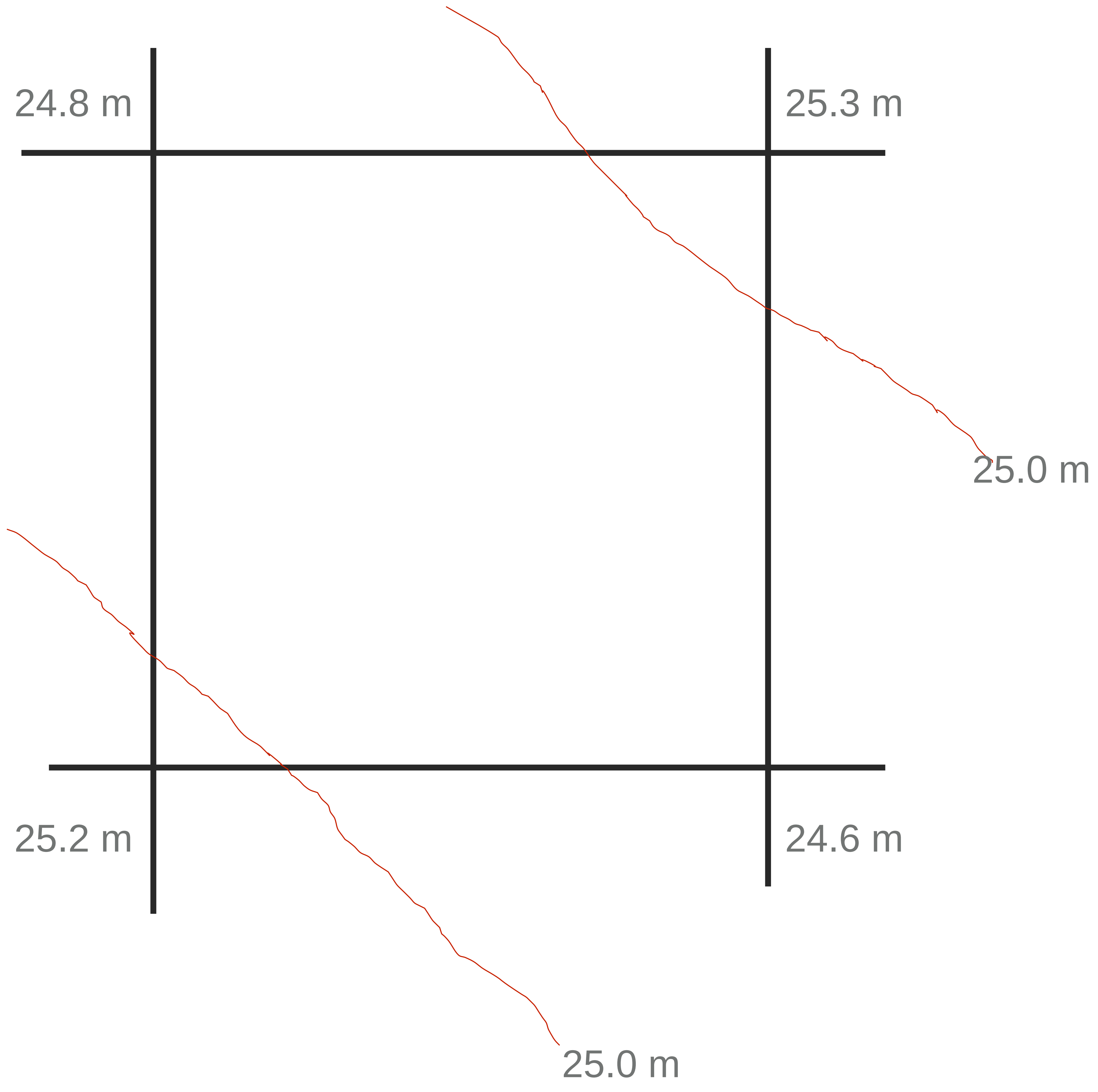


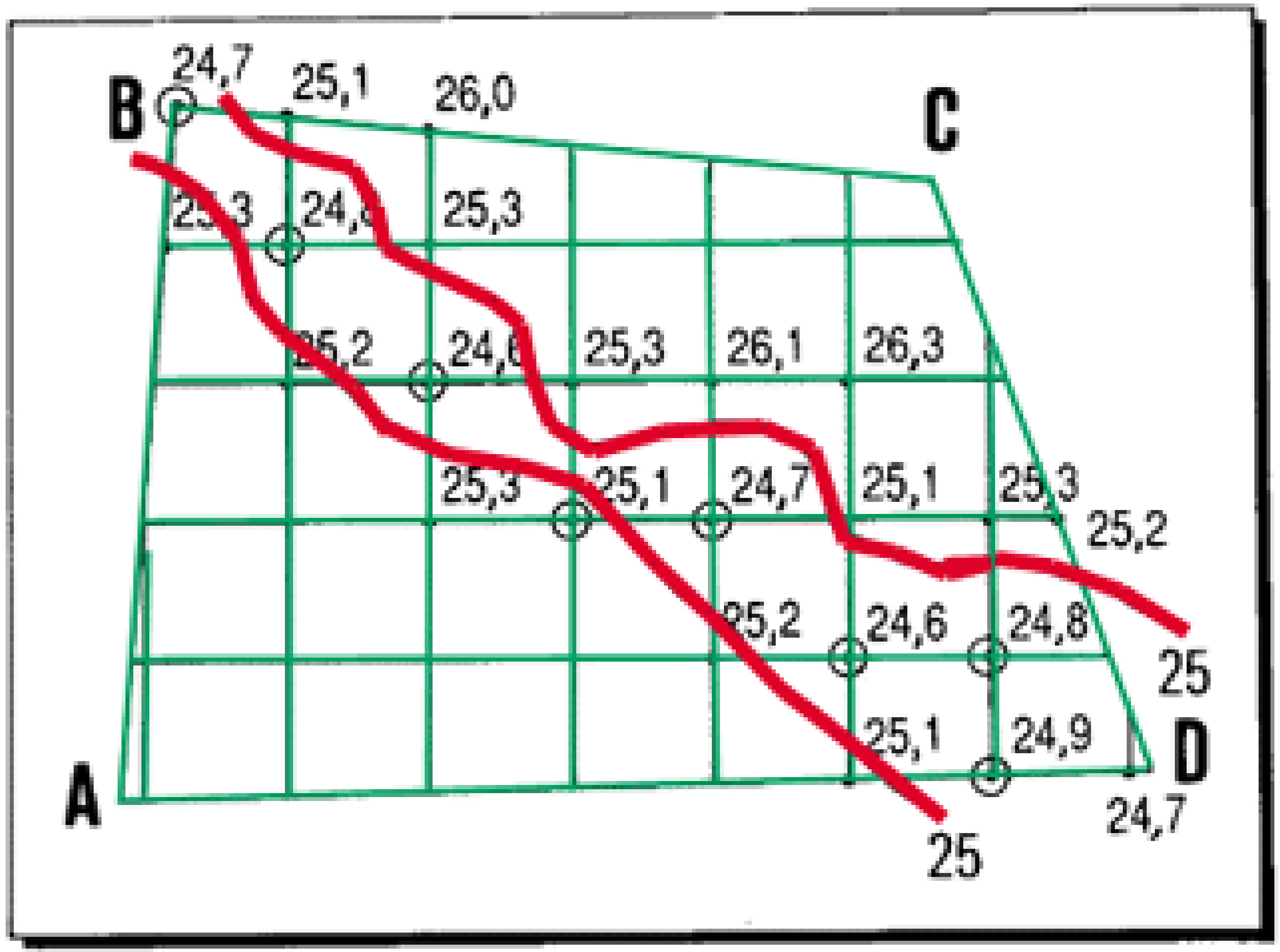
Making a contour map

- A grid cell from the above grid is used here as an example to draw contour line 25.0m

Making a contour map

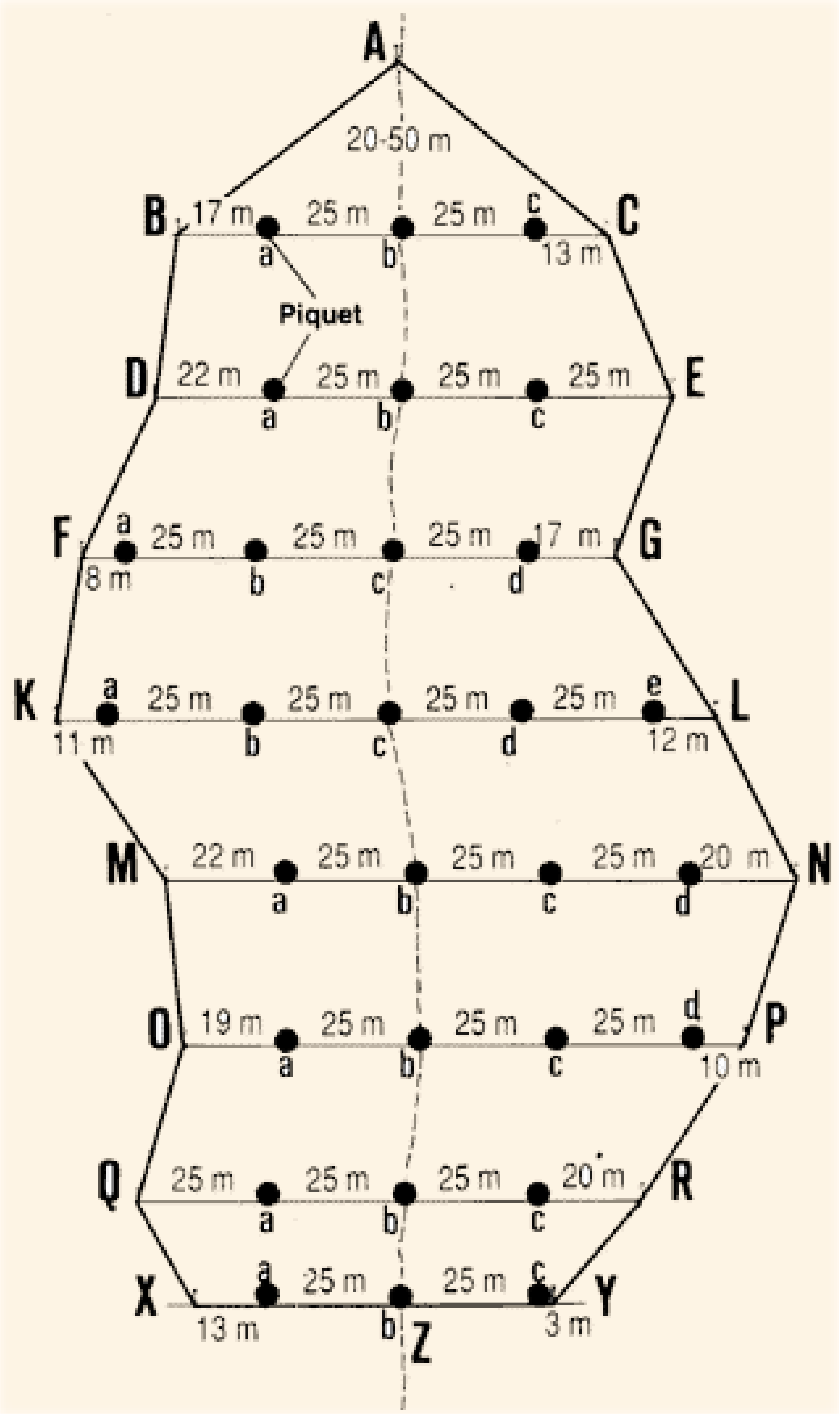
- Using the same procedure, draw the other contour lines. Show the progressively higher elevations as multiples of the selected contour interval.

- Note: contour lines are only drawn for elevations which are multiples of the contour interval. Show the elevations of the contours by writing in numbers at appropriate intervals



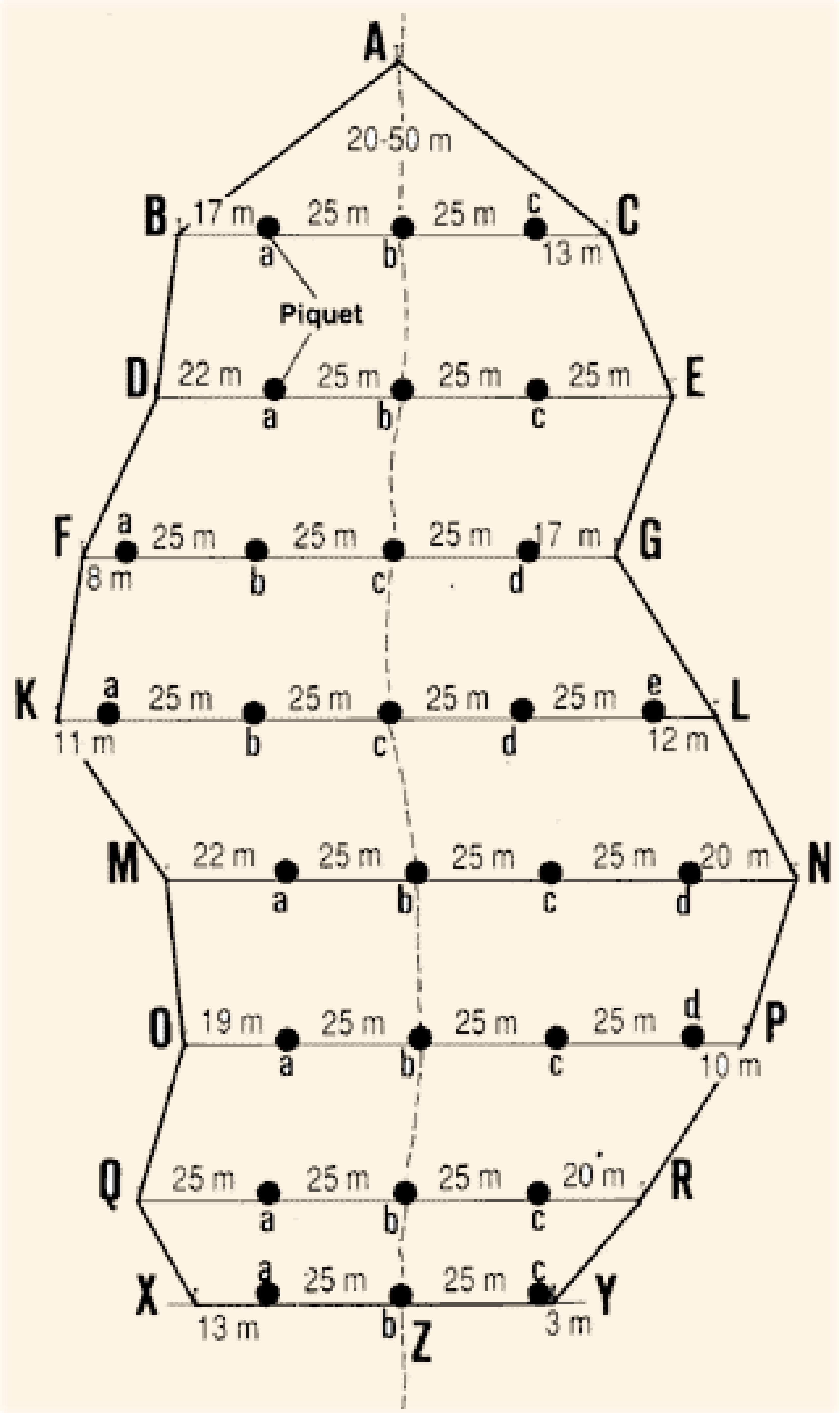
Volume From Longitudinal and Cross Sections

- For determining the volume of earth cut or fill from longitudinal profile:
- 1) Every 20 to 50 m along the longitudinal axis AZ of the project, (reservior) mark perpendicular lines BC, DE ... QR within the area enclosed by contour E(A). Use wooden pegs at equal intervals along the perpendiculars (cross sections), and mark them on each side of the axis AZ.



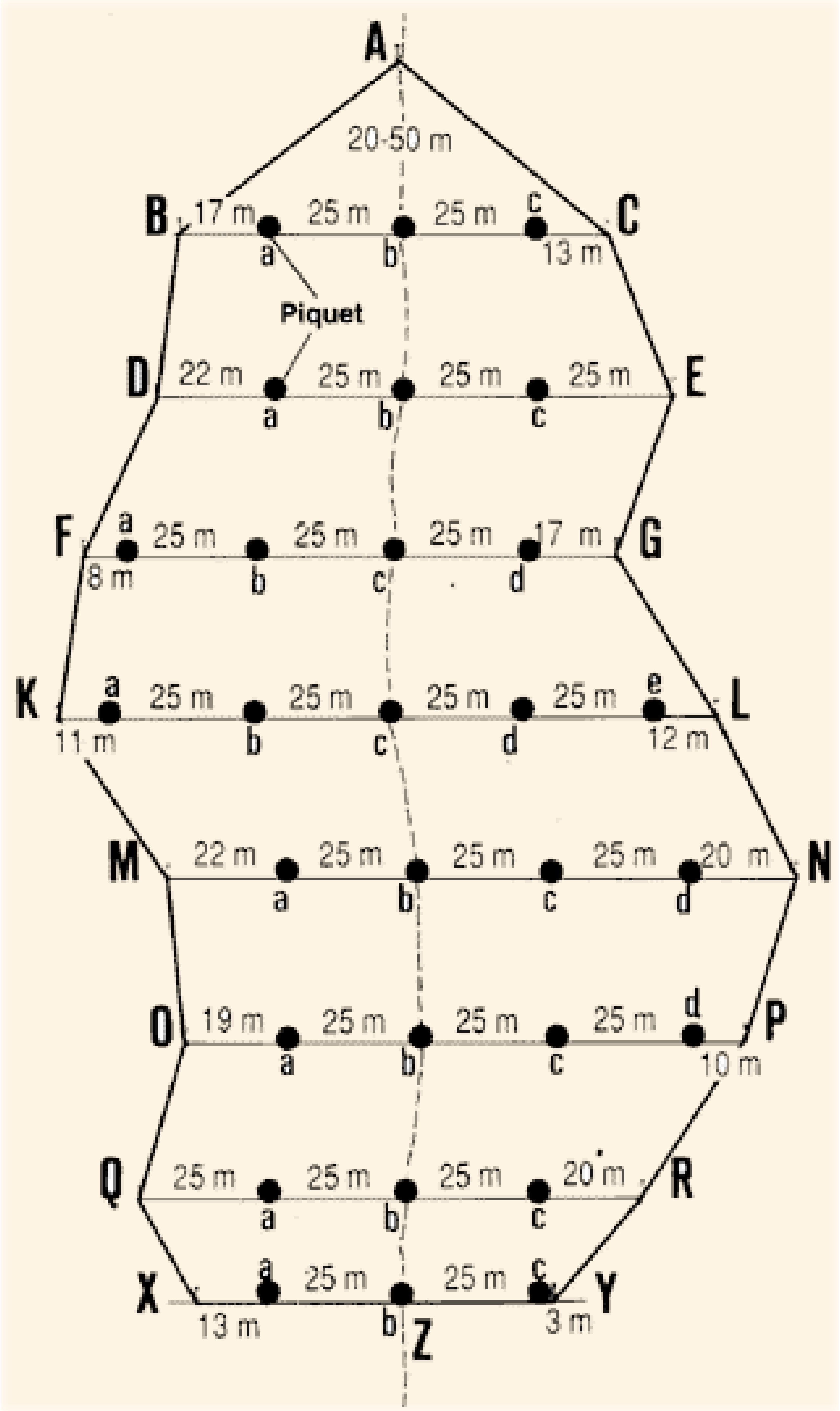
Volume From Longitudinal and Cross Sections

- 2) Start from end-point B of line BC, on contour E(A) where the maximum water level will line up with the ground elevation. Using a target levelling staff and a sighting level, transfer elevation E(A) to the top of the pegs a, b and c. Drive them into the ground until they are at the correct elevation. Pegs a, b and c now clearly show the maximum depth of water which will be present at each of these points when the reservoir is full.



Volume From Longitudinal and Cross Sections

- 3) Repeat this procedure for each transversal line DE, FG ... QR successively; similarly, stake out XY, the centre line of the proposed dike.



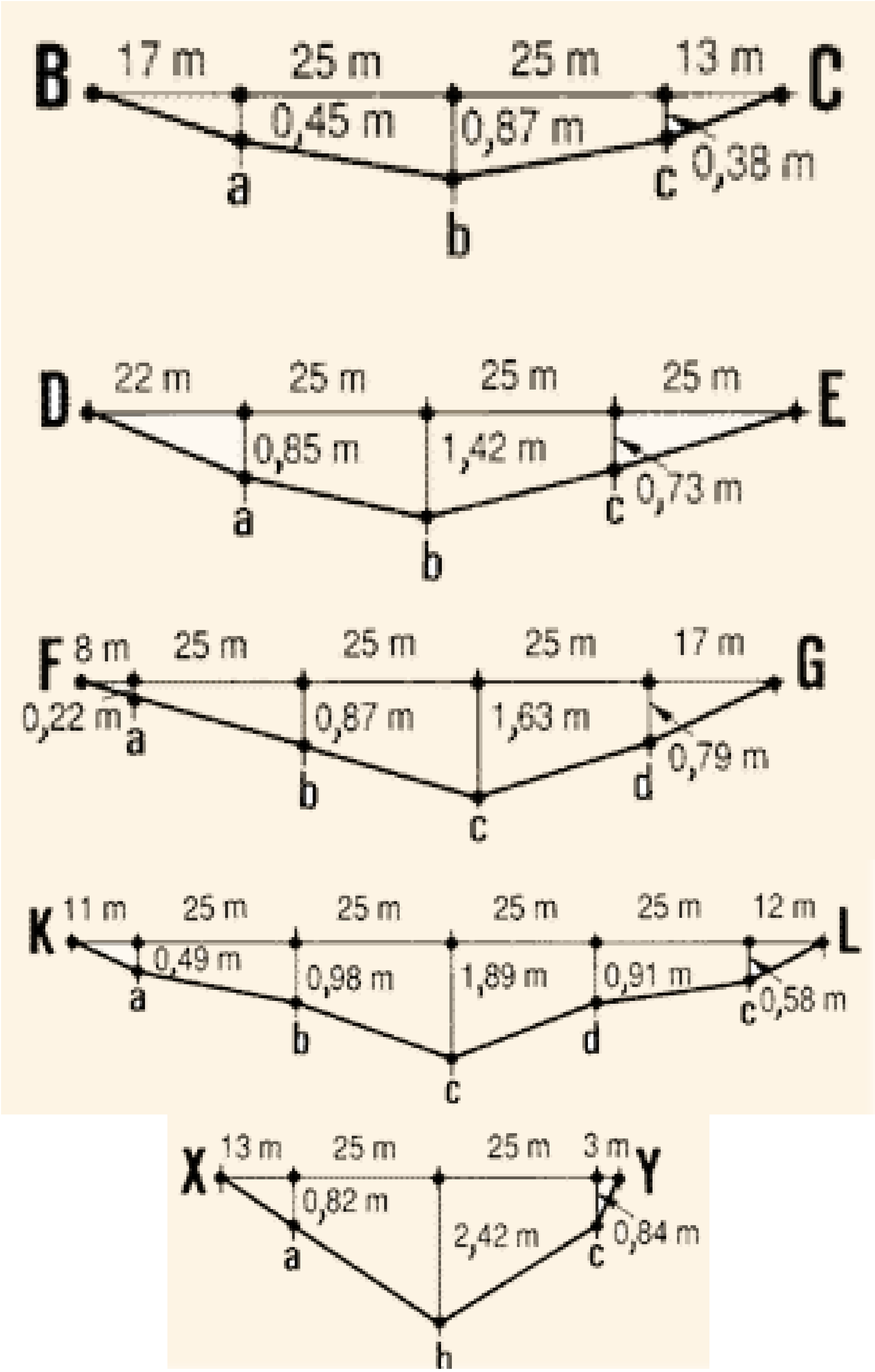
Volume From Longitudinal and Cross Sections

- 4) In a simple table, measure and record the height of each peg above ground level for each transversal line, including line XY, as shown in the example.

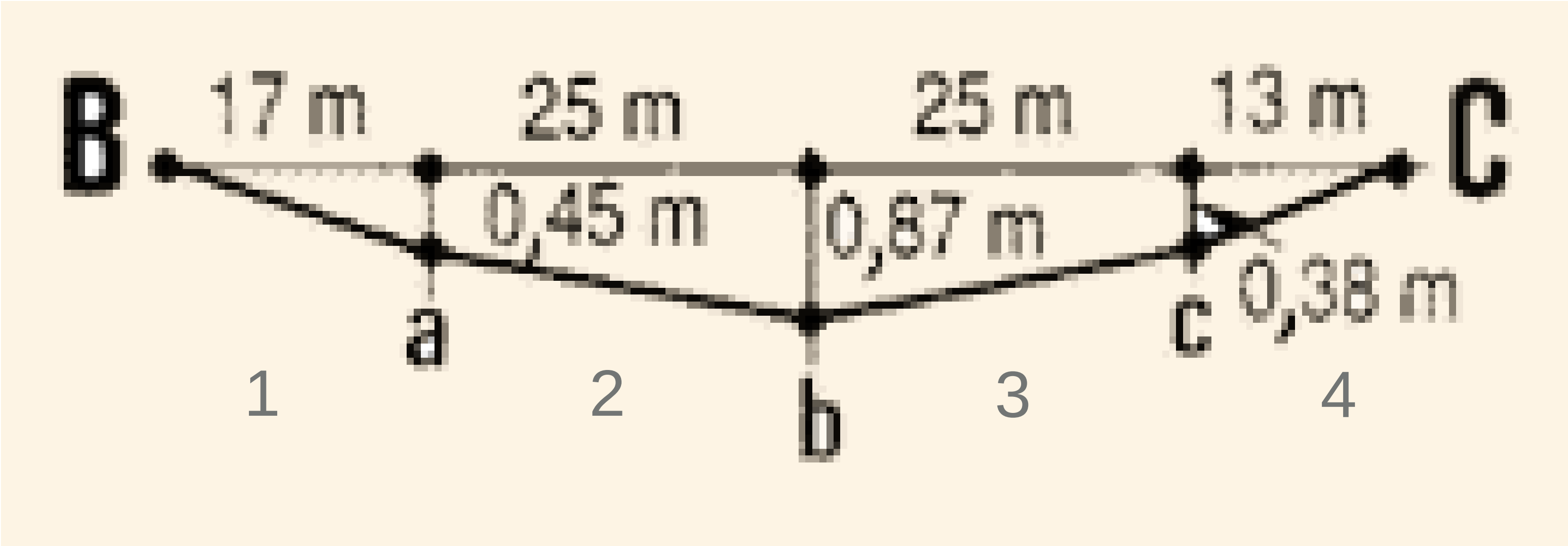
Line	Peg height, m				
	a	b	c	d	e
BC	0.45	0.87	0.38	-	-
DE	0.85	1.42	0.73	-	-
FG	0.22	0.87	1.63	0.79	-
KL	0.49	0.98	1.89	0.91	0.58
...	...	...	...	...	...
XY	0.82	2.42	0.84	-	-

Volume From Longitudinal and Cross Sections

- 5) Using the correct scale, draw the cross-sections BC, DE ... QR, and XY of the completely filled reservoir on square-ruled millimetric paper. Use a vertical scale 10 times larger, for example, than the horizontal distance scale. Remember that the end-points of each cross-section have, by definition, a zero depth of water



Volume From Longitudinal and Cross Sections



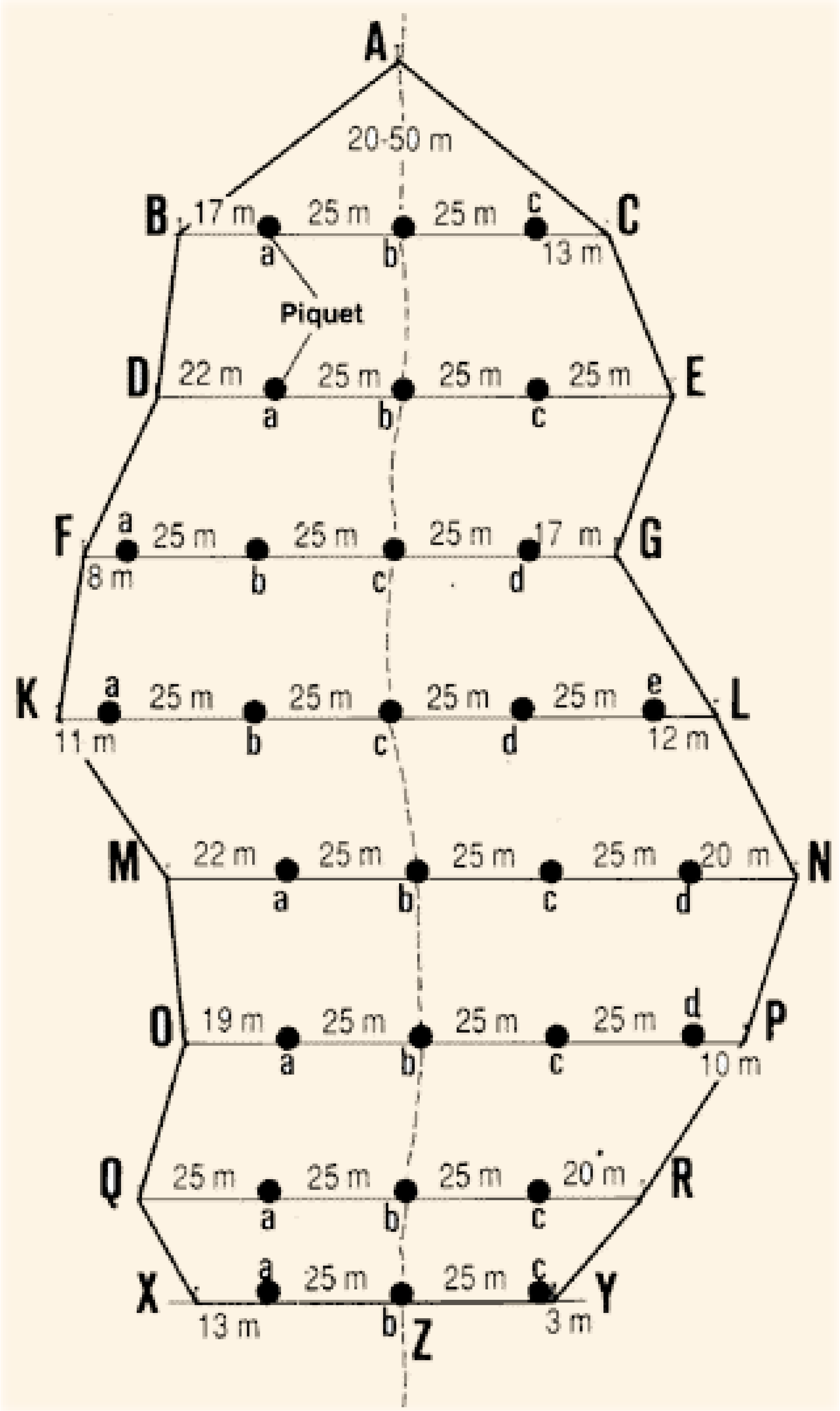
- 6) Calculate the area of each cross-section, adding the partial areas of triangles and trapeziums as necessary.

- Example : Area BC = triangle 1 + trapezium 2 + trapezium 3 + triangle 4

- Triangle 1 = (17 m x 0.45 m) ÷ 2 = 3.825 m2
- Trapezium 2 = [(0.45 m + 0.87 m) ÷ 2] x 25 m = 16.500 m2
- Trapezium 3 = [(0.87 m + 0.38 m) ÷ 2] x 25 m = 15.625 m2
- Triangle 4 = (13 m x 0.38 m) ÷ 2 = 2.470 m2
- Total Area under BC = 38.420 m2

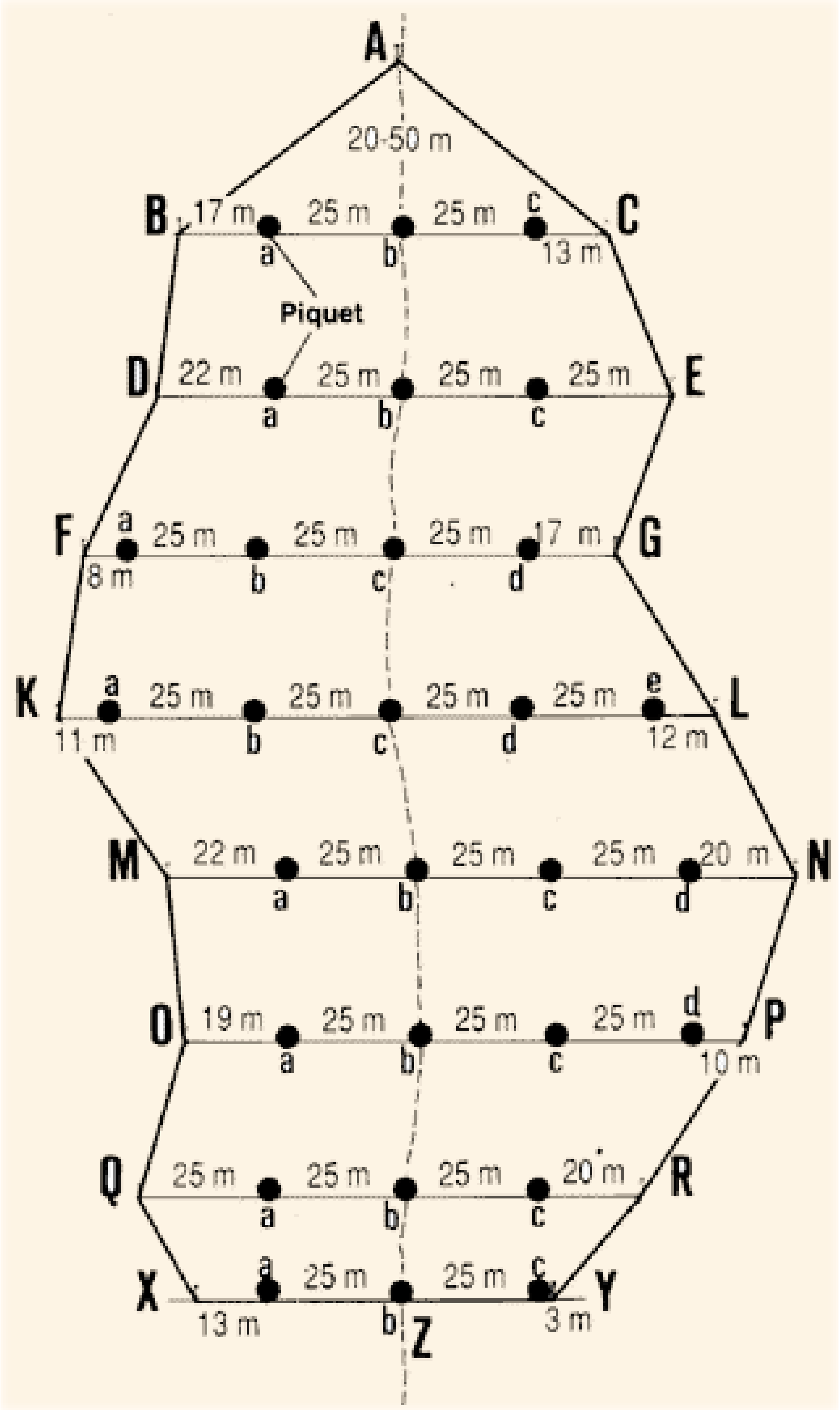
Volume From Longitudinal and Cross Sections

- 7) Add the areas of cross-sections BC, DE ... QR, and multiply this sum by the fixed interval between cross- sections (in this case, 25 m) to obtain an estimate of the volume of the reservoir upstream from the last cross- section QR.
- Example
- Volume of reservoir from point A to line QR = (area BC + area DE + ... + area QR) x 25 m

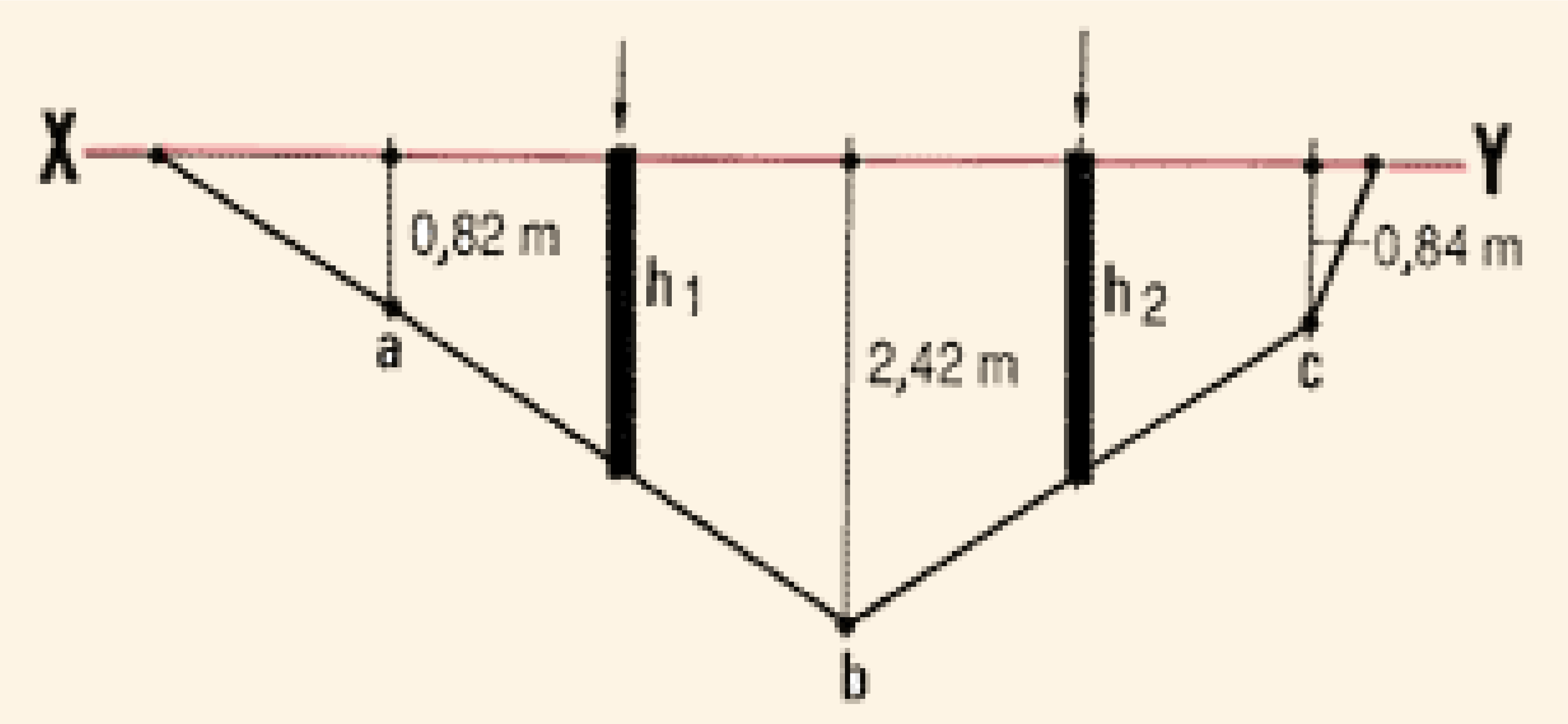


Volume From Longitudinal and Cross Sections

- 8) Estimate the volume of the last section of the reservoir, between cross-section QR and the dike's centre-line XY. Multiply the area of cross-section XY by half the distance between previous cross-sections.
- Volume section QR to XY = (area XY) x (25 m ÷ 2)
- Calculate the volume of the entire reservoir by adding:
- the volume A to QR; and the volume of QR to XY



Estimating the volume of an earth dam



- To rapidly estimate the volume of an earth dike XY to be built across a given valley, use the following method. It will provide a volume estimate about 10 percent smaller than the actual volume. But this level of accuracy is good enough for the initial estimate.
- Using the information from the above table, calculate the heights h of the dam XY at mid-points between consecutive pegs.

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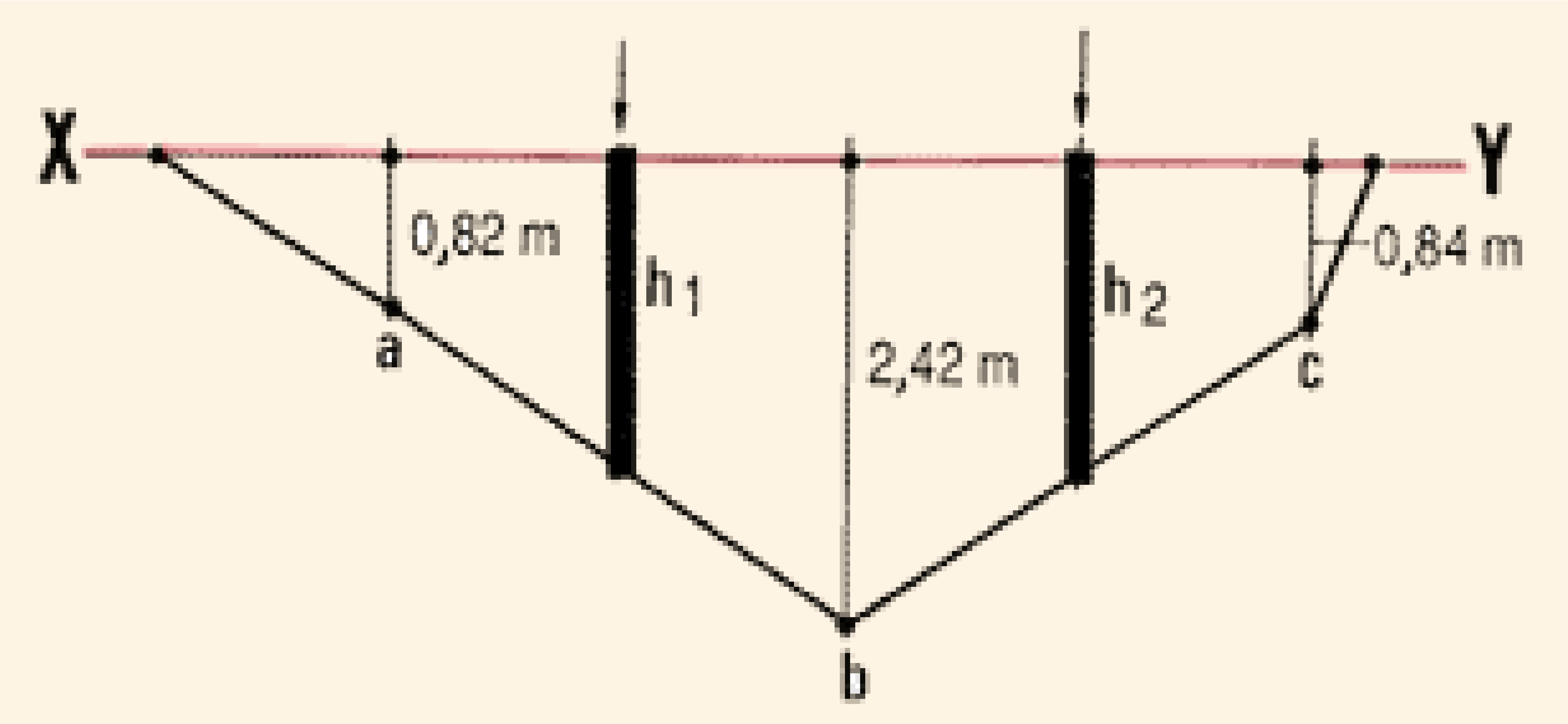
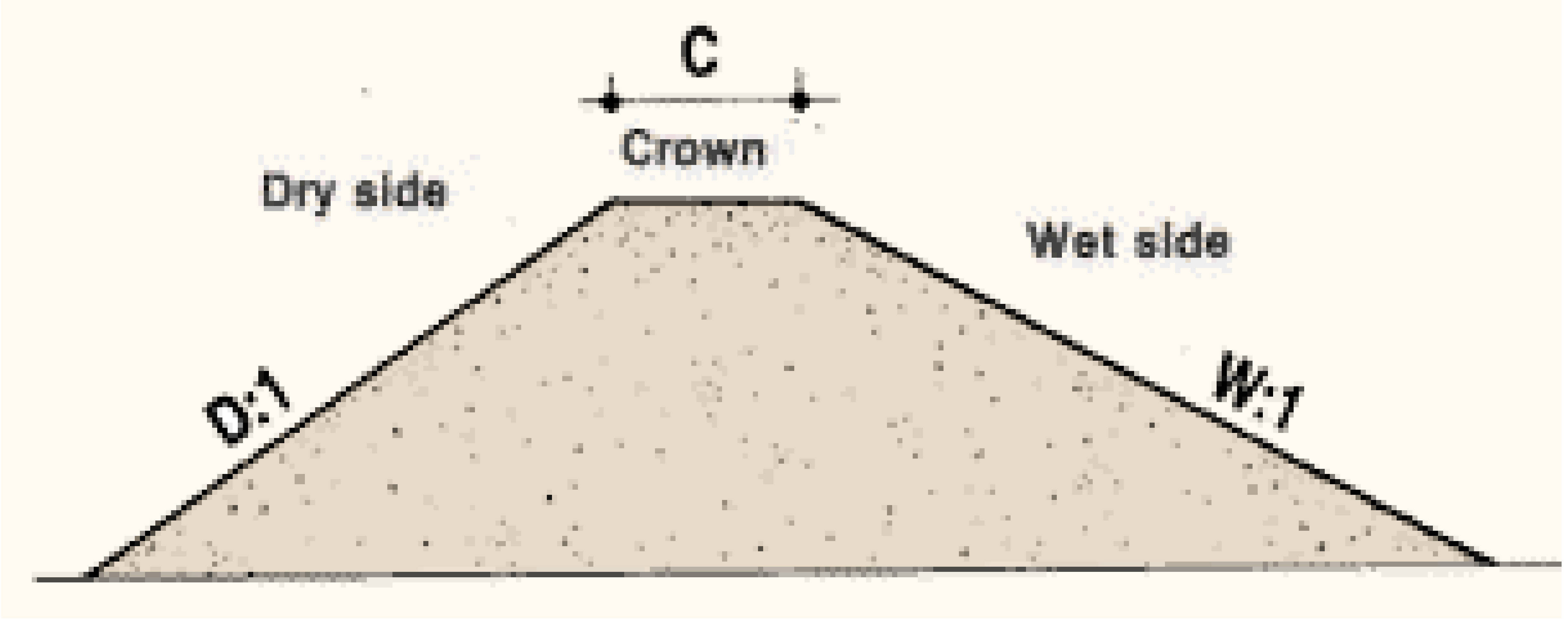
Estimating the volume of an earth dam

- Example
- For the dam XY there are only two mid-points to consider: one between pegs a and b, and one between pegs b and c.
- Dike height a-b: h1= (0.82 m + 2.42 m) ÷ 2 = 1.62 m
- Dike height b-c: h2= (2.42 m + 0.84 m) ÷ 2 = 1.63 m



Estimating the volume of an earth dam

- Using the correct scale, draw the transversal section of the type of dike you plan to build. There are three measurements, in particular, which you must determine:
- •the width C of the highest point, or crown, of the dike;
- •the dry-side slope of the wall outside the reservoir, D: 1;
- •the wet-side slope of the wall inside the reservoir, W: 1.



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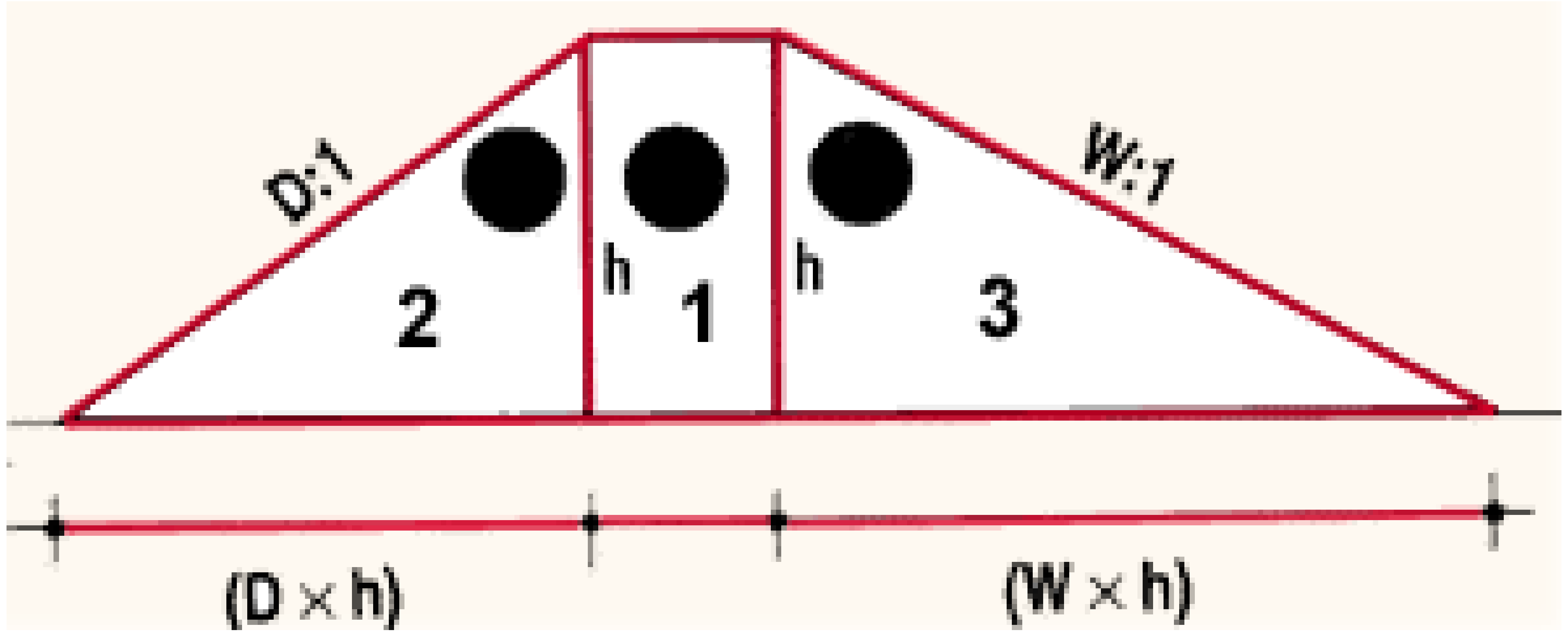
Estimating the volume of an earth dam

- If you know these characteristics of the dike, you can calculate the area of any transversal section of this dike by adding:
- • rectangle 1 area = C x h;
- • triangle 2 area = (D x h) x (h ÷ 2);
- • triangle 3 area = (W x h) x (h ÷ 2).



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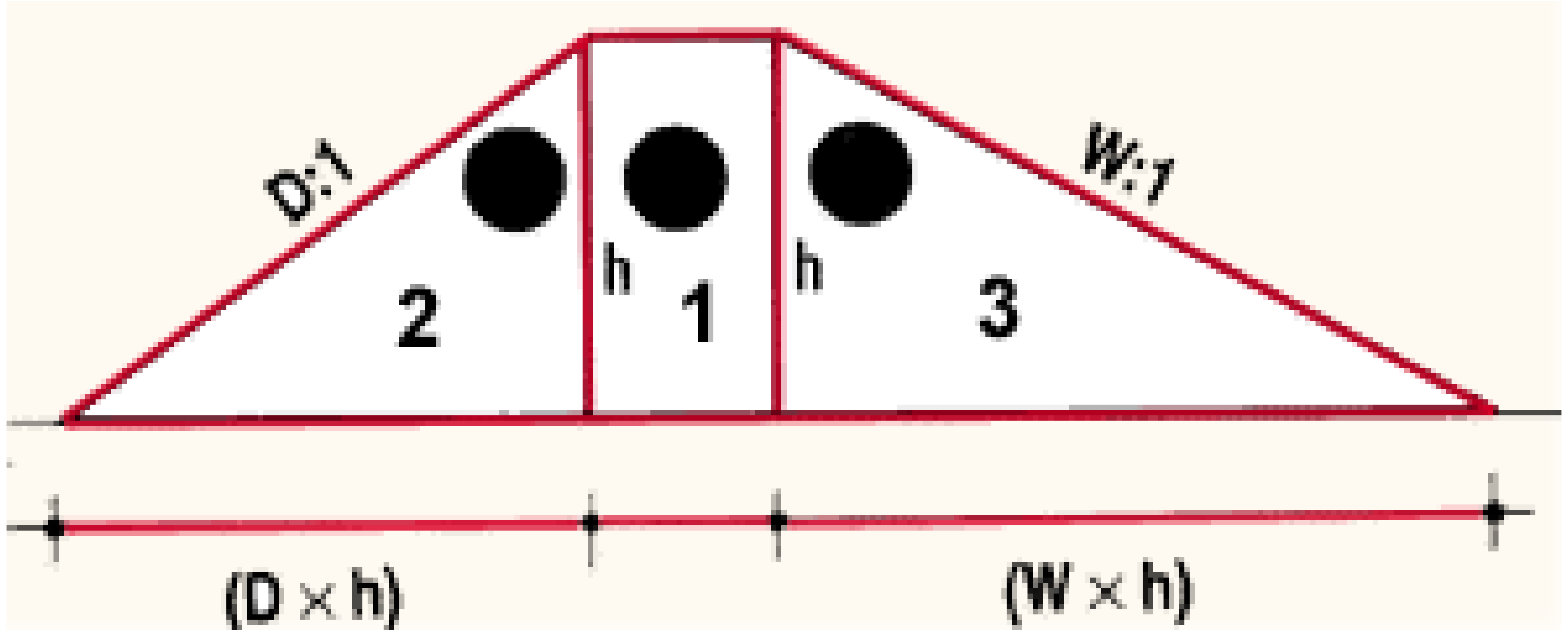
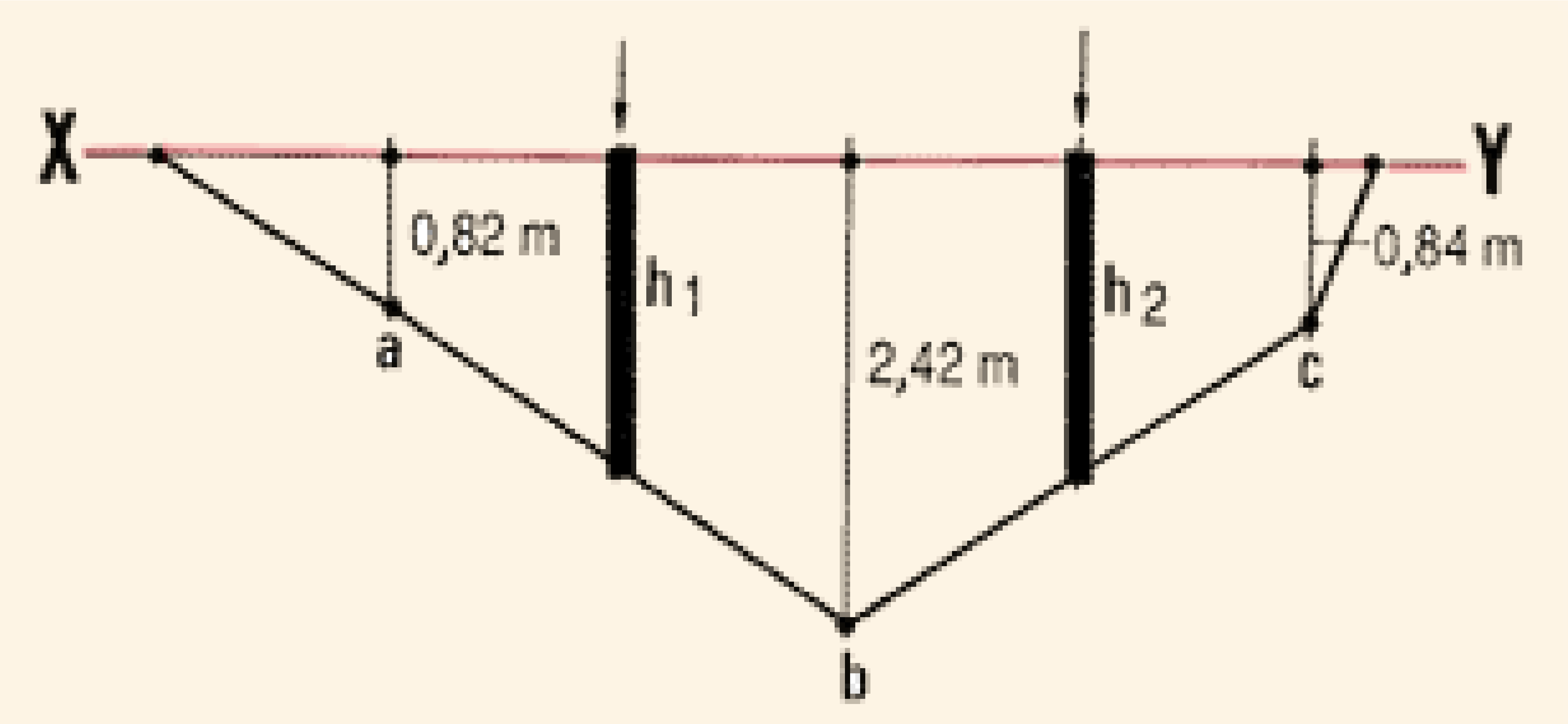
Estimating the volume of an earth dam

- Therefore, the area A of any transversal section of the dike equals:
- $A = (Ch) + (Dh^2 \div 2) + (Wh^2 \div 2)$,
- where C is the crown width of the dike, h the height, D the dry slope, and W the wet slope.



Estimating the volume of an earth dam

- Apply the above formula to successively calculate the section area of the dike at each of the XY mid-points, using the h-values already obtained.
- Example
- If the dike characteristics are fixed as follows:
- C = 4 m; dry slope = 1.5: 1; wet slope = 2: 1;



Estimating the volume of an earth dam

- the dike's transversal section areas are:
- - At mid-point a/b where $h1 = 1.62$ m
- A1= (4 m x 1.62 m) + (1.5 x 1.622 m) ÷ 2 + (2 x 1.622 m) ÷ 2 = 6.48 m2 + 1.97 m2 + 2.62 m2 = 11.07 m2
- - At mid-point b/c where $h2 = 1.63$ m
- A2 = (4 m x 1.63 m) + (1.5 x 1.632 m) ÷ 2 + (2 x 1.632 m) ÷ 2 = 6.52 m2 + 1.99 m2 + 2.66 m2 = 11.17 m2

Estimating the volume of an earth dam

- Calculate the partial volumes of each portion of the dike marked by pegs a, b, c, etc. To do this, multiply each corresponding mid-point section area by the length of the dam portion.
- Example
- Partial volumes of the dike with pegs a, b and c at 25 m intervals:
-     - For portion a/b V1 = A1 x 25 m = 11.07 m2 x 25 m = 276.75 m3
-     - For portion b/c V2 = A2 x 25 m = 11. 17 m2 x 25 m = 279.25 m3
- Obtain the estimate of the total volume of the dike by adding these partial volumes.
- Total volume of dike XY = 276.75 m3 + 279.25 m3 = 556 m3

Estimating the volume of an earth dam

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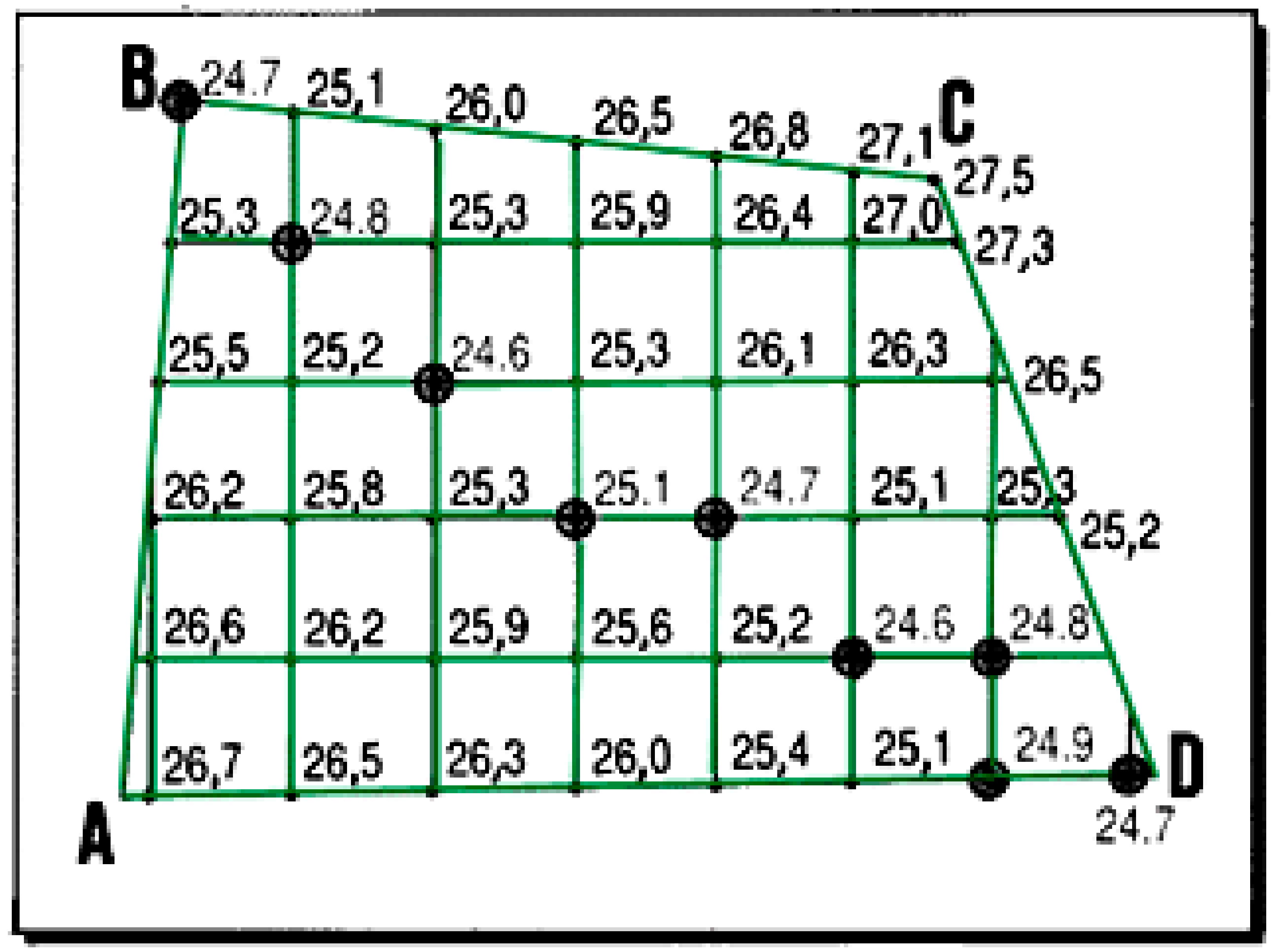
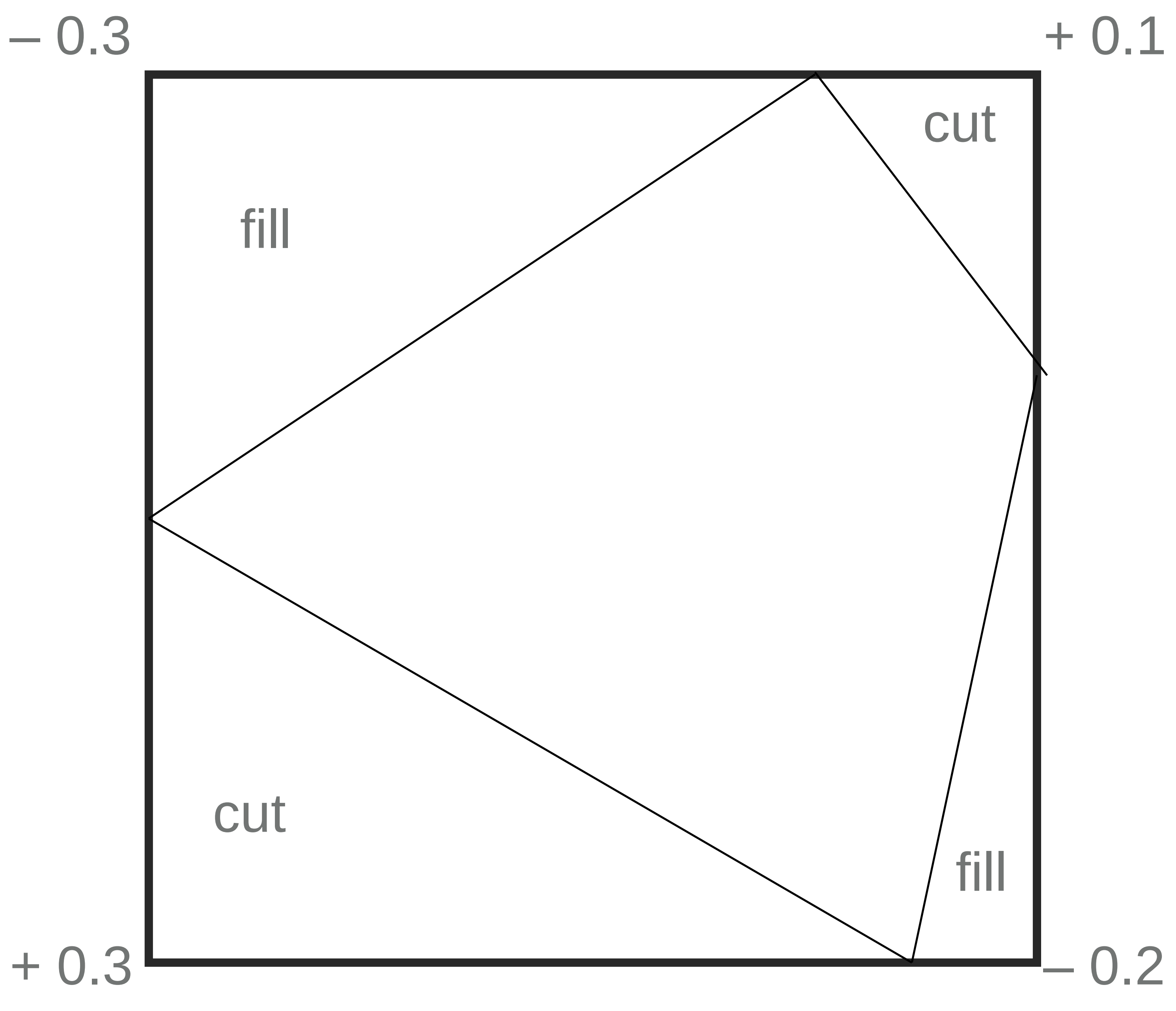
Volume from Grid Levelling

- It is required to compute the volume of cut to level the area to elevation 20.0m.
- For each grid cell,
- the volume of cut = average height of cut for the four corners x base area
- For first grid with left top corner B, assume area of base = 100 m^2
- Average of depths of cut of four corners= (4.7+5.1+4.8+5.3)/4 = 4.975m
- Volume of cut for this cell= 100x4.975= 497.5 m^3
- This is computed for each cell and the total volume is determined by adding them all.



Volume from Grid Levelling

- If the level of this first cell is to be levelled to 25.0m. There will be some parts requiring fill and others requiring cut. These should be separated by plotting contour line 25.0m and then compute cut volume and fill volume separately.
- Points with level 25.0 are joined by straight lines as shown below. Depths of fill and cut are shown on each corner.
- For each triangular area of cut or fill compute the average depth of cut or fill for the three corners of the triangle, for example top left corner triangle with corner B (-0.3)m
- The average depth of ill= (0.3+0.0+0.0)/3= 0.1m. Assume area of this triangle = 18m^2, the volume of fill will be= 0.1x18= 1.8m^3.
- Other volumes of cut and fill will be similarly calculated.



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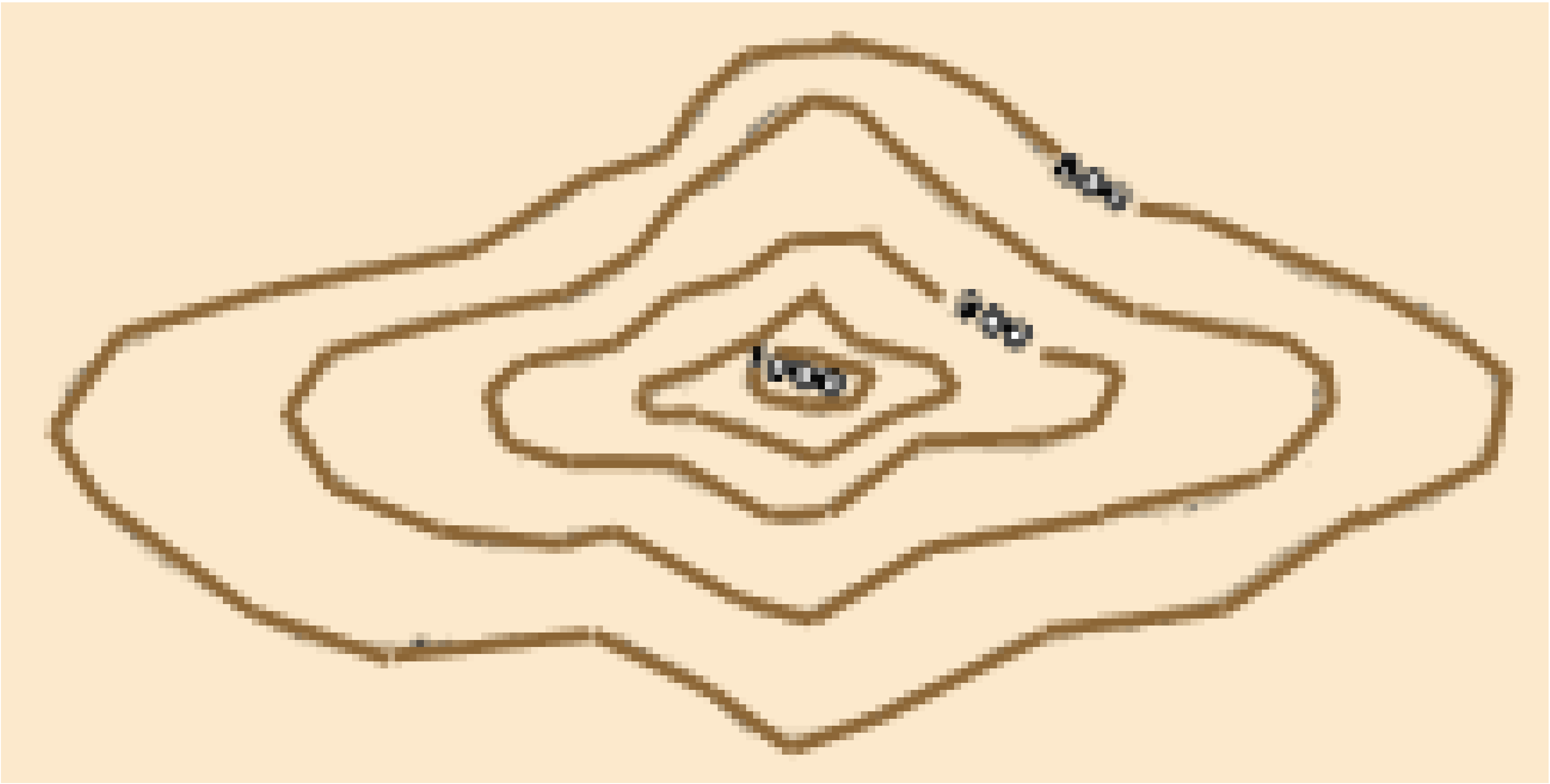
Volume from Contour Map

- The contour plot shows a hilly area contoured from 800m to 1000m. contour interval is 50m.
- Compute the volume of cut to level the area to 800m. Area within each contour line is measured using a planimeter and given in table below:

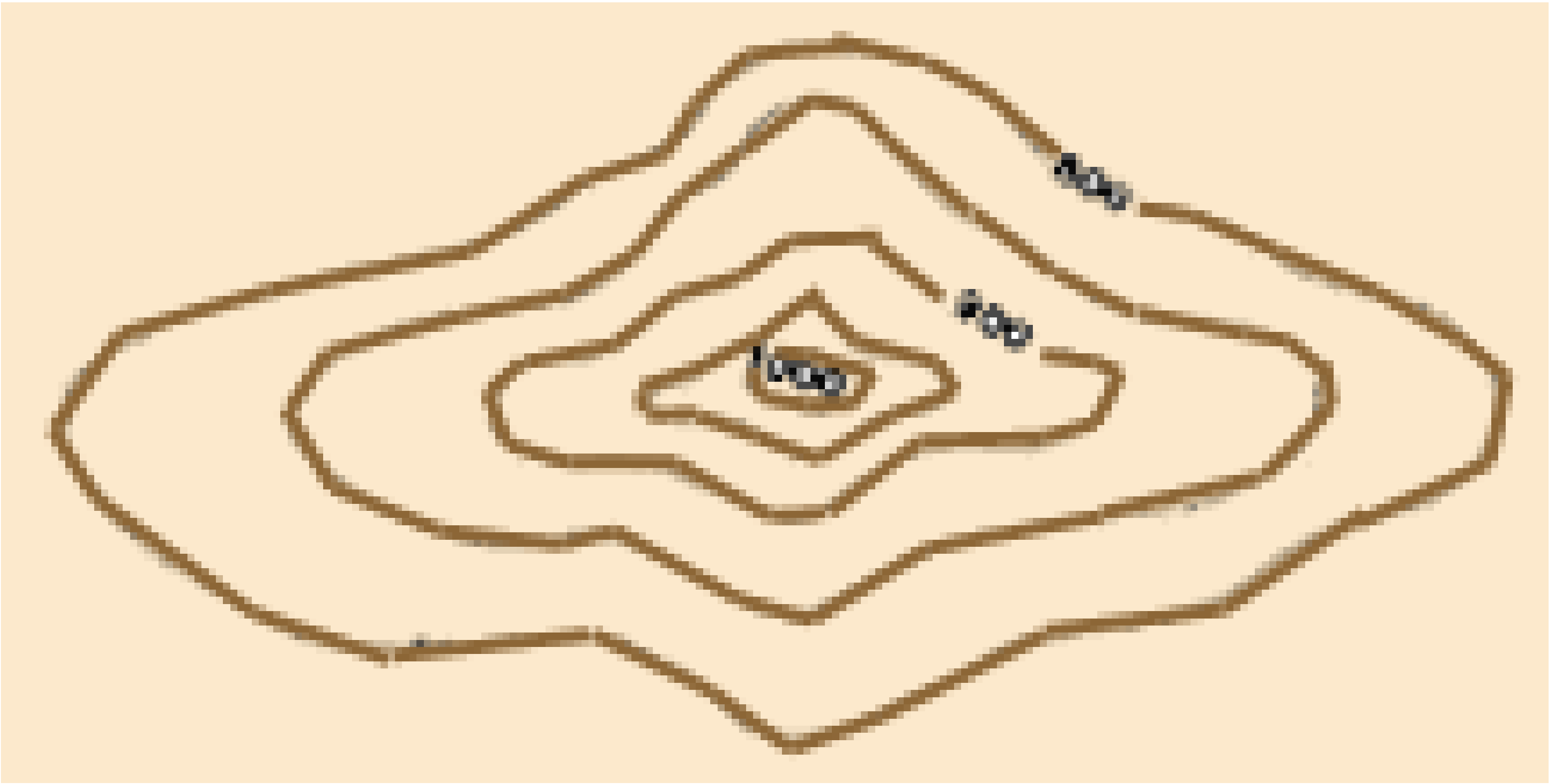


CONTOUR (M)	800	850	900	950	1000
ENCLOSED AREA (M^2)	2000	1600	1000	800	200

Volume from Contour Map

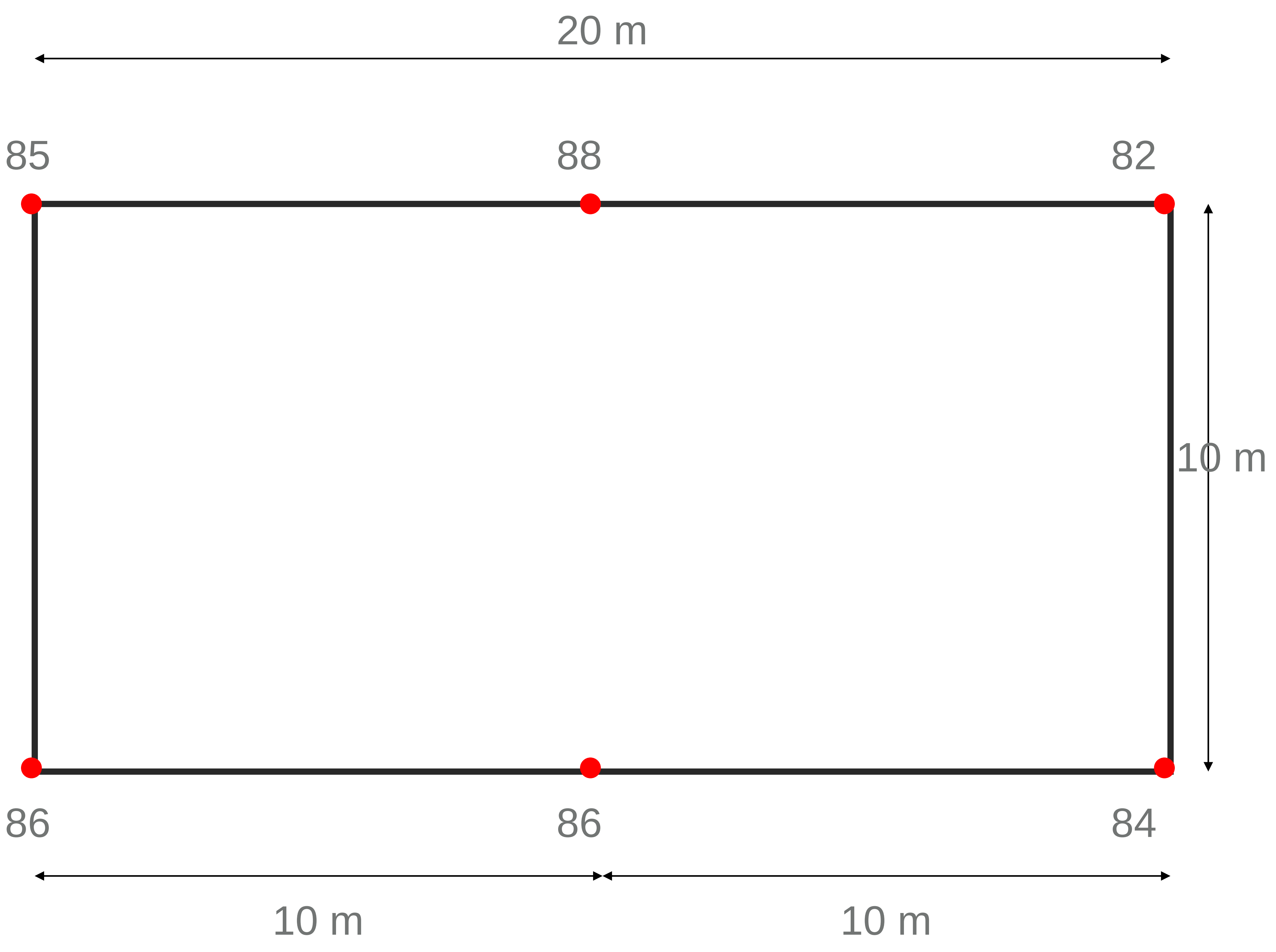
- Volume of cut between 800 and 850m contours = 50x(2000+1600)/2 = 90000m3
- Volume of cut between 850 and 900 contours = 50x(1600+1000)/2 = 65000m3
- Volume of cut between contours 900 and 950m = 50x(1000+800)/2= 45000 m3
- Volume of cut between contours 950 and 1000m = 50x(800+200)/2 = 25000 m3
- Total volume of cut from 800 to 1000 contours = 225000 m3
- There remains the volume between contour 1000m and the peak point of the hill.
- Assume level of peak point is 1020m, then height difference between contour 1000m and peak is 1020 – 1000 = 20m. Volume of cut between contour 1000m and peak point is 20x(200+0)/2 = 2000 m3.
- Total volume of cut from peak to level 800m is 225000+2000= 227000 m3

- Volume of cut between level 800m and 1000m can be computed using one step:
- Volume=(50/2)x(2000+200+2[1600+1000+800]) = 25x9000 = 225000 m3.



Volume from Contour Map

- Example:
- A) Draw contour lines 83, 85, 87m.
- B) The land to be levelled to elevation 85 m. compute the volume of cut and fill.

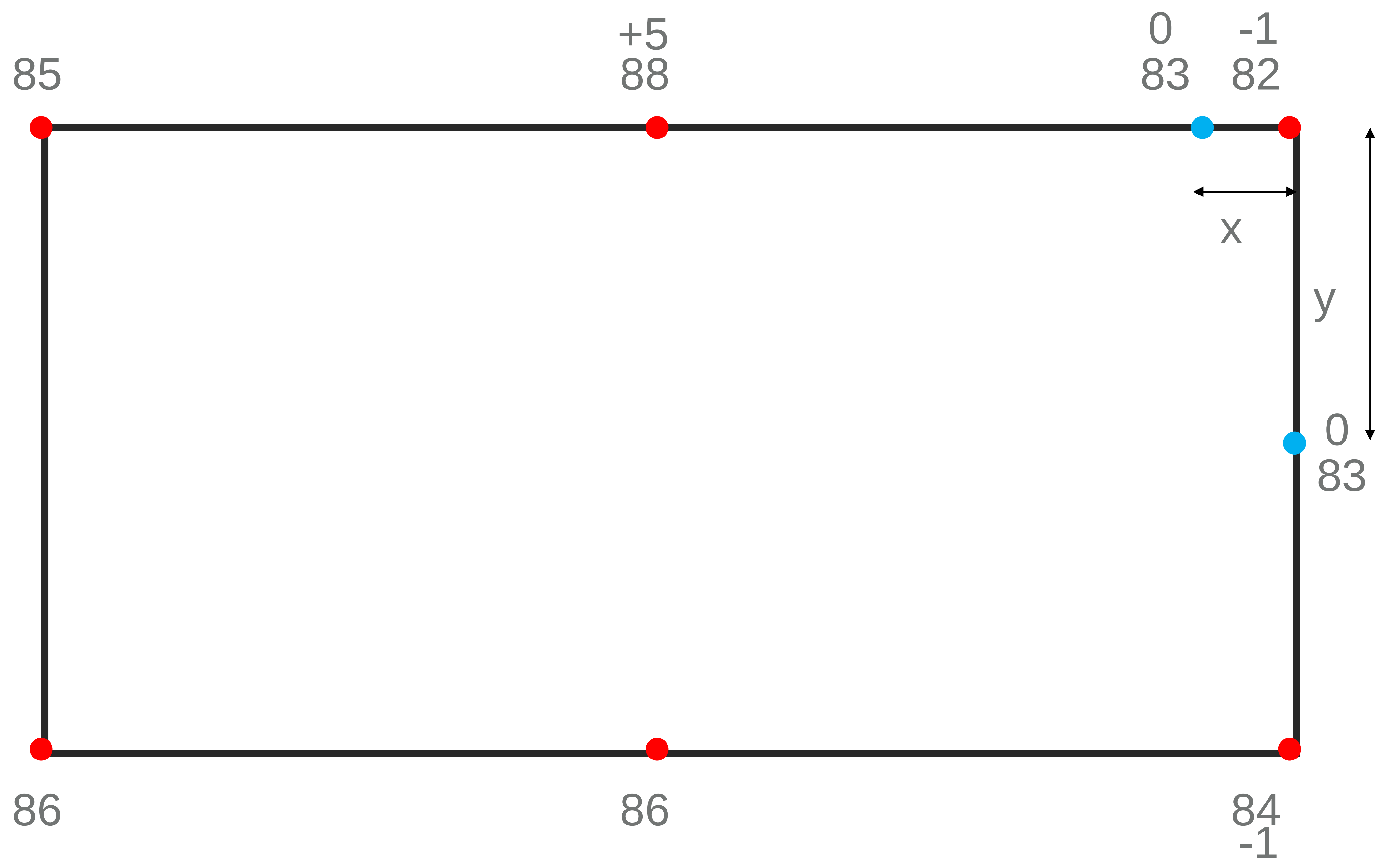


Volume from Contour Map

- Points of contour line 83

$$\frac{88-82}{10}=\frac{83-82}{x} \quad \rightarrow \quad x=1.667m$$

$$\frac{84-82}{10}=\frac{83-82}{y} \quad \rightarrow \quad y=5m$$

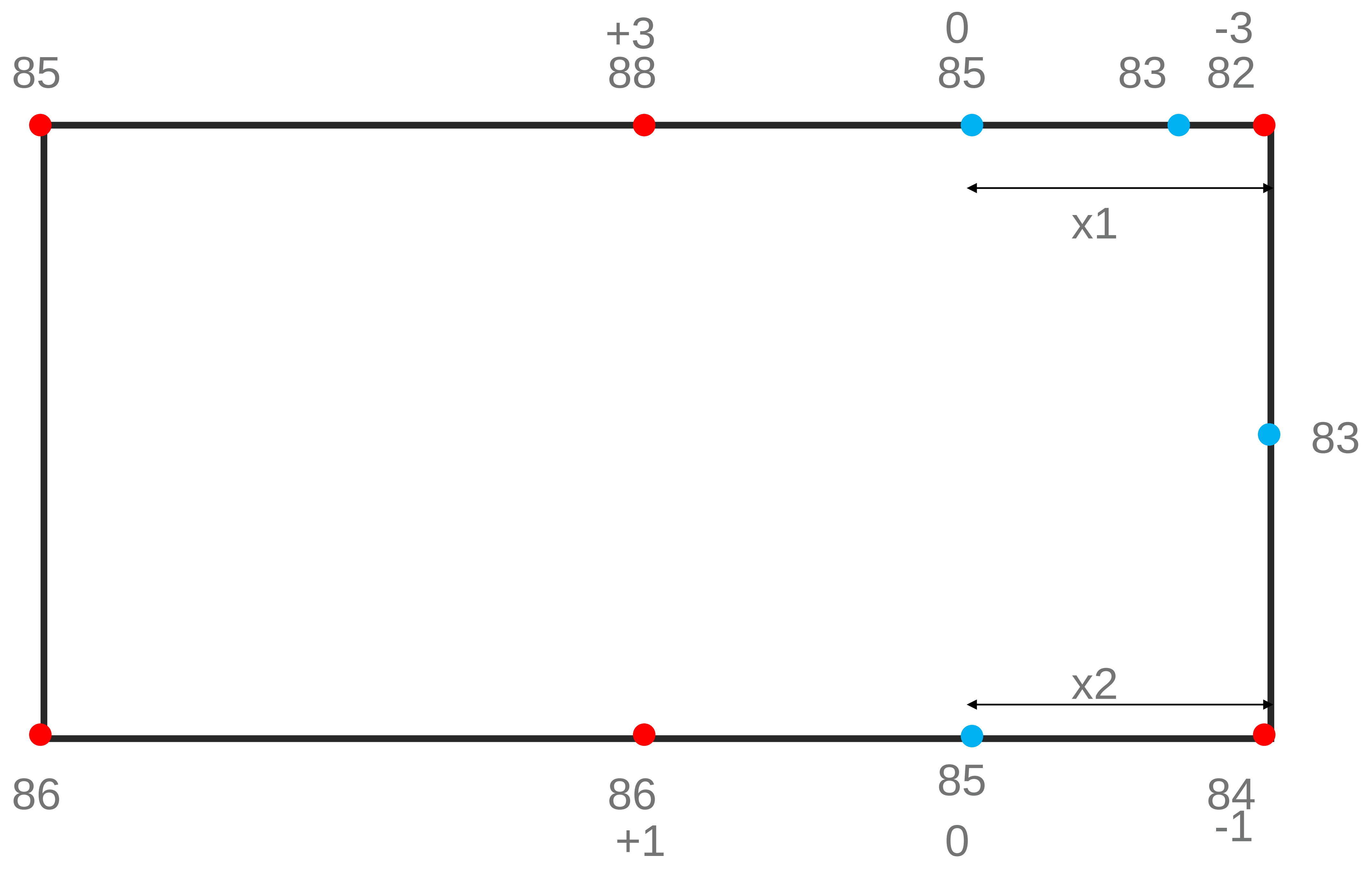


Volume from Contour Map

- Points of contour line 85

$$\frac{88-82}{10}=\frac{85-82}{x1} \quad \rightarrow \quad x1=5m$$

$$\frac{86-84}{10}=\frac{85-84}{x2} \quad \rightarrow \quad x2=5m$$



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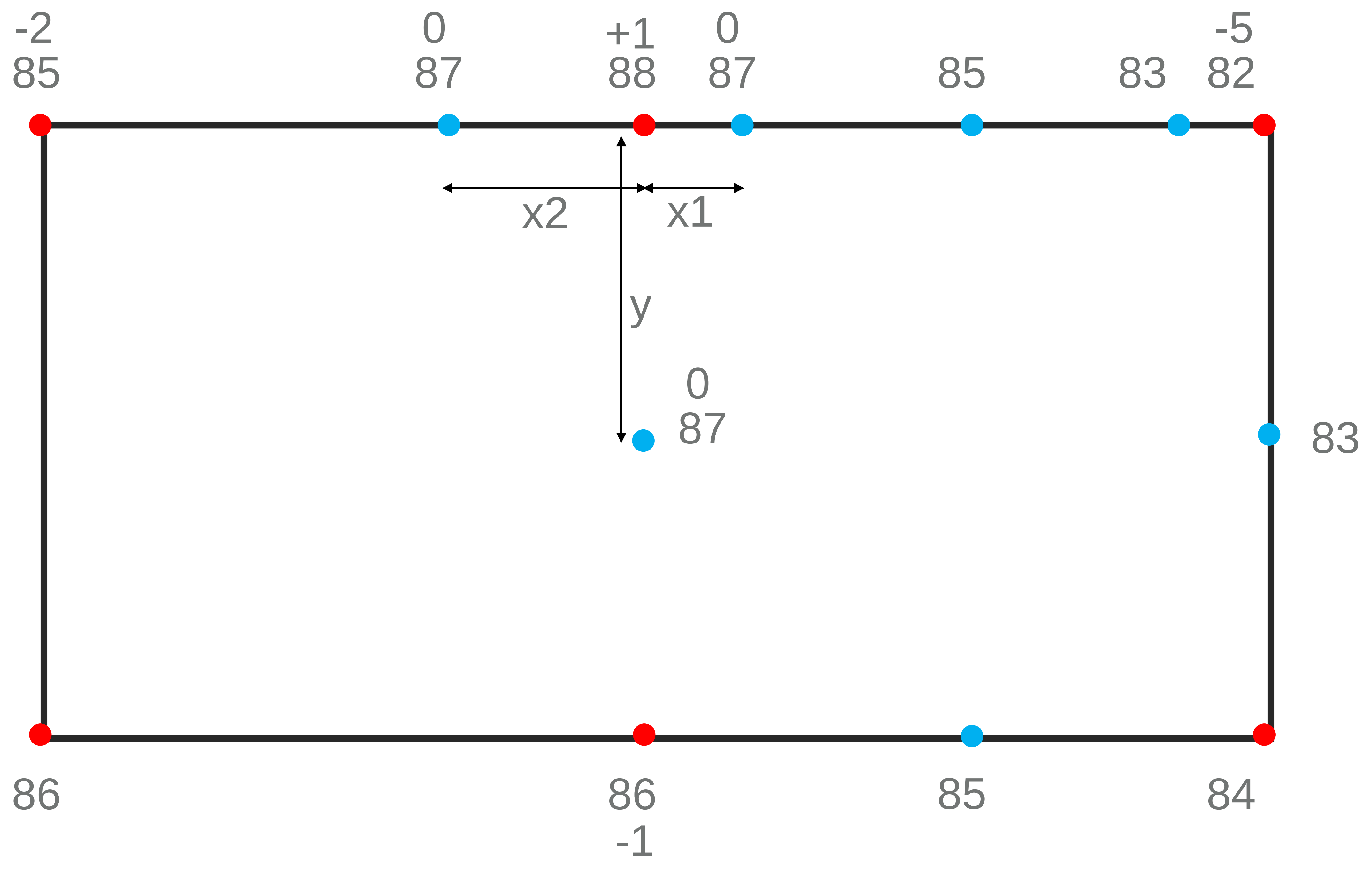
Volume from Contour Map

- Points of contour line 87

$$\frac{88-82}{10}=\frac{88-87}{x1} \quad \rightarrow \quad x1 = 1.667m$$

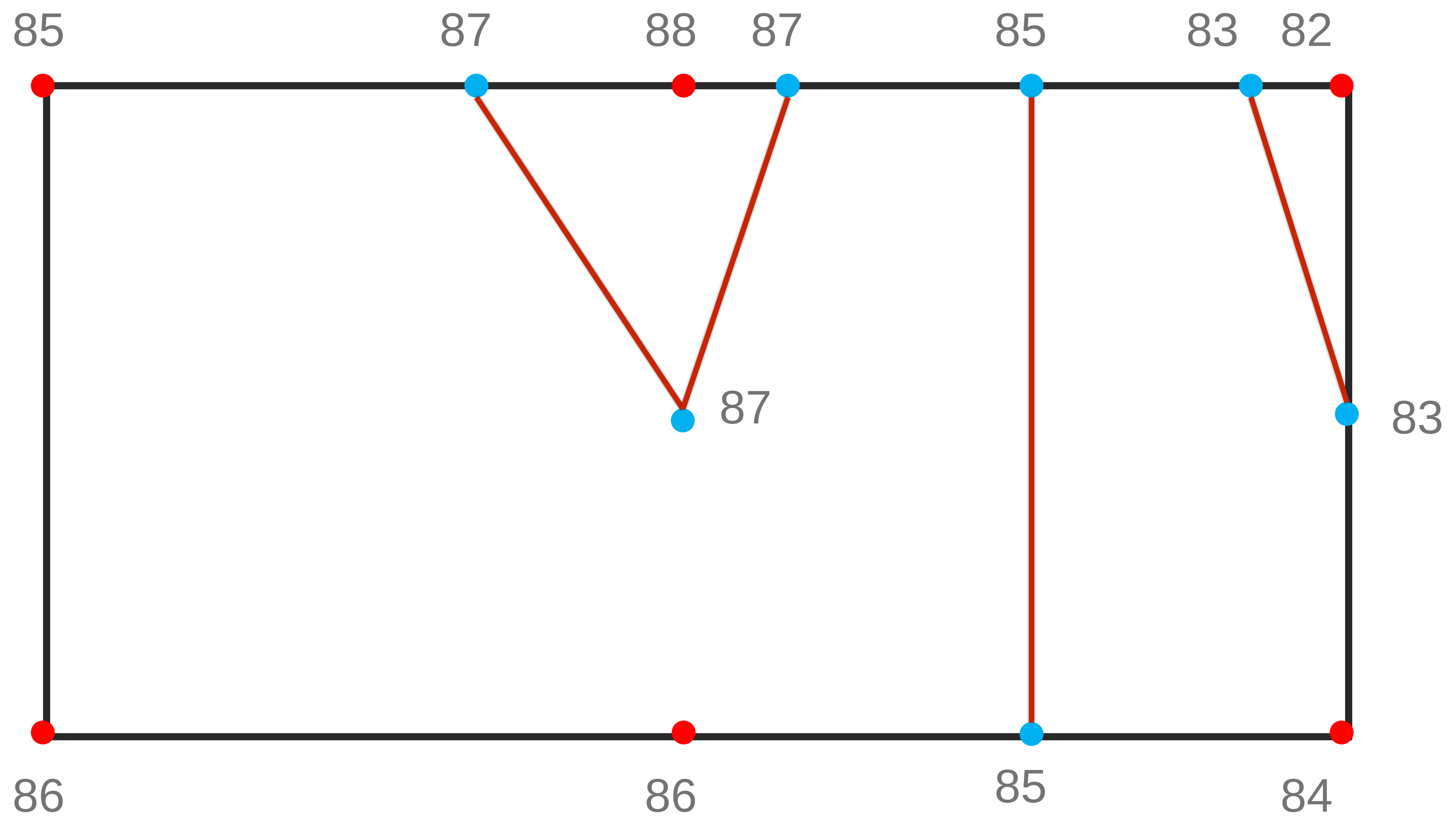
$$\frac{88-85}{10}=\frac{88-87}{x2} \quad \rightarrow \quad x2 = 3.333m$$

$$\frac{88-86}{10}=\frac{88-87}{y} \quad \rightarrow \quad y = 5m$$



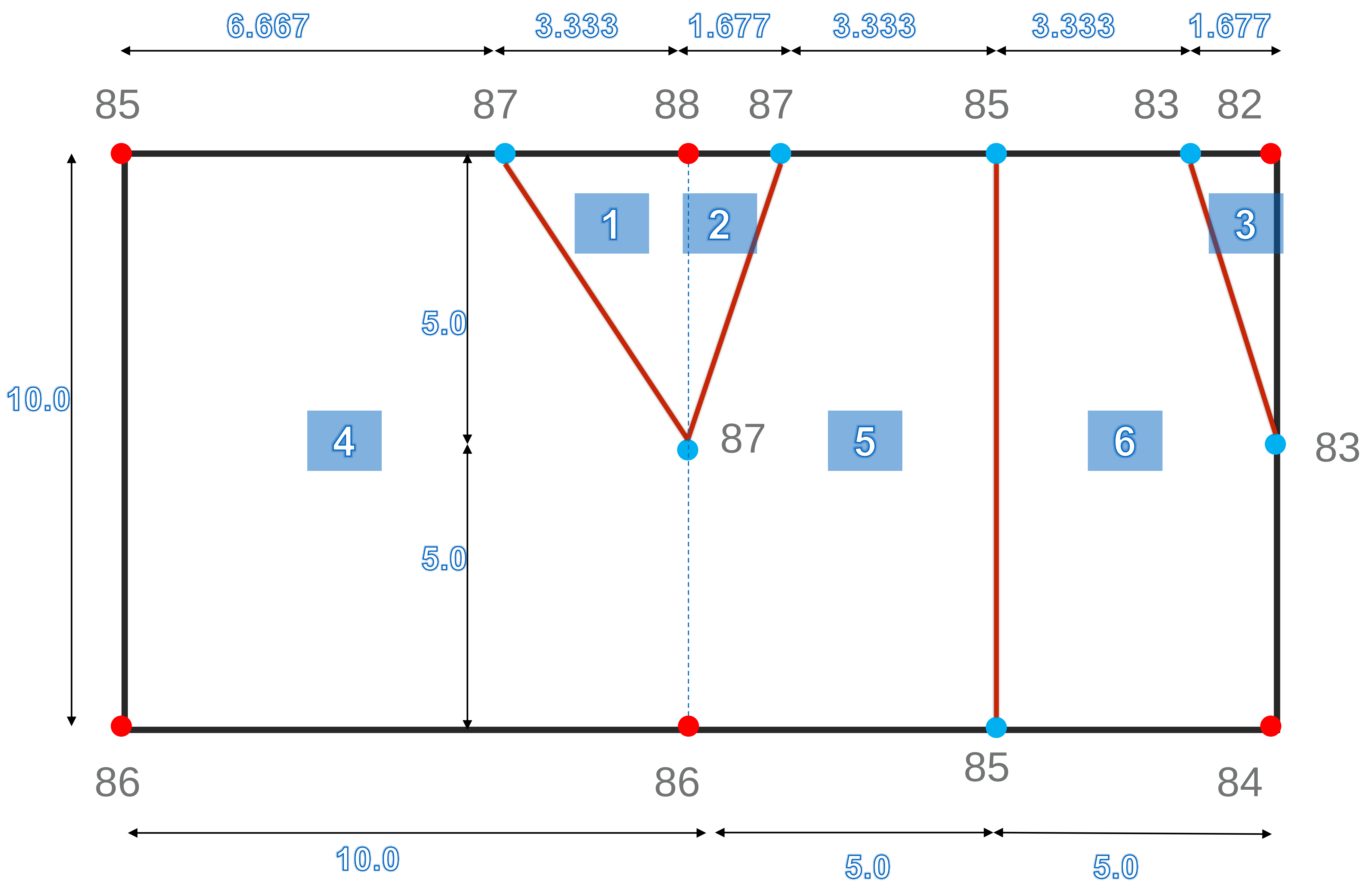
Volume from Contour Map

- connect points



Volume from Contour Map

- levelled to elevation 85 m.
- Calculate areas:
- A1 = 0.5 x 3.333 x 5 = 8.333 m^2
- A2 = 0.5 x 1.667 x 5 = 4.175 m^2
- A3 = 0.5 x 1.667 x 5 = 4.175 m^2
- A4 = (10 x 10) – (A1) = 100 – 8.333 = 91.667 m^2
- A5 = (5 x 10) – (A2) = 50 – 4.175 = 45.825 m^2
- A6 = (5 x 10) – (A3) = 50 – 4.175 = 45.825 m^2



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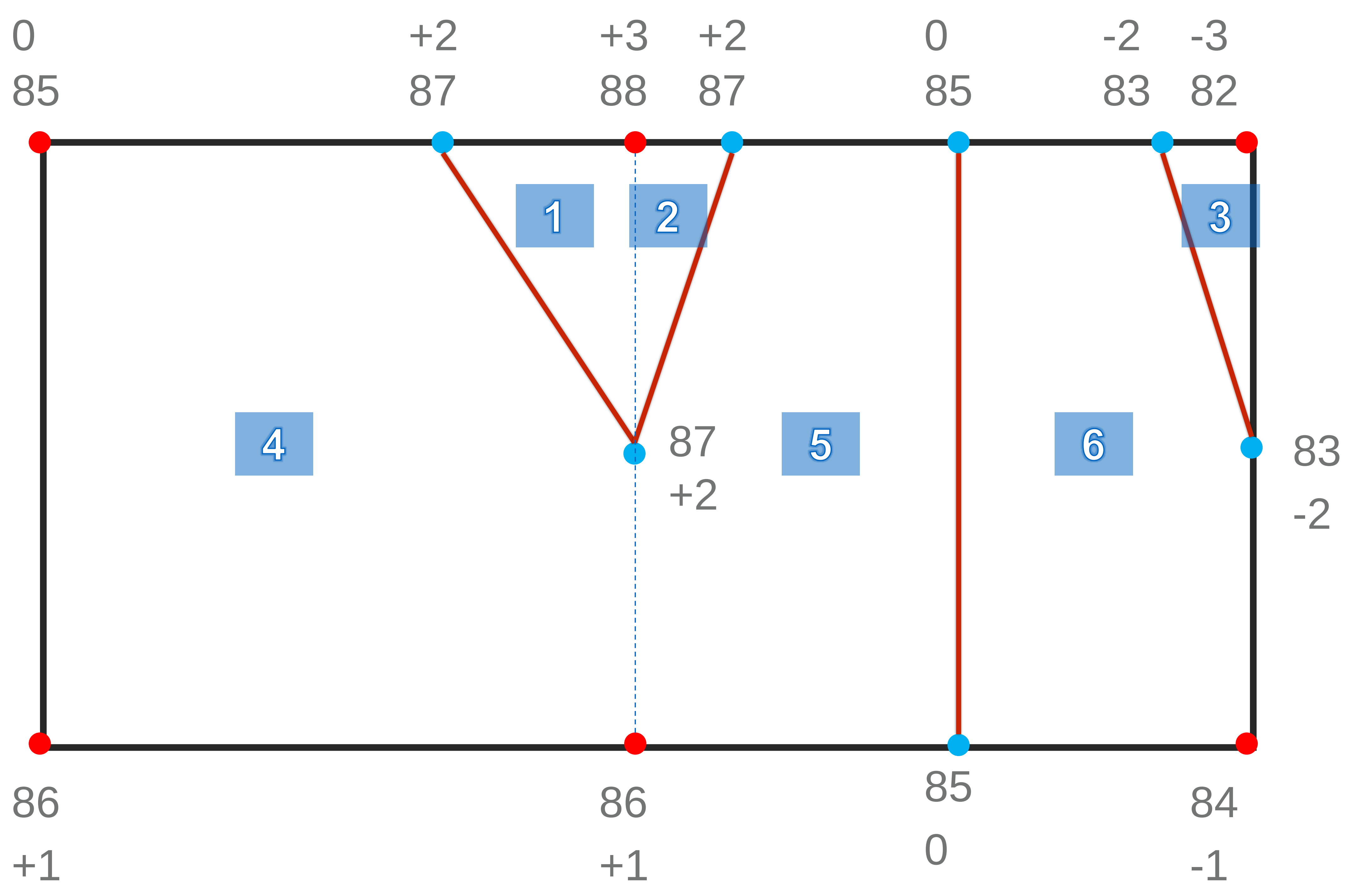
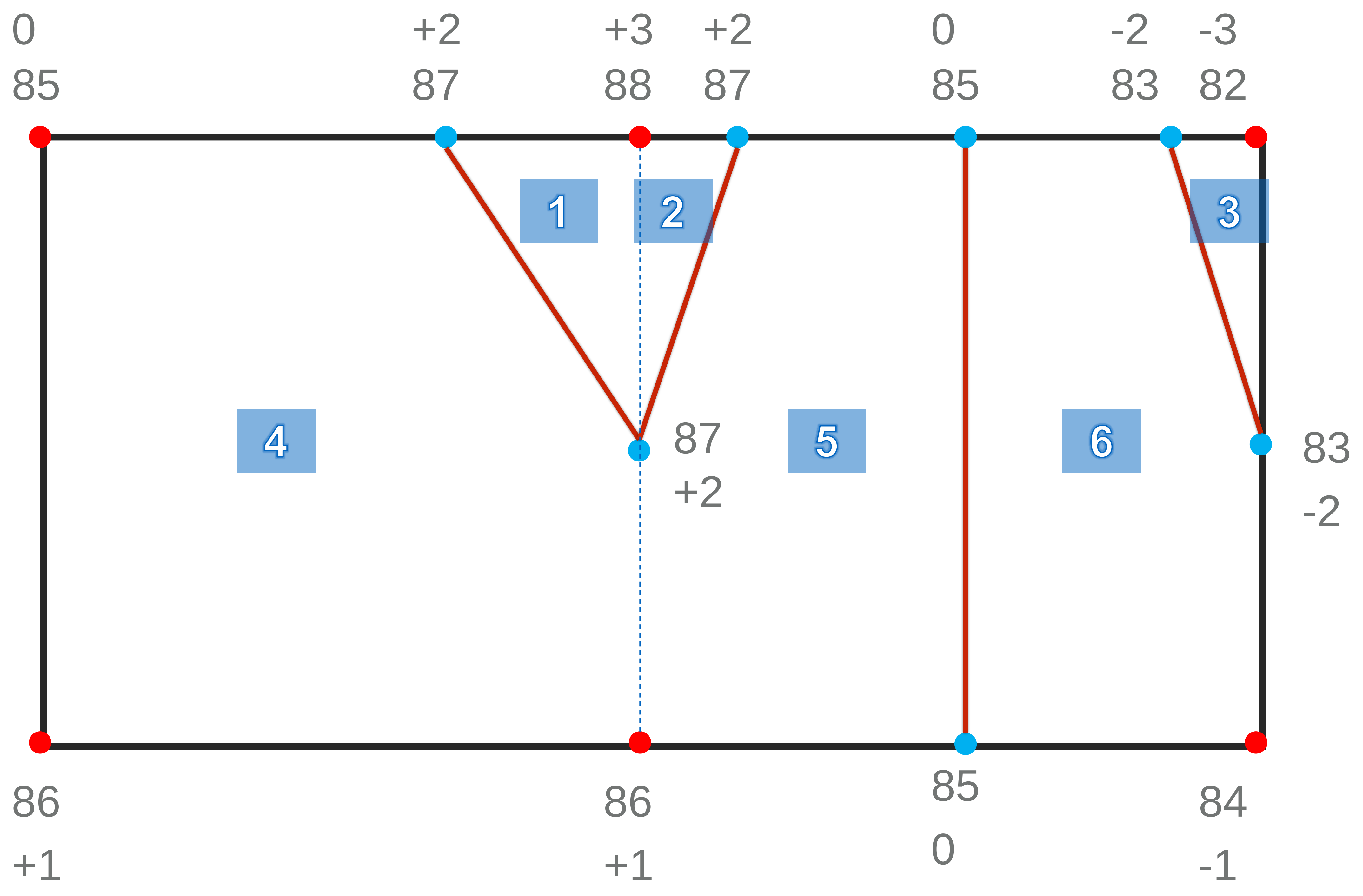
Volume from Contour Map

- levelled to elevation 85 m.
- Determine difference in level



Volume from Contour Map

- levelled to elevation 85 m.
- Determine average height
- h1 = (2+3+2)/3 = + 2.333 m
- h2 = (3+2+2)/3 = + 2.333 m
- h3 = (-2-3-2)/3 = - 2.333 m
- h4 = (0+2+2+1+1)/5 = + 1.2 m
- h5 = (2+0+0+1+2)/5 = + 1.0 m
- h6 = (0-2-2-1+0)/5 = - 1.0 m



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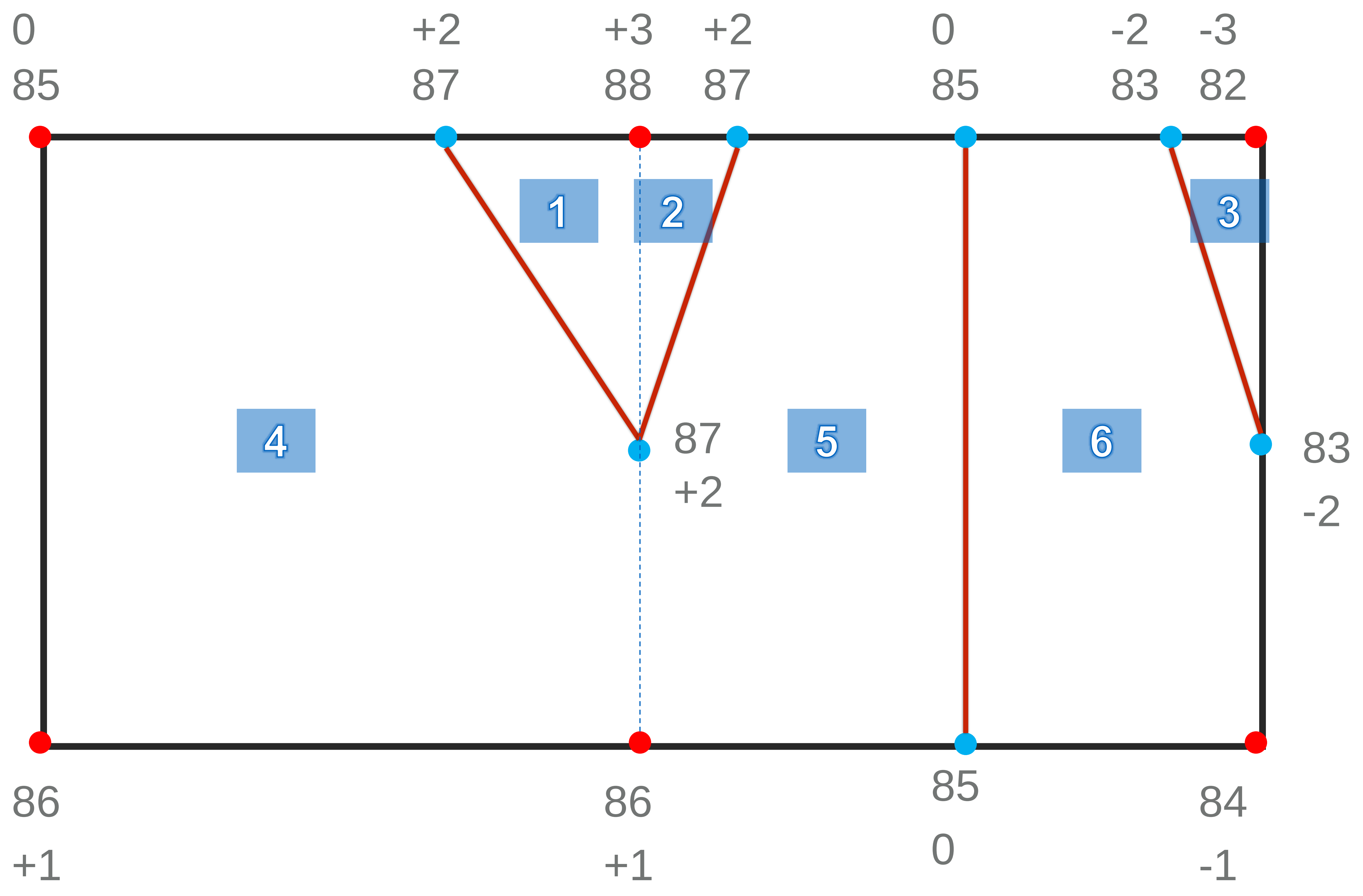
Volume from Contour Map

- levelled to elevation 85 m.
- Calculate volume = area x average height
- v1 = 8.333 x (+ 2.333) = +19.444 m^3
- v2 = 4.175 x (+ 2.333) = +9.742 m^3
- v3 = 4.175 x (- 2.333) = -9.742 m^3
- v4 = 91.667 x (+ 1.2) = +110.0 m^3
- v5 = 45.825 x (+ 1.0) = +45.825 m^3
- v6 = 45.825 x (- 1.0) = -45.825 m^3



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Volume from Contour Map

- levelled to elevation 85 m.
- Calculate total cut and fill volume
- Fill volume = v3 + v6 = 55.567 m^3
- Cut volume = v1 + v2 + v4 + v5 = 185.011 m^3