CHAPTER 6: ELEVATION

OBJECTIVES OF THE UNIT

1. At the end of this unit, the reader must be able to:
2. Define elevation,
3. Explain the difference between elevation and slope,
4. Calculate elevation using the differential levelling method,
5. Identify different surveying instruments used in levelling.

RATIONALE FOR THE UNIT

This unit is designed to develop the learners' understanding of elevation, instruments used to measure elevation as well as basic principles of calculation of elevation using differential levelling.

ASPECTS AND ISSUES

Our coordinates in Figure 2 (refer to Unit 1) have a third aspect (elev 1016m) that we have not covered so far. This represents the elevation or height of BA ISAGO University. According to Van Sickle (2004: 65):

> Coordinates for latitude and longitude, northing and easting often come in pairs, but that is not the whole story. For a coordinate pair to be entirely accurate, the elevation it represents must well-defined that might be may be above or below the surface of the Earth at a particular place.
>
> Elevations are usually measured in meters or feet. They can be shown on maps by contour lines, which connect points with the same elevation; by bands of colour; or by numbers giving the exact elevations of particular points on the Earth's surface. Maps that show elevations are called topographic maps (Available online: https://www.nationalgeographic.org/encyclopedia/elevation/ (Accessed: 21 January 2021).

Besides contour lines, elevation is also shown by means of spot heights and trigonometrical stations. It is important for one be able to read the map and understand the elevation and slope of properties before starting the development. The elevation and slope of the site have the cost implications during and after the development phase.

Ghilani and Wolf (2012) defined elevation as the distance measured along a vertical line from a vertical datum (reference point) to a point or object (point of unknown height). A vertical datum is any level surface to that elevations are referenced. This is the surface that is arbitrarily assigned an elevation of zero. This level surface is also known as a reference datum since points using this datum have heights relative to this surface. A geoid is defined as a level surface that serves as a datum for all elevations and astronomical observations as shown in Figure 48.

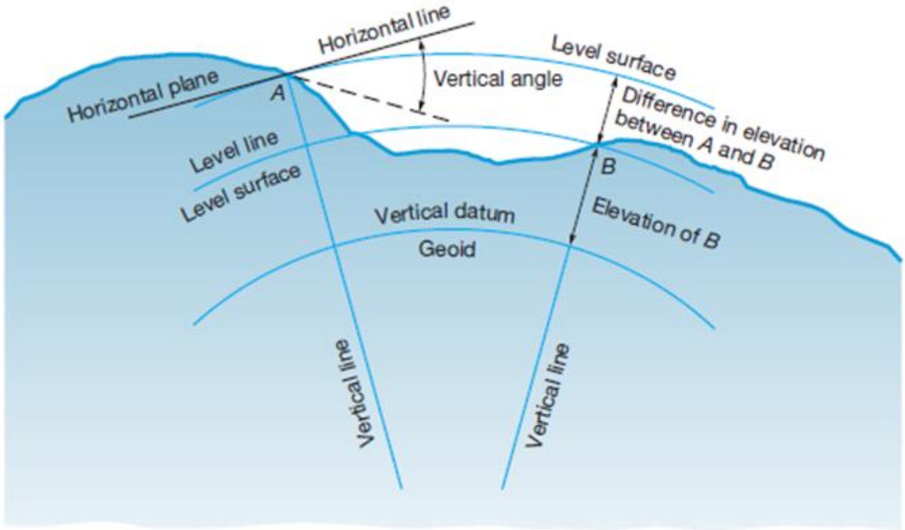

Figure 48: Levelling terms (Ghilani and Wolf, 2012:74).

If the elevation of point A is 802.46m, what it means is A is 802.46m above the reference datum. The elevation of a point is also called its height above the datum.

MEASURING ELEVATION (FIELD)

Real estate and planning practitioners are not expected to be highly skilled in levelling since this is the job of Land Surveyors. When part of the property practitioner requires levelling, then he/she must seek the services of a qualified Land Surveyor, the same way he/she is supposed to get BOQs from Quantity Surveyors when doing the cost approach to valuation or doing development appraisal. However, it is important to have an appreciation of how Levelling is done, so this section will discuss basic principles of levelling so that students will appreciate how it is done.

Levelling is the general term applied to any of the various processes by that elevations of points or differences in elevation are determined. A Benchmark (BM) is a relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed. Common examples are metal disks set in concrete, reference marks chiselled on large rocks, non-movable parts of fire hydrants, curbs, *et cetera* (Ghilani and Wolf, 2012).

The vertical distance between two points is called the difference in elevation. The process of measuring differences in elevation is called levelling. So, levelling refers to height measurements for representing the relative difference in height (altitude) between various points on the earth's surface. One could simply say it is the process of measuring heights. According to Ghilani and Wolf (2012), several techniques are used when determining elevation and these include but not limited to differential levelling, barometric levelling, and indirectly by trigonometric levelling. Let us just focus on differential levelling to give one a general picture of how it is done.

DIFFERENTIAL LEVELLING

Differential levelling most employed method and it is simple in principle. An instrument called a level is used to establish a line of sight that is perpendicular to gravity in other words, a level line. With reference to Figure 49, please take note of the Datum elevation that is 0.00. This is the starting point for all elevation measurements. Do not worry about measurements that are shown in ft in the illustration, we will explain using metres. Also, take note of the Benchmark that is labelled as BM in Figure 49. Ghilani and Wolf (2012) defined a Benchmark (BM) as a relatively permanent object, natural or artificial, having a marked point whose elevation above or below a reference datum is known or assumed. Common examples are metal disks set in concrete, reference marks chiselled on large rocks, non-movable parts of fire hydrants, curbs, etc. In simpler terms, this is a point of known height, that is used as a starting point whenever one is measuring elevation for unknown points. In this example our known elevation is 820.00. What it simply means is that BM rock is 820m from the Datum elevation and remember that this distance is measured vertically.

Now that we have our benchmark (BM) and our point of unknown height that is X (to the right side of Figure 49), let us now discuss how we can determine the elevation of point X. With the benchmark and the point X it is now possible to measure the unknown elevation and the instrument used to do this is known as a level that works with level rods. With reference to Figure 49, level is midway between BM and X. The illustration also shows two rods, are held vertically resting on two solid points in this case the solid points are the BM and the point X. Rods marked with the same graduations, like rulers (see Figure 49). We can now proceed to discuss how the measurements are taken.

THE PROCESS OF DIFFERENTIAL LEVELLING

The first step is to look at the rod to the rear (BM) through the telescope of the level, there is a graduation at the point at that the horizontal level line of sight of the level intersects the vertical rod. That reading is taken and noted. This is known as the backsight (BS) and it tells the height, or elevation, that the line of sight of the level is above the mark on that the rod is resting. In the case of Figure 49 the BS is 8.42m (remember we are using m the ft illustrated on the diagram. Back-sights are also called plus sights (+ S), because one must always add them to a known elevation to find the height of the instrument (HI). With reference to Figure 49 the HI is calculated by adding the BS (8.42m) to the BM (820m) that is 828.42m. What it simply means is that the line of sight of the level is **828.42m** above the Datum level.

The HI is not the end of the process, we need it to calculate the final elevation but for us to do so we need to rotate the level to observe the vertical rod ahead (at point X) and a value is read there. This is known as the foresight (FS). Said in other words, FS is the reading taken towards the point of unknown height (in this case point X). Foresights are also called minus sights (-S), because they are always subtracted from HI to obtain the elevation E of the point. The FS on Figure 49 is 1.20m. To determine the elevation of point X, one subtract the FS (1.20) from the HI (828.42): 828.42m – 1.20m = **827.22m**. If this procedure is repeated, then, the height of points along the route of survey can determined (Van Sickle, 2004).

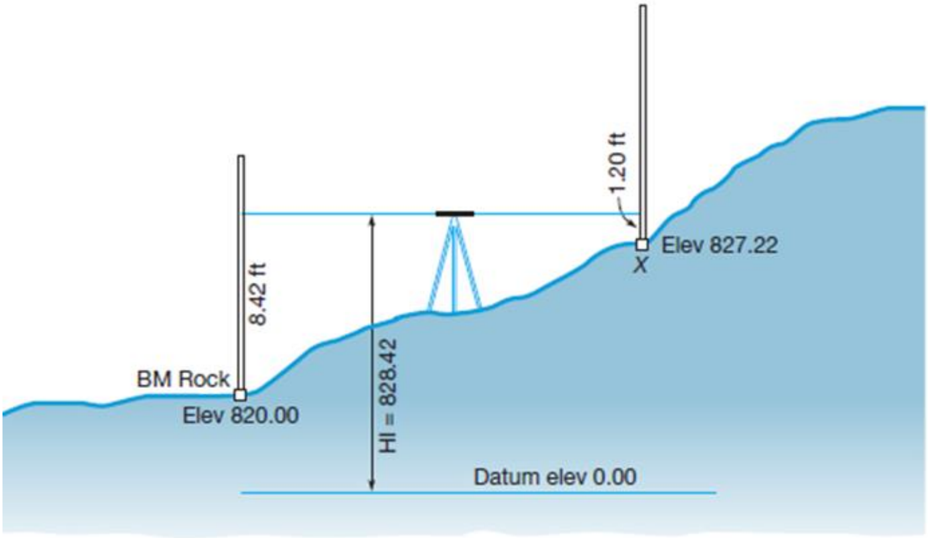

Figure 49: The process of differential levelling (Ghilani and Wolf, 2012:79).

EXAMPLE

Let us use Figure 50 to calculate the unknown elevation.

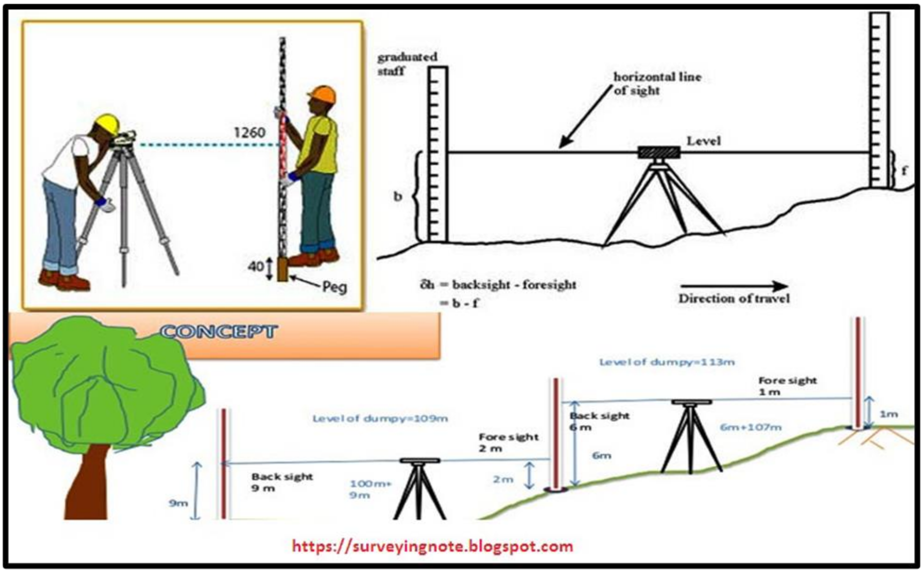

Figure 50: Levelling example (*Available online: https://surveyingnote.blogspot.com/2019/0/4/lavelling-lavelling-surveying.html (Accessed: 27 December 2020)*.

Example

a) The unknown elevation on Figure 50 will be calculated as follows:

1. The surveyor sets up between the benchmark (BM) and Point1.
2. A back sight (9m) is taken to the BM.
3. This lets one calculate the height of instrument (HI) as 100m + 9m = **109m**.
4. The surveyor then turns and takes a foresight reading on of 2m.This permit calculating the elevation of Point1 as 109m – 2m = **107m.**
5. The surveyor then moves forward to a location between Point1 and Point2. A back sight reading on Point1 is 6m. This allows a calculation of the new HI as follows: 107m + 6m = **113m**
6. The surveyor then turns and takes a foresight reading on Point 2 of 1m. This allows the calculation of the elevation of Point 2 as 113m – 1m = **112m**.
7. The height difference between A and B is equal to the sum of the back sight and the foresight.

Table 6.1: Calculation of Elevations (Adopted from Ghilani and Wolf, 2012:79).

Point	Backsight (B.S) +	Height of Instrument (H.I)	Foresight (F.S.) -	Elevation (Elev.)
BM				100m
	+9m	109m		
Point 1			-2m	107m
	+6m	113m		
Point 2			-1m	112m

Therefore, the elevation for point 2 is **112m.**

Height difference between BM and Point 2:

Sum of B.S.: 9+6 =**15m**

Sum of F.S.: -2m + -1m = **-3m**

B.S. – F.S.: 15m – 3m = **12m**

Or simply 112m – 100m = **12m.**

LEVELLING EQUIPMENT

LEVEL

The level, its tripod, the staff, and the staff bubble are all precision items of equipment upon that the accuracy of the work is highly dependent. A surveyor's level also known as the optical level is basically a telescope, fitted with cross wires for sighting, and attached to a levelling device that is mounted on a tripod (a support with three legs) so that it can rotate horizontally through 360 degrees (Ghilani and Wolf, 2012). In older instruments, the horizontality of the sighting line was adjusted with a sensitive spirit level and fine-threaded adjusting screws. In more recently made instruments (known as self-levelling or automatic levels), the line of sight is automatically brought to the horizontal, that makes surveying operations much easier. The telescope magnifies far-away objects that means one can observe the graduation on a levelling staff at a much greater distance than one could with their ordinary eyesight. There are three basic types of level that are dumpy levels, tilting levels and Automatic levels. Figure 51 shows an example of a level.

Figure 51: Optical Level (Image taken by authors)

TRIPOD STANDS

A tripod stand, as shown in Figure 52 below, is a device used to support any one of several surveying instruments, such as theodolites, total stations, and levels. There are two different kinds of tripods, such as adjustable-leg tripods and fixed tripods. Adjustable-leg tripods are the more common of the two in the construction world, especially outdoors because of generally uneven terrain. A tripod is made up of three legs, each with metal points called shoes; and a head that the theodolite or other levelling device attached (Ghilani and Wolf, 2012).

Figure 52: Tripod Stand (Image taken by Authors)

ROD / STAFF

A rod also known as a staff is a rectangular cross section and is used to determine the relative heights of the different points. A variety of level rods are available, some of which are made of wood, fiberglass, or metal. The most common engineer's rod is called the Philadelphia Rod. The lower part of the rod with metal is used to protect from spoil while using. The instrument is sectional, and it can be shortened for storage and lengthened for use (Ghilani and Wolf, 2012). Figure 53 is an example of a level rod.

Figure 53: Rod / Staff (Image taken by authors)

ACTIVITIES FOR THE READER

1. Define elevation.
2. Explain the difference between elevation and slope.
3. Write brief notes on the following surveying instruments:
4. Level,
5. Tripod stand,
6. Level rods.
7. Refer to Figure 54 and answer questions which follows. Calculate elevation using the differential levelling method,

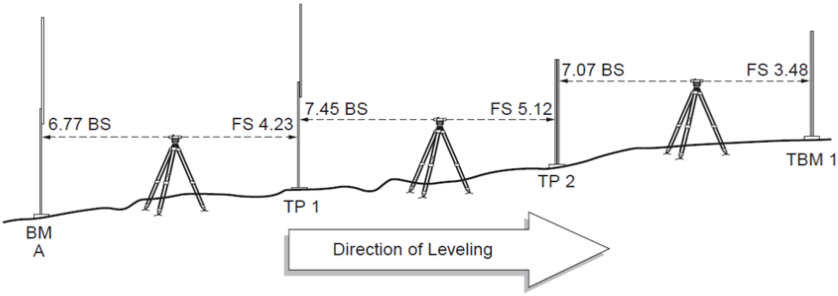

Figure 54: Levelling

Calculate the level of TBM1 using differential levelling.
Calculate the height difference between BMA and TBM 1.

CONCLUSION

Having completed this unit, learners are expected to be able to define elevation and confidently point out instruments used to measure elevation as well as to calculate of elevation using differential levelling.

SUGGESTIONS FOR FURTHER READINGS

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Field, H., L. and Long, J., M. 2018. Introduction to agricultural engineering technology: A problem solving approach (Fourth Edition). Springer: ISBN 978-3-319-69678-2; ISBN 978-3-319-69679-9 (eBook). https://doi.org/10.1007/978-3-319-69679-9.

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