

ACBA4002

2014439

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Introduction

General Overview of Levelling Survey

The term level refers to a surface being perfectly horizontal or flat, or having no 'part higher than another' or 'having a flat or even surface' (Dictionary.com, n.d.). However, levelling refers to a method of calculating the level or height of one point relative to another point. To do this, we must work from a datum or known point. In most countries the altitude zero is taken at mean sea level, and the UK, this was established at Newlyn in County Cornwall from studying tidal data between May 1915 and April 1921. From here, throughout the country there are Ordnance survey datums that can be used as benchmarks for levelling surveys. These are commonly carved arrows cut into walls of permanent structures (R Chudley, 2020). However, these can often be difficult or impractical to access from new construction sites, so it is necessary to set a temporary benchmark or datum, which could be a Hilti pin in concrete, a pencil mark on a concrete wall or a wooden peg driven into the ground that's out of the way of any potential disturbance. Local Authorities also hold a list of benchmarks that are located within their areas. See the two figures below.



Figure 1 Ordnance Survey Datum http://www.buildingopinions.com/wp-content/uploads/2015/03/20140705_182021x.jpg

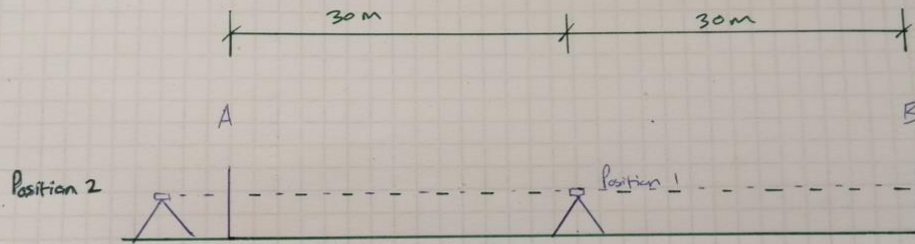
(photo of datum)

Equipment used in Levelling Survey

The Automatic Level (Dumpy)

The automatic level, more commonly referred to as a dumpy level, provides a horizontal plane using a telescope with a horizontal crosshair. From this horizontal plane, all heights or levels can then be calculated. Before using any equipment, you should check the equipment as an in-date calibration record. If the dumpy hasn't been used for some time the engineer or surveyor can carry out a two-peg test to determine the instruments accuracy. In a two-peg test you set the instrument up in the middle of two points, for instance point A and point B. Typically the dumpy level will be positioned 30 metres away from both A and B, and then a set of readings is taken using a chain person or assistant holding the staff at these points. Once these have been taken the dumpy can be moved past one of the points and a new set of readings taken. If the instrument is accurate, the height of point A minus the height of point B taken at position 1, should equal the height at point A minus point B taken from position 2. See figure 2 below.

Two Peg Test



	A	B	
Position 1	1.540	1.550	= 0.020 ✓
Position 2	1.560	1.570	= 0.020 ✓

$$A-B = A-B$$

∴ Instrument is working correctly.

Figure 2 illustration of a two-peg test

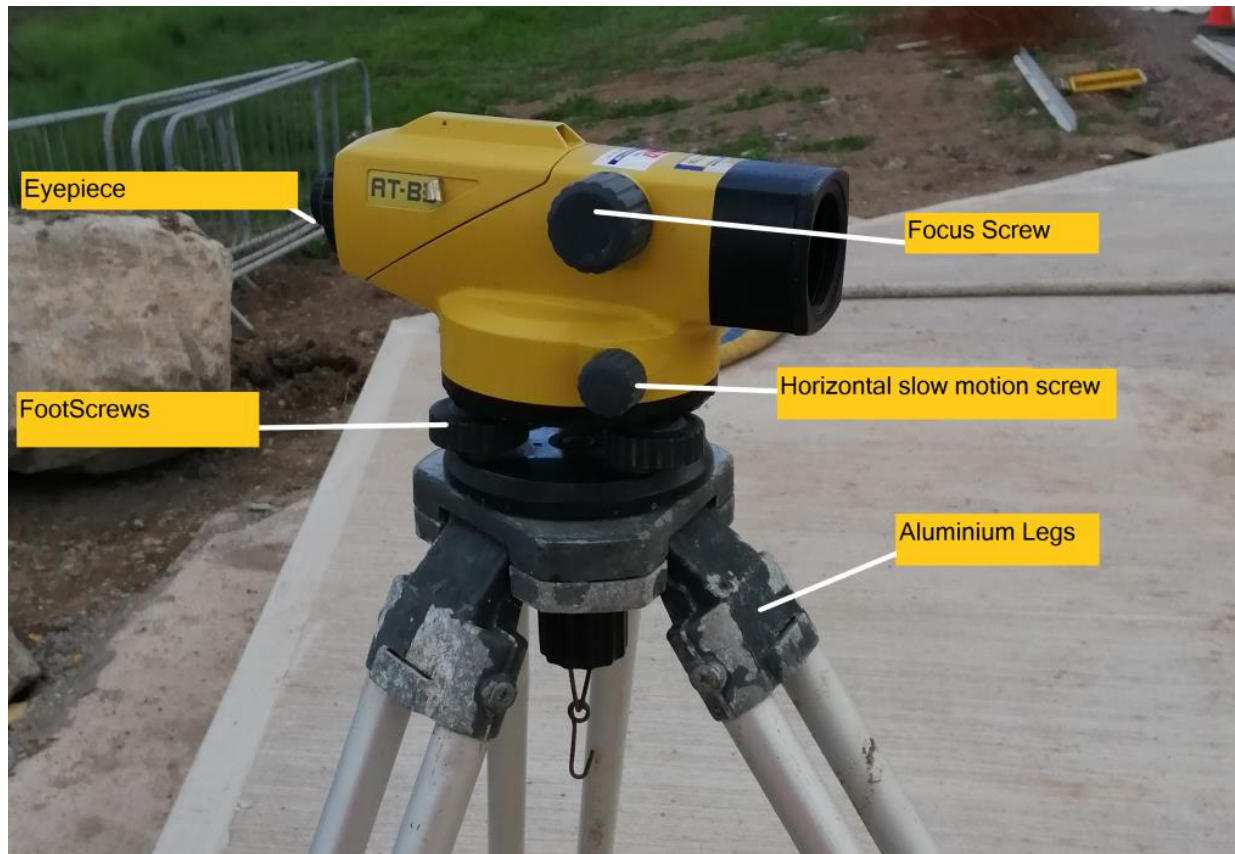


Figure 3- Dumpy Level taken on my current site 26/04/2022

Tripods

The dumpy should be placed atop of a tripod. Tripods can be made of wood or like in figure 3 above the legs of the tripod can be made of aluminium. Tripods with aluminium legs are probably better suited for levelling surveys across long distances as they are considerably lighter than wooden legs, and thus easier for the surveyor or engineer to carry.

Levelling staff and chain person.

Conducting a levelling survey requires two people. Typically, an engineer to use the dumpy level, and a chain person to hold the levelling staff as instructed by the engineer. A chain person is an assistant to the engineer, and an engineer in training. It is important for the chain person to hold the levelling staff upright or plumb. Some levelling staffs are equipped with a bubble to aid with this. See Figure 4 and figure 5 below. The staff should be kept free of any dirt or grit as best as possible to allow readings to be taken

accurately by the engineer. When finished with, best practice would be to clean all sections of the staff and keep it stored in its case in a safe place.



Figure 4 Plumb bubble that can be clipped to a levelling staff



Figure 5 Chain person holding levelling staff

Levelling Procedure

Setting up the Dumpy Level

The first step in conducting a levelling survey is to position yourself in an appropriate place to take your first reading to your benchmark, both in terms of line of sight and distance. It's also good practice to find an area of ground that is stable and hopefully out of the way of another construction activity. Ideally you would set up the tripod in the central area that you are surveying. The base plate should be at chest height and relatively level, with the legs of the tripod to be spread wide enough apart to support the instrument. The three legs should then be stamped into the ground as far as possible to ensure the tripod doesn't move. This make the baseplate out of level, so the relevant tripod leg or legs will need to be unlocked and adjusted.

Once this is done, the dumpy level can be removed from the box and attached to the baseplate using the central screw. To level the dumpy itself, turn the scope so it is parallel to two of the foot screws. The two-foot screws should then be turned concurrently in opposite directions until the air bubble becomes central. The scope should then be turned 90 degrees to its current position, and the other foot screw turned to level the small spirit bubble. Turn back 90 degrees to the first position to check the other bubble is central. This process may have to be repeated several times until both bubbles are centred when the scope is in position 1 and 2. The picture below is a Top Con AT-B4 Automatic Level that I used in my survey, and only has the one bubble to level. This is because it is built with an internal compensator.

However, if the legs or instrument receive a significant knock, say by being kicked or moved by mistake, the process of setting the instrument up should be repeated.



Figure 6 Top Con AT-B4 Automatic Level

Backsight Reading and Height of Plane Collimation

Once the instrument is set up, you will be ready to take your first reading. This is called your back sight. The first backsight in a levelling survey is always to a known point or datum, as this will allow you to calculate the collimation or height of the instrument.



Figure 7 Backsight to known point or datum

As you can see above, I have back sighted to my known point or datum of 0.439 and taken a reading of 1.468. Therefore, my collimation or height of the instrument is $0.439 + 1.468 = 1.907$. When taking the reading you should ensure the staff is placed level on the datum, and the person holding the staff has it plumb. It is also good practice for the person to gently rock the staff gently backwards and forwards. For the person reading the staff, they will see the lowest reading will be the correct one. These figures should then be recorded into your levelling book.

40.439 2014439

Date Monday 14th March 2022 Levels

From

BACK SIGHT	INTER-MEDIATE	FORE SIGHT	COLLIMATION OR H.P.C.	REDUCED LEVEL
1.468			1.907	439
	1.444			463
	1.406			501
1.602		1.193	2.316	714
	1.475			841
	1.806			710
1.550		1.706	2.160	610
	1.747			413
	1.741			219
1.435		2.056	1.646	104
	1.435			211
	1.301			345
1.207				

Backsight + Datum or TBM = Collimation

Figure 8 Level Booking the first backsight and calculating the collimation.

Below is an illustration of my levelling survey. Showing the backsights, intermediate and foresight readings.

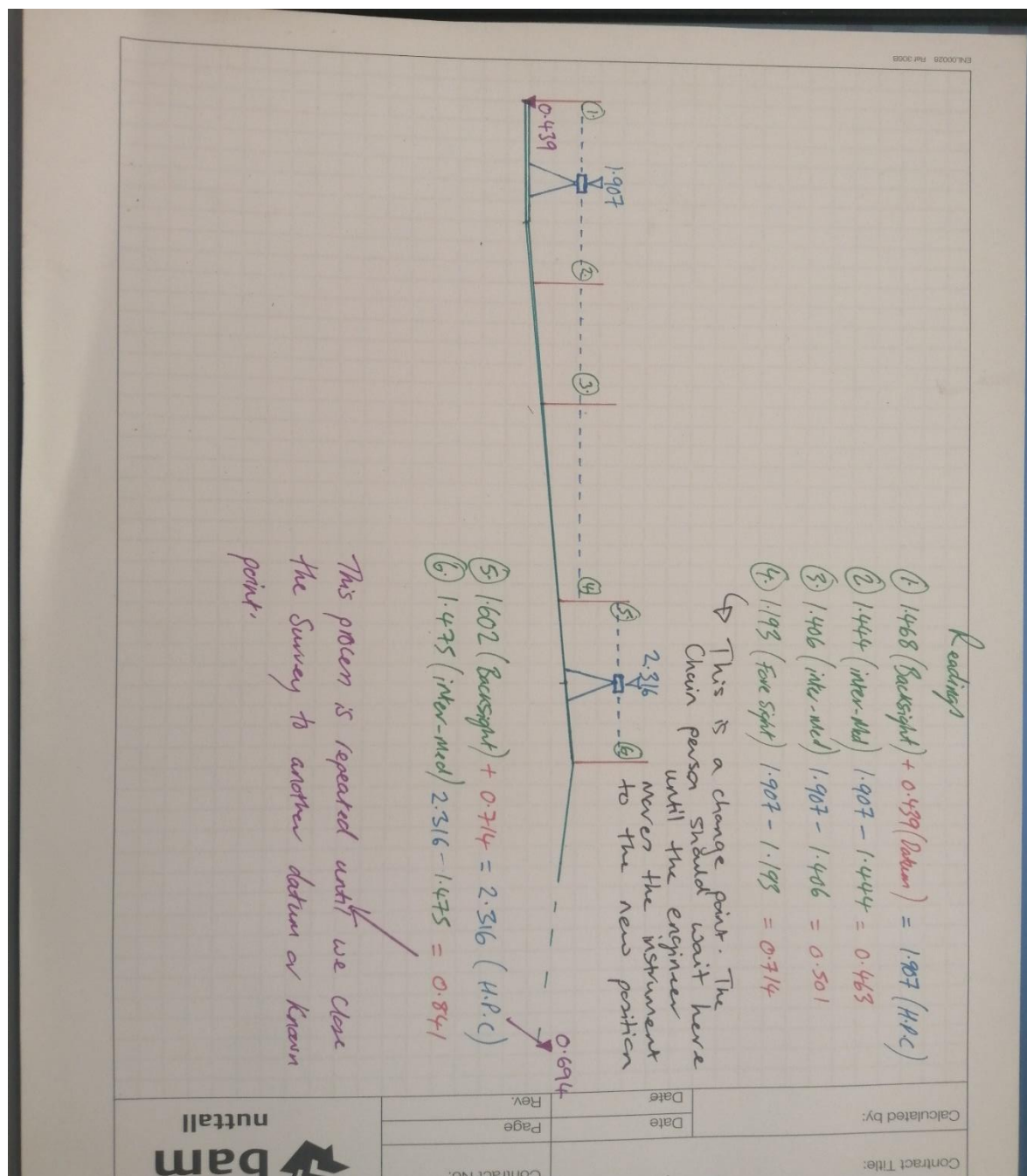


Figure 9 Levelling Survey Illustration

Below is a copy of my booking sheet for the levelling survey I conducted.

Date:			 Prifysgol Cymru Y Drindod Dewi Sant University of Wales Trinity Saint David		
Name of Surveyor:					
Project ID:					
Back Sight	Intermediate Site	Fore Sight	Height of Collimation	Reduced Level	Remarks
1.468			1.907	0.439	Datum
	1.444			0.463	
	1.406			0.501	
1.602		1.193	2.316	0.714	Change pt 1
	1.475			0.841	
	1.606			0.710	
1.550		1.706	2.160	0.610	Change pt 2
	1.747			0.413	
	1.941			0.219	
1.435		2.056	1.539	0.104	Change pt 3
	1.328			0.211	
	1.194			0.345	
1.307		1.028	1.818	0.511	Change pt 4
	1.199			0.619	
	1.104			0.714	
1.385		1.007	2.196	0.811	Change pt 5
	1.207			0.989	
	1.046			1.150	
1.470		0.895	2.771	1.301	Change pt 6
	1.518			1.253	
	1.609			1.162	
1.482		1.756	2.497	1.015	Change pt 7
	1.566			0.931	
	1.586			0.911	
	1.676			0.821	
		1.803		0.694	Datum

Once you have closed your survey back to another datum or known point you can then begin to check the results for accuracy. A quick way of doing this is to add all the backsights and add all the foresights. The foresights can then be taken away from the backsights.

$$1.468+1.602+1.550+1.435+1.307+1.385+1.470+1.482= 11.699$$

$$1.193+1.706+2.056+1.028+1.007+0.895+1.756+1.803=11.444$$

$$11.699-11.444=\mathbf{0.255}$$

Then you should take away your to known reduced levels and these number should be matched or at least close to each other.

$$0.694-0.439=\mathbf{\underline{0.255}}\checkmark$$

Therefore, in this case my survey had checked out perfectly, but this is very rarely the case, as reading a staff involves a tiny element of guess work by the engineer.

However, it is necessary to know the error allowance of the instrument you are using. For this you will have to refer to the manufacturer's specifications.

Telescope	AT-B2	AT-B3	AT-B4
Magnification	32x	28x	24x
Field of View	1°20'	1°25'	1°25'
Min. Focus from center of the instrument		0.3m (1 ft.)	
Image		Erect	
Stadia		Yes (1:100)	
Focusing Knob	2-speed	1-speed	1-speed
Accuracy (1km double run leveling)			
Without Micrometer	0.7mm (0.03 in.)	1.5mm (0.06 in.)	2.0mm (0.08 in.)
With Micrometer	0.5mm (0.02 in.)	n/a	n/a
Compensator			
Type	Pendulum compensator with magnetic damping system		
Setting Accuracy	0.3"	0.5"	0.5"
Working Range	±15'	±15'	±15'
Horizontal Circle			
Minimum Division	1°/1gon	1°/1gon	1°/1gon
General			
Water Resistance	IPX6 (IEC 60529:2001)		
Operating Temperature	-4°F to +122°F (-20°C to +50°C)		
Width	5.12 in. (130mm)	5.12 in. (130mm)	5.12 in. (130mm)
Length	8.46 in. (215mm)	8.46 in. (215mm)	8.46 in. (215mm)

Figure 10 Topcon instrument specifications (Anon., n.d.)

You can see the model is AT-B4, and the accuracy is 2.00mm over 1 km double run levelling. To check our allowance, we must use the formula.

$$n.n \times \sqrt{2XS}$$

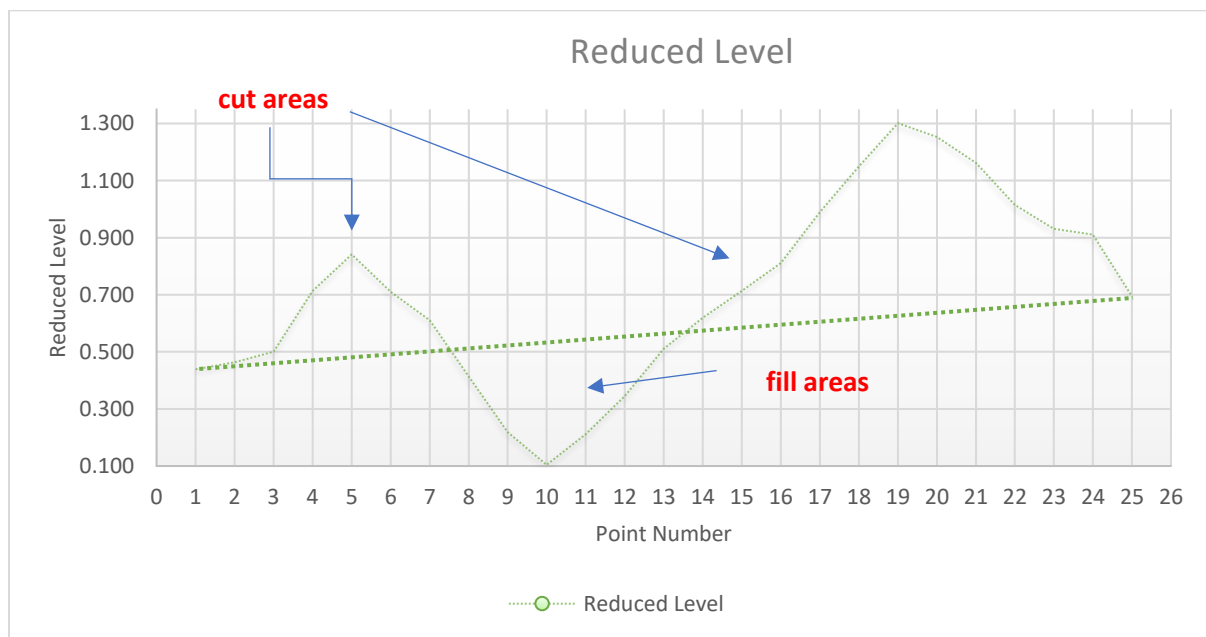
n.n is the accuracy provided by the manufacturer, and s is equal to the number of times you changed the instruments position if the survey.

$$2.0 \times \sqrt{2 \times 7} = 7.4833$$

Therefore, the allowance for error in my survey is 7mm.

Computation and Plotting and Conclusion

Once this is done you can compute the levels from your survey into excel to work out the cut and fill quantities. By drawing a line between the two datums or known points on the graph you can produce a graph of your results. The area of the above the trend line will indicate the areas that will need to be cut, with the areas below the trend line being the areas that will need to be filled on your site.



cut			
	unit		
	volume/constant	number/quantity	total/volume
c-1	0.2*20=4	4.7	18.8
c-2	0.2*20=4	17.9	71.6
total cut = 90.4			
fill			
	unit		
	volume/constant	number/quantity	total/volume
f1	0.2*20=4	6.3	25.2
total fill =25.2			

Therefore, the total area to be removed is $90.4 - 25.2 = 65.2 \text{ m}^2$

This is because the levels taken were at 20m intervals.

Therefore, the volume of site material to be removed would be 65.2 m^3 per metre of road in total.

Bibliography

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https://www.topconpositioning.com/sites/default/files/product_files/atb_series_broch_7010_2057_rev_c_tf_sm.pdf

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