



# ACBA4002 DIGITAL SURVEYING

Assignment 2: Practical - Levelling and  
Computation.

ALED EVANS  
Student ID: 2014489

## Table of Contents

|                                                    |    |
|----------------------------------------------------|----|
| 1. Introduction .....                              | 2  |
| 2. General Overview of Levelling Computation ..... | 2  |
| 2.1 Application of Levelling Surveying .....       | 2  |
| 2.2 Different Types of Levelling .....             | 2  |
| 2.2.1 Differential Levelling .....                 | 3  |
| 2.2.2 Profile Levelling .....                      | 3  |
| 2.2.3 Cross Section Levelling .....                | 4  |
| 2.2.4 Reciprocal Levelling .....                   | 4  |
| 2.3 Advantages of Levelling .....                  | 5  |
| 2.4 Challenges of Levelling Surveying .....        | 6  |
| 3. Equipment Used in Levelling .....               | 7  |
| 3.1 Level Staff .....                              | 8  |
| 3.2 Measuring Tape .....                           | 9  |
| 3.3 Tripod .....                                   | 10 |
| 3.4 Dumpy Level .....                              | 11 |
| 4. Levelling Procedure .....                       | 12 |
| 5. Computation and Plotting of Level .....         | 13 |
| 6. Conclusion .....                                | 16 |
| 7. References .....                                | 16 |

## 1. Introduction

Utilising a level staff with a numbered scale and an optical levelling instrument, levelling is the measuring of geodetic height and is undertaken in order to ascertain differences in elevation between points on the ground (Gutti, 2015). The objective is to establish a given points elevation in relation to the assumed or given datum. A major road reconstruction around its campus in the city is being organised by UWTSD and a consultation exercise has been undertaken to allow a client to carry out a levelling survey between two points on the road. The report below explains in detail how the levelling exercise was undertaken, identifying the equipment used and the data that was collected from the survey. The report will also include computation and plotting of the reduced level of the points using the rise and fall method. Additionally, an estimation of the volume of earthwork involved assuming the slope of the road with a straight line connecting the reduced level of the Temporary Benchmark (TBM) with the reduced level of the last station is included in the report below.

## 2. General Overview of Levelling Computation

As already stated, levelling is the process used to determine the differences in elevation between points on the ground (Gutti, 2015). The objective is to establish points, with respect to an assumed or given datum, at a variety of elevations or a provided elevation (Dream Civil, 2022). Initially in this section, the application of levelling surveying will be examined, followed by the various types of surveying, the advantages and limitations.

### 2.1 Application of Levelling Surveying

The importance of the application is illustrated in the planning and estimating of civil engineering projects such as canals, roads and bridges, where levelling is required. The alignment of survey of bridges and roads is another example of where it is required (Dream Civil, 2022). As well as balancing earthworks, Levelling Surveying is used to calculate quantities of cut and fill. In order to ensure the appropriate slope of the land to facilitate the smooth flow of liquid within a pipe, levelling also plays a vital role in pipeline survey (Dream Civil, 2022). The preparation of topographical and contour maps are other areas where it plays a crucial role. (Dream Civil, 2022).

### 2.2 Different Types of Levelling

One of the commonest methods of levelling is Direct levelling, where to establish the relative distance in elevation between 2 points that are adjacent, the vertical distances with respect to a horizontal line is utilised. (Dream Civil, 2022). Direct Levelling can be further categorised in relation to the instrument position and observation points viz;

### 2.2.1 Differential Levelling

This process is used if the distance between two points is quite substantial and locates the number of the two original inter stations. To establish the difference between the two original-based points, the instrument observes the elevation of the inter-station points by transferring to each station (figure 1) (Civillseek, 2022).

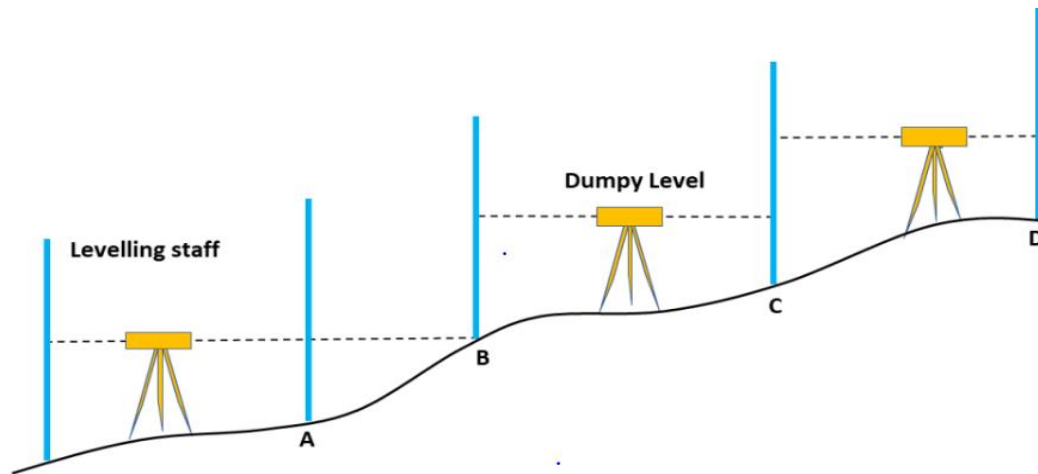


Figure 1: Differential Levelling (Vin CivilWorld, 2021).

### 2.2.2 Profile Levelling

To obtain a profile of the surface along the line, this method is utilised to ascertain at measured intervals, the elevations of points (figure 2) (Dream Civil, 2022). Along lines such as roads, rail and rivers, this method is ideally suited to find elevation points (Civillseek, 2022).

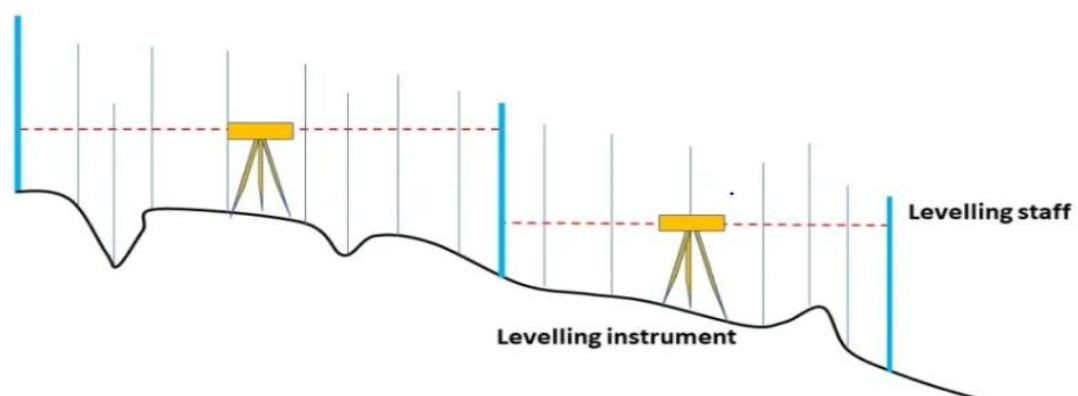


Figure 2: Profile Levelling (Vin CivilWorld, 2021).

### 2.2.3 Cross Section Levelling

To establish the vertical cross-section of an underlying layer, the ground surface or even both, Cross Section levelling takes the levels at right angles to the main baseline and on each side (Dream Civil, 2022).

### 2.2.4 Reciprocal Levelling

Where points are divided by interposing spaces - a depression or body of water for example, the variation in elevation between the two points is determined by two sets of reciprocal observations (figure 3) (Dream Civil, 2022)

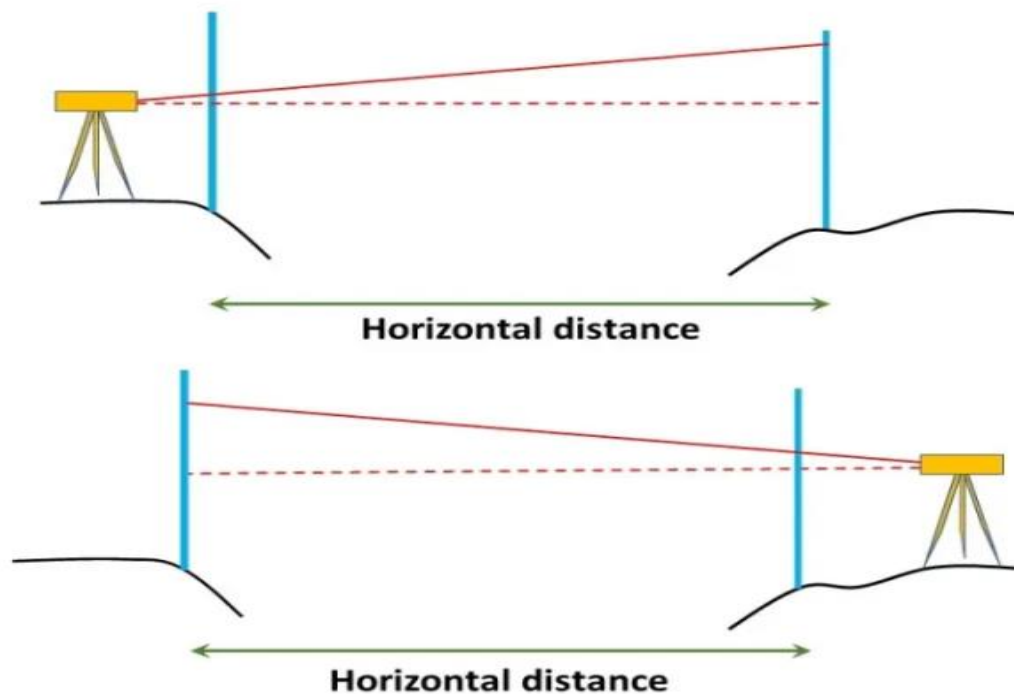


Figure 3: Reciprocal Levelling (Vin CivilWorld, 2021).

However, indirect levelling can also be used, whereby the difference between the points or the point of elevation is established from observing in the field, the distances horizontally and the angles vertically (Civilseek, 2022). This is also known as Trigonometric Levelling because trigonometric relation is involved to determine the elevation of a point from horizontal distance and angle (figure 4) (Civilseek, 2022).

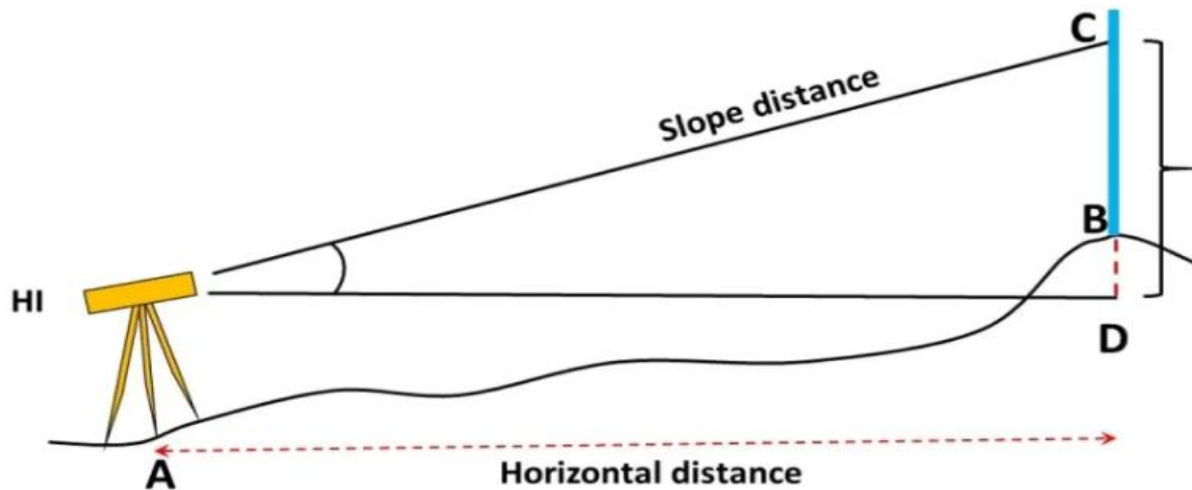


Figure 4: Trigonometric (indirect) levelling (Vin CivilWorld, 2021).

### 2.3 Advantages of Levelling

Levelling in surveying presents several advantages. It can provide industry with essential information in relation to the environment they are working in or on by establishing the elevation of points on the ground's surface and it is also useful when laying the centreline of a road (Rajput, 2020). The data obtained from levelling processes provides an understanding of the ground's terrain and levelling can play an important role in the design of structures, allowing designers to understand how a project can be a success in a particular environment (Rajput, 2020). The planning of a project can be improved thereby decreasing opportunities for expensive mistakes as the project progresses, because the parties involved can gain a greater understanding of a site.

## 2.4 Challenges of Levelling Surveying

However, there are also some disadvantages to levelling in surveying such as;

1. Levelling is a time-consuming process (Rajput, 2020).
2. It must be undertaken by a technically skilled person.
3. Many calculations are required to plot levels on a map – it is a convoluted process. (Rajput, 2020).

Other challenges may also be experienced during a levelling survey, including structures that have been altered, the presence of natural phenomena and varying ground conditions. Difficulties may occur in obtaining the same values in fore sight and back sight readings when levelling along steep slopes such as in areas with hills or mountains. Because the flow of water in a river is constant, levelling a river presents another challenge as it cannot be considered as a levelled surface, with different water levels at the two banks. To overcome such challenges, different methods of surveying can be used, as discussed in section 2.2.

### 3. Equipment Used in Levelling

For the consultation, 4 specialist pieces of equipment were used and during the field work, a levelling sheet, and a pen (figure 5) was used to record back sight, intermediate sight and fore sight (Note: although a levelling sheet was used for the exercise, a levelling book is frequently used). The equipment was a Level Staff (figure 6), 50 metre fibreglass measuring tape (figure 7), tripod stand (figure 8) and a dumpy level (figure 9).

GROUP 5

| Date:   |            | Name of Surveyor: |            | Project ID: |      | <br>Prifysgol Cymru<br>University of Wales<br>Swansea |  |
|---------|------------|-------------------|------------|-------------|------|----------------------------------------------------------------------------------------------------------------------------------------|--|
|         | Back Sight | Intermediate Site | Fore Sight | Rise        | Fall | Reduced Level                                                                                                                          |  |
| Control | 1.370      |                   |            |             |      |                                                                                                                                        |  |
| A       |            | 1.250             |            |             |      |                                                                                                                                        |  |
| B       |            | 1.255             |            |             |      |                                                                                                                                        |  |
| C       |            | 1.492             |            |             |      |                                                                                                                                        |  |
| 1/D     | 1.460      |                   | 1.412      |             |      |                                                                                                                                        |  |
| E       |            | 1.380             |            |             |      |                                                                                                                                        |  |
| 2/F     | 1.550      |                   | 1.345      |             |      |                                                                                                                                        |  |
| G       |            | 1.525             |            |             |      |                                                                                                                                        |  |
| H       |            | 1.954             |            |             |      |                                                                                                                                        |  |
| 3/I     | 1.370      |                   | 1.22       |             |      |                                                                                                                                        |  |
| J       |            | 1.480             |            |             |      |                                                                                                                                        |  |
| K       |            | 1.240             |            |             |      |                                                                                                                                        |  |
| L       |            | 1.241             |            |             |      |                                                                                                                                        |  |
| 4/M     | 1.440      |                   | 1.328      |             |      |                                                                                                                                        |  |
| N       |            | 1.730             |            |             |      |                                                                                                                                        |  |
| O       |            | 1.490             |            |             |      |                                                                                                                                        |  |
| P       |            | 1.500             |            |             |      |                                                                                                                                        |  |
| Q       |            | 1.920             |            |             |      |                                                                                                                                        |  |
| 5/R     | 1.230      |                   | 1.390      |             |      |                                                                                                                                        |  |
| S       |            | 0.700             |            |             |      |                                                                                                                                        |  |
| T       |            | 0.490             |            |             |      |                                                                                                                                        |  |
| U       |            | 0.230             |            |             |      |                                                                                                                                        |  |
| 6/V     | 1.200      |                   | 1.390      |             |      |                                                                                                                                        |  |
| W       |            | 1.390             |            |             |      |                                                                                                                                        |  |
| X       |            | 1.550             |            |             |      |                                                                                                                                        |  |
| Y       |            |                   | 0.980      |             |      |                                                                                                                                        |  |

Figure 5: Levelling sheet used to collect results.

### 3.1 Level Staff

The metric staff has graduations numbered in tenths of a metre and metres, with a very small decimal point between the numbers. Our staves have an "E" shape mark with horizontal spaces between them of 10 mm.



*Figure 6: Level staff used on site to take measurements.*

### 3.2 Measuring Tape

A 50-metre steel tape was used to measure distance between surveying points.



*Figure 7: 50m Fibreglass tape that is used on site to take measurements. Image 2 demonstrating how the steel tape, dumpy level and staff pole are used to take measurements.*

### 3.3 Tripod

Most surveying instruments are fixed on a tripod, which acts as a support. Tripods have three legs which can be extended or lowered as required.



*Figure 8: Tripod that was used to install the dumpy level on top of it. The legs of the tripod were extended so the dumpy level would be higher.*

### 3.4 Dumpy Level

A dumpy level is used to establish or verify points in the same horizontal plane and consists of a telescope-like device that is fitted to a tripod stand. It is used during building surveys to measure differences in height and transfer elevations, in conjunction with a vertical staff. There is a circular level bubble on the dumpy to ensure the level equipment is correctly fitted, which can be adjusted by the level screws on the bottom. The measurement can be taken by looking into the lens once the correct level has been obtained.



*Figure 9: Dumpy level that was used to measure height differences.*

## 4. Levelling Procedure

This is the levelling procedure that was undertaken during the field study;

Firstly, the nearest OS Benchmark (BM) was located by taking a benchmark measurement. This Benchmark is a reference frame for height above mean sea-level and is part of mainland UK's national height system. When all equipment had been set up then measuring could start and for this investigation, each reading was taken 20 metres apart and as follows:

1. Levelling instrument set up at level position 1.
2. Take a reading whilst holding the staff vertically on the datum. Because this is the first staff reading after the instrument is set, it will be the back sight.
3. Take a reading after moving the staff to point A - an intermediate sight.
4. Take a reading after moving the staff to point B - also be an intermediate sight.
5. Take a reading after moving the staff to point C - another intermediate sight.
6. Take a reading after moving the staff to point D - this is a foresight, because the level will be moved after taking this reading
7. Measure the distance between the stations and record in the field book.
8. Take a reading with the level set up at position 2 and level the staff at point D - a back sight.
9. Take a reading after moving the staff to point E - an intermediate sight.
10. Take a reading after moving the staff to point F - a fore sight, because after this reading the level will be moved.
11. Leaving the staff at point F, move the level to position 3.

This procedure was repeated until measuring point Y was reached and using 6 level stations. All measurements were recorded in the field book and changes in level position were noted in the 'Comments' section, as was chainage of all measurements.

## 5. Computation and Plotting of Level

Once the results were collected from the field, the data was collated in excel. A computation and plotting of the reduced level of the points using the rise and fall method was then carried out (figure 10). Figure 10 illustrates the difference in the reduced level with chainage from the BM measurement to point Y. It can be observed that the elevation difference at each point ranges from 488.824 meters (point H) to 490.591 meters (point T). The triangles in figure 9 represent the Levelling Positions -there were 6 in total. The reduced level was established by calculating the rise and fall from the back sight, intermediate sight and fore sight measurements and then, adding the result of Rise/Fall to each measuring point, starting from the TBM of an assumed level of 489.

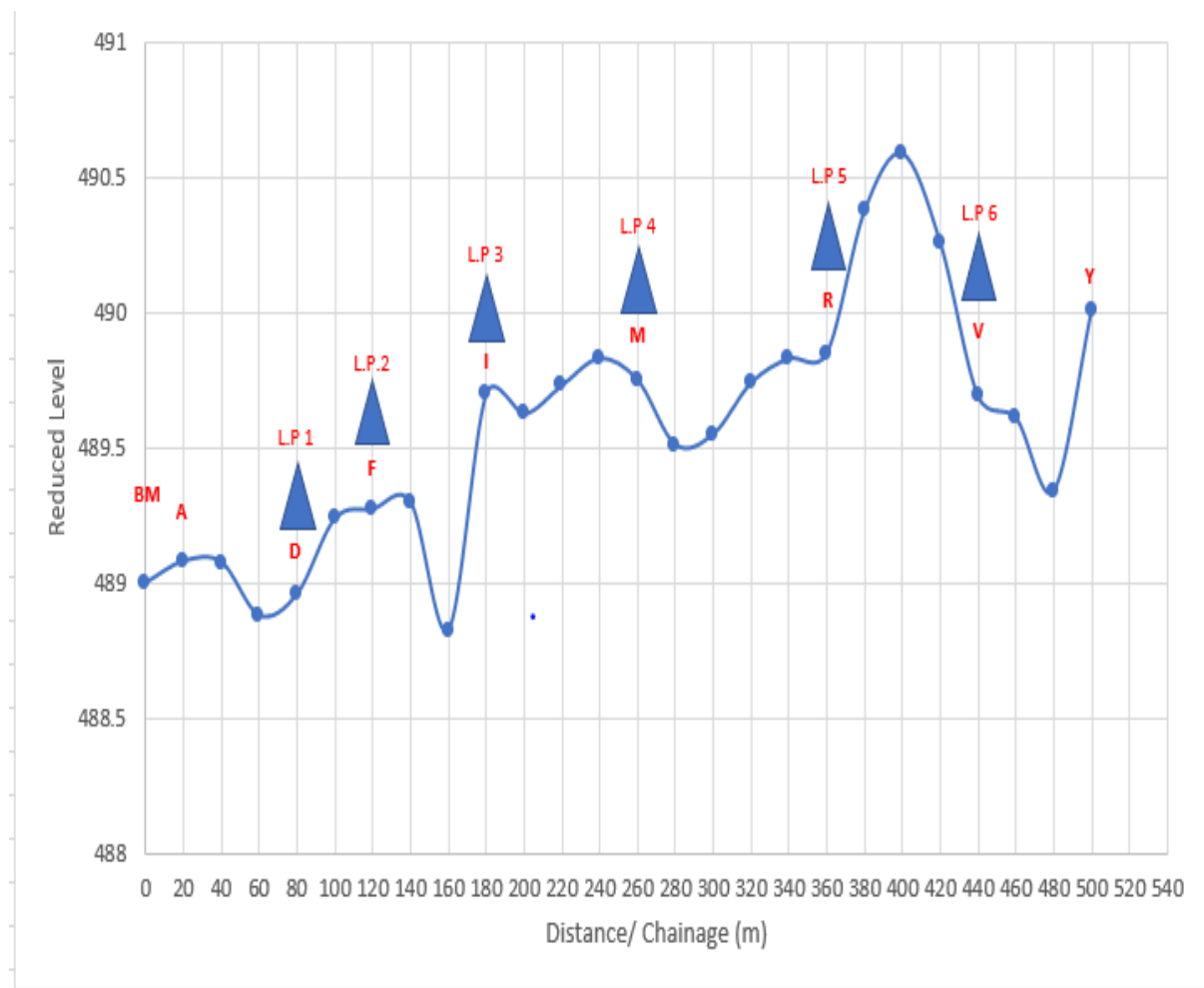


Figure 10: Computation of Levelling using the Rise and Fall method.

Following these actions as illustrated in figure 10, an estimation of the volume of earthwork at the site was carried out (figure 11). This was done by assuming the slope of the road with a straight line connecting the reduced level of the TBM with the reduced level of the last station. From this, we were able to calculate the Cut and Fill (figure 11), by counting the number of blocks in the Cut region and then the Fill region. Consequently, it can be seen if additional earth will need to be delivered to site or if earth will need to be taken away to make the ground level. These calculations are illustrated in figures 12-14. The figures indicate that a total volume of 26.25 m<sup>3</sup> of earthworks needs to be cut off to make the ground level, with the cost of earth removal approximately £34/m<sup>3</sup> (Buildhub, 2021). The Earthwork volume of the site is 26.25 m<sup>3</sup> (26250 tonnes) and it will cost £892 to remove the excess earthworks. This does not include the excavation and hiring out of equipment to undertake this.

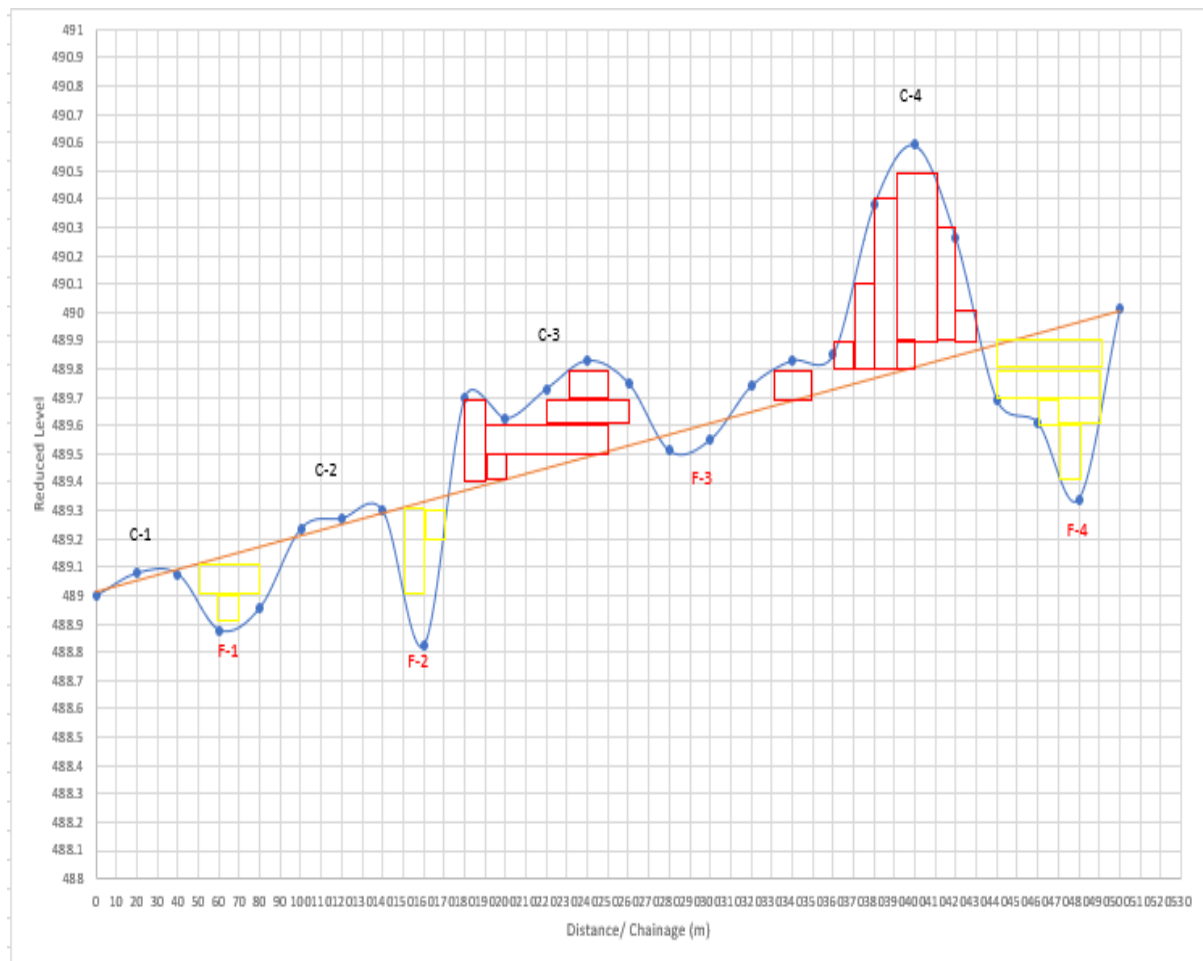


Figure 11: Blocks counted from the Cut and Fill regions to give total earthwork volume.

| Cut | Unit Volume/ Constant | Number/Quantity  | Total Volume (m3) |
|-----|-----------------------|------------------|-------------------|
| C-1 | 1                     | 0.75             | 0.75              |
| C-2 | 1                     | 1.75             | 1.75              |
| C-3 | 1                     | 23.5             | 23.5              |
| C-4 | 1                     | 39               | 39                |
|     |                       | <b>Total Cut</b> | <b>65</b>         |

Figure 12: Cut calculation for total volume earthwork (m3).

| Fill | Unit Volume/ Constant | Number/Quantity   | Total Volume (m3) |
|------|-----------------------|-------------------|-------------------|
| F-1  | -1                    | 7.5               | -7.5              |
| F-2  | -1                    | 8.5               | -8.5              |
| F-3  | -1                    | 1.75              | -1.75             |
| F-4  | -1                    | 21                | -21               |
|      |                       | <b>Total Fill</b> | <b>-38.75</b>     |

Figure 13: Fill calculation for total volume of earthworks (m3).

|                                    |                   |              |
|------------------------------------|-------------------|--------------|
| <b>Total Volume Earthwork (m3)</b> | <b>Cut + Fill</b> | <b>26.25</b> |
|------------------------------------|-------------------|--------------|

Figure 14: Total volume of earthwork for Cut and Fill calculation.

## 6. Conclusion

Levelling Surveying is vital for understanding the study area, although there are many challenges which can increase the chances of error whilst surveying. Despite this, carrying out different methods of surveying and using the equipment properly, will provide every best chance in combating these errors and ensure the project is carried out correctly with validity to the results collected, allowing UWTSD to effectively plan for a major road reconstruction around the city campus. The results collected from the levelling survey carried out demonstrates that the ground is relatively level, ranging from 488.824 meters to 490.591 meters in elevation. Despite this, cut and fill analysis shows that there is excess earthwork of 26.26 m<sup>3</sup> and this will need to be removed for the ground to be level which will cost an estimated £892.

## 7. References

- Buildhub, 2021. *Soil removal costs*. [Online]  
Available at: <https://forum.buildhub.org.uk/topic/20963-soil-removal-costs/>  
[Accessed 2 May 2022].
- Civilseek, 2022. *Types of Levelling in Surveying*. [Online]  
Available at: <https://civilseek.com/types-of-levelling-in-surveying/>  
[Accessed 14 April 2022].
- Dream Civil, 2022. *Levelling in Surveying*. [Online]  
Available at: <https://dreamcivil.com/levelling-in-surveying/>  
[Accessed 14 April 2022].
- Gutti, M. B., 2015. *A Report of Levelling Surevy*, Maiduguri: University of Maiduguri. .
- Rajput, K., 2020. *What Is Levelling in surveying | Types of Levelling in surveying | Advantages & Disadvantages of Levelling in Surveying*. [Online]  
Available at: [https://civiljungle.com/types-of-levelling-in-surveying/#Advantages\\_of\\_Levelling\\_in\\_Surveying](https://civiljungle.com/types-of-levelling-in-surveying/#Advantages_of_Levelling_in_Surveying)  
[Accessed 24 April 2022].
- Vin CivilWorld, 2021. *Types of Levelling – Uses and advantages*. [Online]  
Available at: <https://vincivilworld.com/2021/11/15/types-of-levelling-uses-advantages/>  
[Accessed 14 April 2022].