Accuracy Comparison of Relative Height Determination Using Handheld GPS Approach and Automatic Level in Engineering Projects in Sri Lanka

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Abstract- Height determination is a main task for any engineering project. And it is necessary to determine the height within the required accuracy levels for different tasks. Mostly, in Sri Lanka, automatic Levelling method is used for determining the heights of points in construction projects such as roads, railways, bridges, cannels, dams and drainages etc. However, currently, height determination can be done by using different instruments with different methods such as GPS, Auto Level, Total Station, Theodolites. The purpose of this study is to compare the accuracy of relative height differences using Hand held GPS with Auto level instrument.

Pambahinna pipe line construction project area was selected for this study. Further, 13 points were recognized for height determination and one point was selected as the base point to determine the relative heights of other points. The height of the base point was determined using GPS (GS15) instrument and Hand-held GPS (Leica Zeno 20) instrument was used to determine the height of other points. These data were collected with different modes such as Streaming, SBAS OFF and SBAS ON. Further the collected data were processed with the DGPS and without DGPS approaches. The height differences of the control points were assumed as true values and they compared with the hand-held GPS approach. Finally, the result of this study indicated that 77% accuracy can be obtained through the SBAS ON mode of DGPS in hand held GPS system. This level of accuracy level is enough for some aspects in engineering projects.

Indexed Terms- Relative Height, Handheld GPS, Auto level

I. INTRODUCTION

Levelling is the process of identification of the vertical distance relationship of different points on the surface of the earth (Alak 2000). Information on the surface of the earth with their height relationship is prerequisite to the any engineering project such as construction of roads, railways, bridges, cannels, dams, sewerage and drainage works and water distribution networks. Before 1990, Automatic Levelling was the main technique used in to determine the heights of points on the surface of the earth (Nestorovic & Delcev 2014, Yousif et al. 2017, Storesund 2008). This method is very traditional and cost effective and it provides very accurate data for small areas.

After 1990, with the development of science and technology, Global Positioning Systems (GPS) was introduced in order to get a reliable solution for positioning and navigation. Nowadays, this system is playing a major role in Geodesy, Land Surveying, Earth Science and Cadastral Surveying, by giving a positioning system with high level accuracy (Seyed et al, 2009). Handheld GPS is one of method to capture the data in GPS and it provides a quick and very accurate result. Handheld instrument is a portable instrument and uses Differential GPS (DGPS) services or Wide Area Argumentation System (WAAS) /EGNOS signals (Kamruzzaman et al 2014, Volker 2003). WAAS is a system of satellites and ground stations that provide GPS signal corrections to enhance the Point Positioning Accuracy (PPS).

By using the handheld GPS system, data can be collected in different modes such as streaming mode, SBAS off mode & SBAS on mode. According to these modes, different accuracy levels can be achieved. Furthermore, when it is compared traditional leveling approach with Handheld GPS system for engineering projects, Handheld GPS system saves the entire cost of the project by 50 % through the minimization of working staff and time savings. However, each system has its own advantages and disadvantage thus the purpose of this study is to compare the levels of accuracies of Handheld GPS height component with trusted precise data which were obtained through conventional automatic leveling process for the installation of a pipeline. Generally, water supply projects are very complicated with the objective of gathering water, storing and distribution among the people as a continuous supply. To fulfill these multi purposes, it is very important to have a plan based on correct data with 1m level accuracy.

II. STUDY AREA

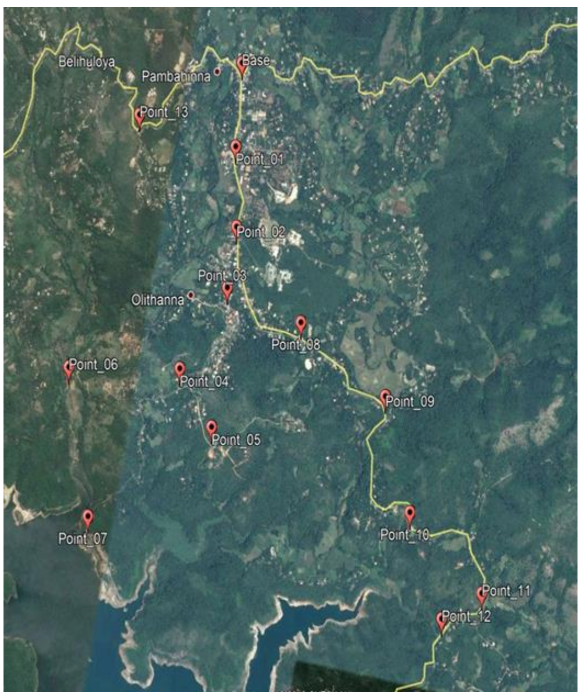

Figure 01: Study Area

Hirikatu Oya water supply project was chosen as the study area which is located closer to Samanala wewa Reservior in Belihuloya, Rathnapura District in Sri Lanka. As shown in figure 01, 14 points were selected along the pipe line including base point (NSG 01). Those points were established by water project with available height data collected by Automatic Leveling process.

III. AUTOMATIC LEVELING PROCESS AND HAND-HELD GPS

In leveling, the difference of height between two points is determined by differences of readings of the leveling staff placed on those points. An automatic level is consisted with a telescope fitted with cross hairs, rotating around a vertical axis, with a very sensitive spirit level or other device fixed to it that enables the line of sight to become horizontal. The reading on a graduated vertical leveling staff is measured through the telescope. If the leveling staff is placed on successive ground points, and the telescope is truly leveled, the difference between the readings at the cross hairs will equal to the height difference between those two points (Figure 02). By moving the level and the leveling staff along a path and repeating the measurement procedure, differences in heights of various points can be measured (Alak 2000, Storesund 2008).

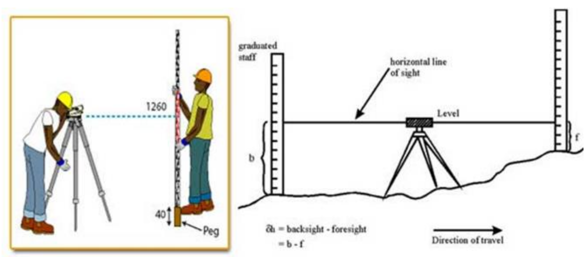

Figure 02: Basic Concept of Leveling

Introduced in the late 1990s, handheld GPS has many features, including navigation assistance and survey data (Jayathissa et al 2008). For some models, features may also include information about geographic locations, such as national and historical landmarks. This device is often used by outdoor activity enthusiasts to determine the position of coordinates (X, Y and Z) of a particular location. A Satellite-Based Augmentation System (SBAS) is a large-scale differential augmentation system. A network of ground stations at known locations is deployed over the SBAS service area to monitor the satellite constellation ranging signals. The SBAS collects and processes all input data provided by the station network to calculate and to provide corrections to the original primary constellation navigation information (satellite orbit errors, ionospheric errors) and their information integrity limits information about one certain region (Jayathissa et al 2008, Odera and Jatani 2017).

Figure 03: Zeno 20 Hand held GPS

According to the literature, longitude and latitude of points given by a hand-held GPS is trustable and equal to the specifications of equipment while the elevation obtained through hand-held GPS is doubtful (Ceylan et al 2005, Paar et al 2014). In the light of this discussion, purpose of present work is to verify the accuracy of elevation by hand held GPS system compared with the automatic leveling system.

IV. METHODOLOGY

Firstly, GPS (GS15) instrument was fixed at NSG 01 point and heights of other 13 points were taken by using streaming mode of the Zeno 20 Hand held GPS. Here 01 second login interval was used and around 15 minutes, the observations were taken for each and every point. Same procedure was followed for other two data collection methods which were used Zeno 20 hand held GPS SBAS on mode and SBAS off mode. Finally, all the collected data were compared with the Automatic Level measurements which were used in the project as shown in figure 04. To compare the accuracies of relative height determination using automatic level measurements with the hand-held GPS system, following five different measuring methods were employed.

- Mode 1- Streaming mode
- Mode 2-SBAS OFF mode pre processing
- Mode 3-SBAS OFF mode post-processing
- Mode 4-SBAS ON mode pre processing
- Mode 5 - SBAS ON mode post-processing

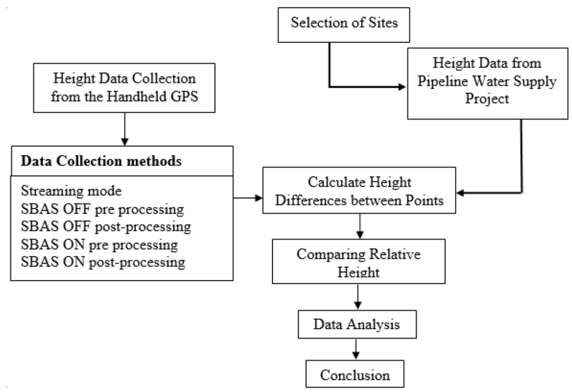

Figure 04: Flow chart of Methodology

V. RESULTS AND DISCUSSION

Station	Relative Height (m)	Mode 1 (m)		Mode 2 (m)		Mode 3 (m)		Mode 4 (m)		Mode 5 (m)	
	Auto Level	h	Δh	h	Δh	h	Δh	h	Δh	h	Δh
Point 1	36.552	38.011	-1.459	28.223	8.329	42.486	-5.934	41.539	-4.987	36.779	-0.227
Point 2	51.566	48.714	2.852	46.492	5.074	53.048	-1.482	53.908	-2.342	51.103	0.463
Point 3	60.357	52.173	8.184	49.771	10.586	61.551	-1.194	63.341	-2.984	60.429	-0.072
Point 4	91.88	90.728	1.152	89.828	2.052	106.717	-14.837	95.628	-3.748	91.168	0.712
Point 5	103.633	101.129	2.504	89.654	13.979	105.13	-1.497	100.838	2.795	104.447	-0.814
Point 6	179.380	177.340	2.040	157.651	21.729	183.163	-3.783	179.900	-0.520	180.171	-0.791
Point 7	181.390	174.740	6.650	165.35	16.040	185.205	-3.815	174.521	6.869	181.312	0.078
Point 8	93.404	89.445	3.959	87.788	5.616	94.542	-1.138	107.176	-13.772	92.535	0.869
Point 9	114.587	114.330	0.257	111.516	3.071	117.712	-3.125	119.815	-5.228	116.002	-1.415
Point 10	105.392	107.424	-2.032	101.209	4.183	112.650	-7.258	122.766	-17.374	106.394	-0.802
Point 11	124.902	128.388	-3.486	127.227	-2.325	132.243	-7.341	127.82	-2.918	123.473	1.429
Point 12	147.002	146.679	0.323	145.868	1.134	166.923	-19.921	151.695	-4.693	148.934	-1.932
Point 13	12.9380	12.778	0.160	8.458	4.480	16.036	-3.098	16.054	-3.116	13.348	-0.410

Table 01: Measured Relative Height

From the results shown in Table 01, it can be noticed that a number of points have being achieved 1m accuracy range under mode 05. Graphical presentation of the results is shown below in the figures.

- Handheld Streaming Mode with SBAS ON

In the streaming mode with SBAS ON, the minimum relative height achieved is 0.16m and the maximum relative height difference is 8.18m. Out of the all points, 3 points are within the range and other 10 points have not achieved this accuracy level within the range as shown in figure 03. According to these results, it can be noticed that 23% of the points are within the range in the streaming mode,

- Handheld GPS in SBAS OFF mode pre-processing.

In the SBAS OFF mode without DGPS correction, the minimum relative height is 1.134m and the maximum relative height is 21.729. There are no any points within the range in this mode as seen in Figure 04. Those errors have been affected to the accuracy of the measurements considerably and no technique has been used here to improve the accuracy.

- Handheld GPS in SBAS OFF mode post-processing.

When the instrument in SBAS OFF mode and the DGPS correction is done, the minimum relative height is 1.138m and the maximum relative height is 14.837m. Out of 13 points, there are no points within the range as represent in the figure 05. Though it is expected to improve the accuracy level by applying the DGPS correction, the accuracy has not been improved through it.

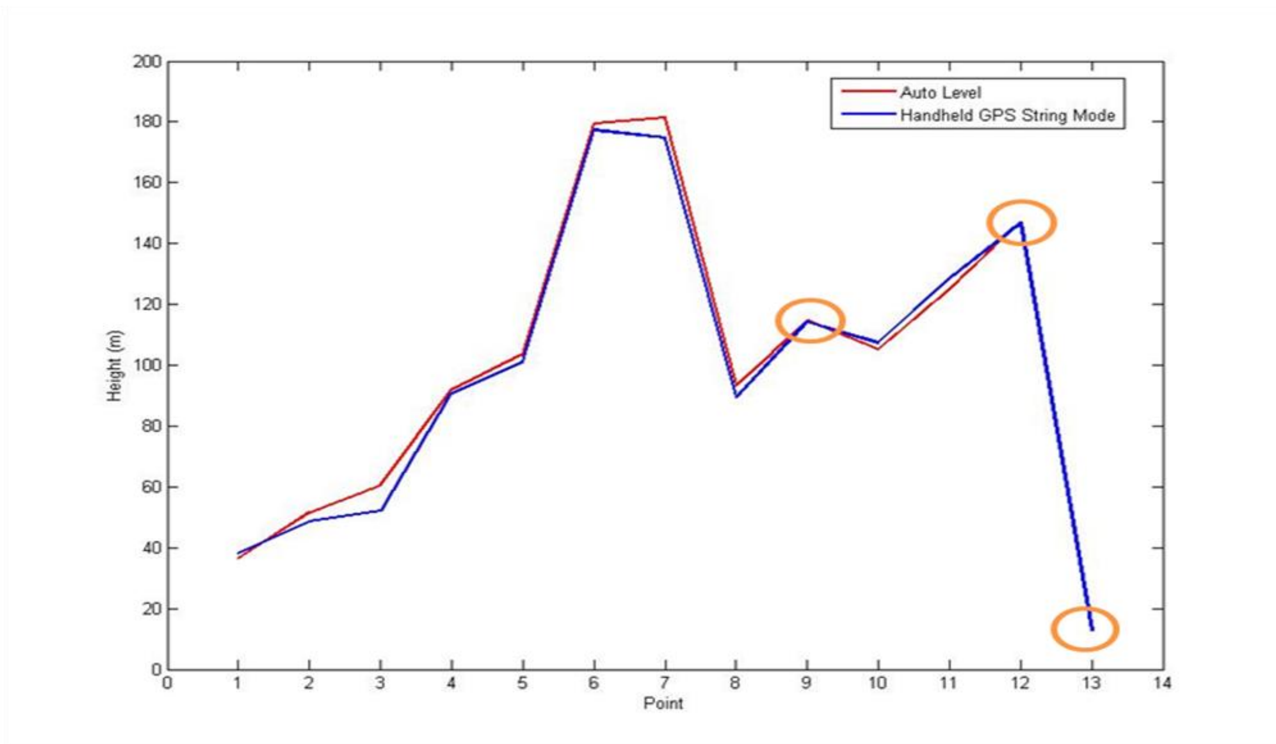

Figure 05: Graphical Representation between Auto Level and Mode 1

- Handheld GPS in SBAS ON mode pre-processing.

It is clearly visible that the height difference is minimized when the observations have been taken with the SBAS ON mode. In this, the minimum relative height difference is 0.52m and the obtained maximum height difference is 17.374m. The increment in the accuracy is observed as the correction parameters obtained with the SBAS. The effect of the orbital and ionospheric errors for the data is very high. One point out of 13 points found in within the range and around 5 points are very closer to the range as shown in figure 06.

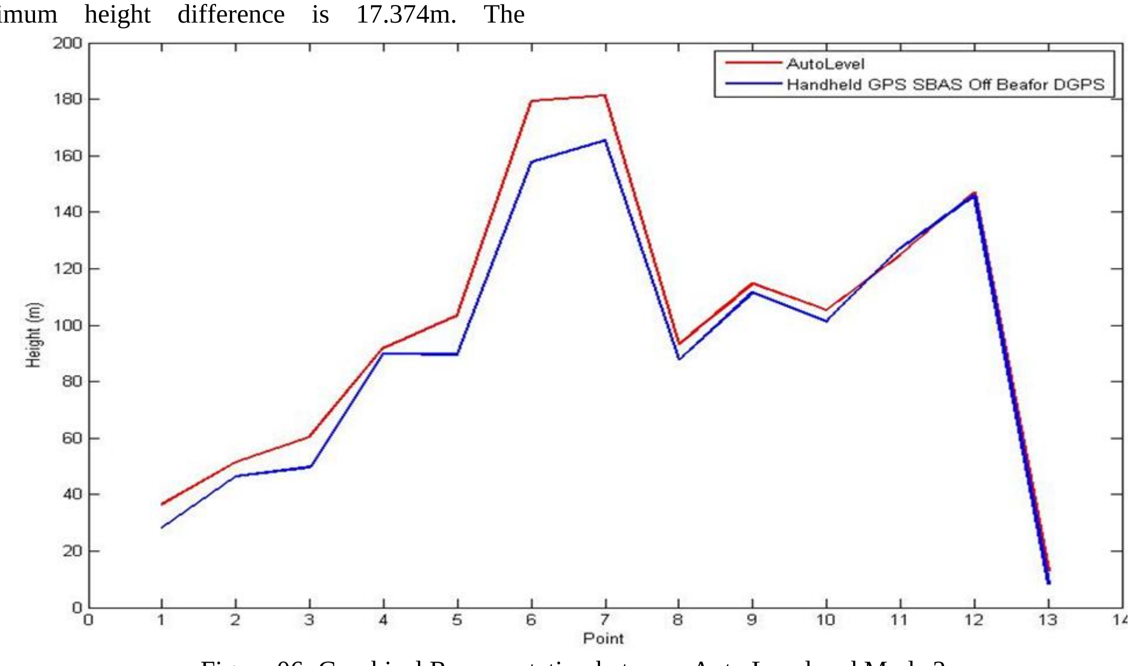

Figure 06: Graphical Representation between Auto Level and Mode 2

- Handheld GPS in SBAS ON mode post-processing

It is clearly visible that the height difference is minimized when the observations are taken with the SBAS mode on. Here the minimum relative height difference is 0.072m and the obtained maximum height difference is 2.429m. 10 points out of 13 points found within the range and other 3 points are between the 1m to 2m as mention in figure 07. The increment in the accuracy is observed as the correction parameters obtained with the SBAS. With the DGPS correction, the accuracy increases as the environment of the base and rover has been same throughout the observation period. The error parameters which effect the base station observations would directly deduce in the rovers as well.

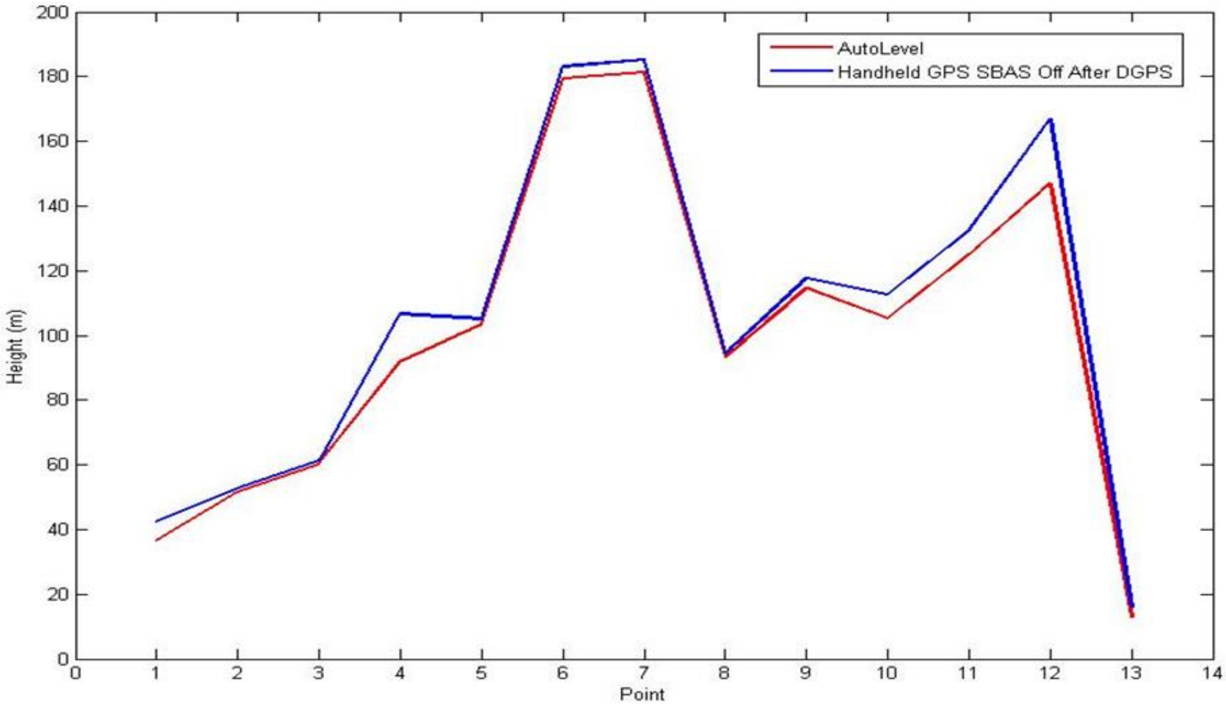

Figure 07: Graphical Representation between Auto Level and Mode 3

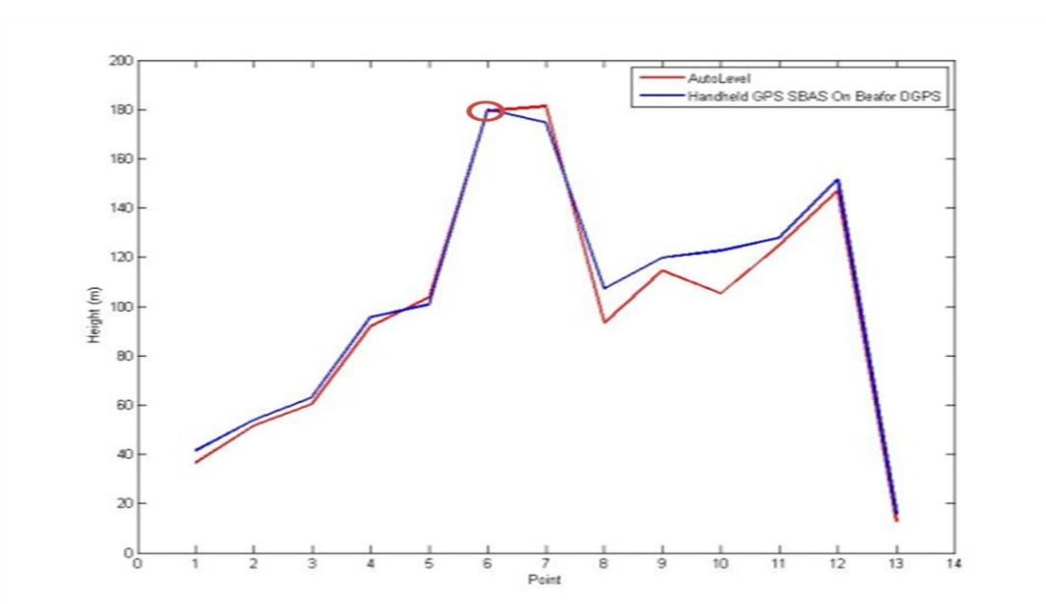

Figure 08: Graphical Representation between Auto Level and Mode 4

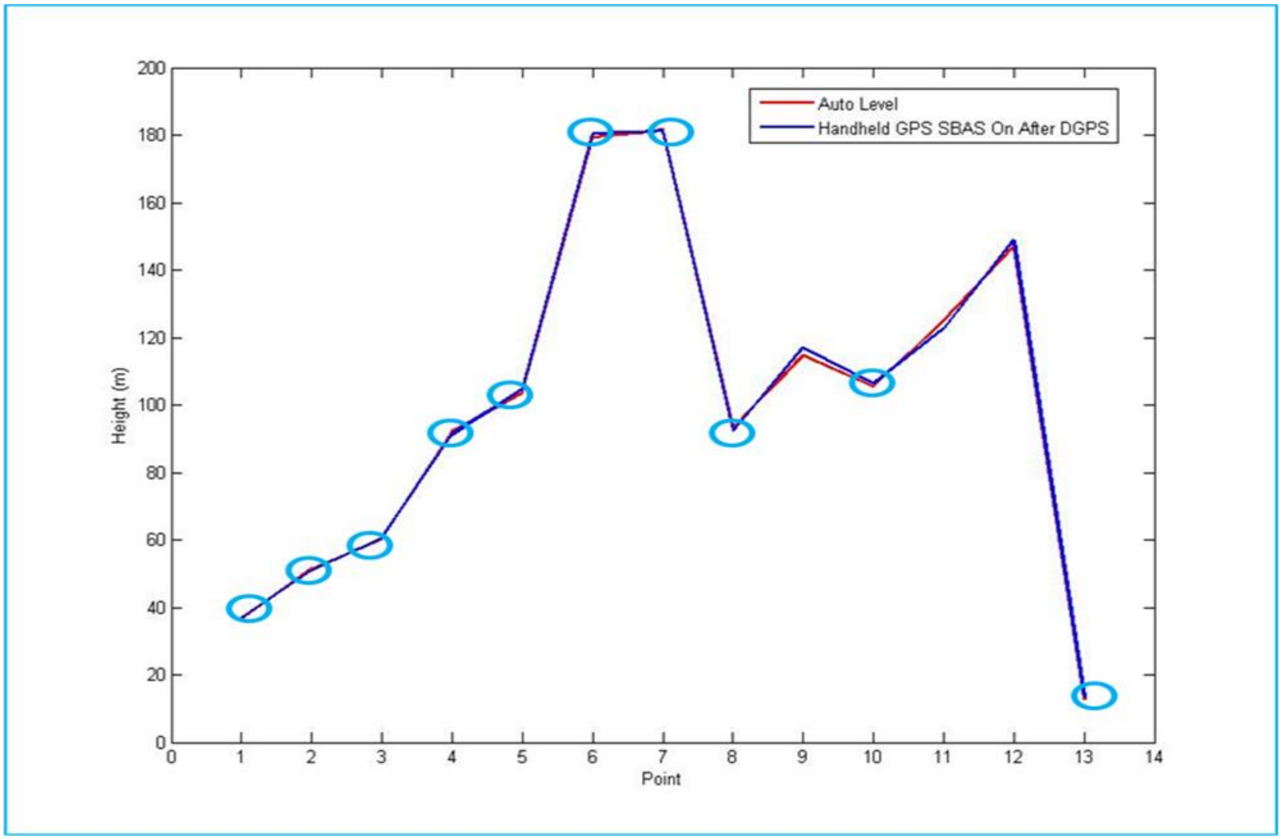

Figure 09: Graphical Representation between Auto Level and Mode 5

Table 2:Achived Accuracy

Method	Minimum Relative Height	Maximum Relative Height	No Points within the Range	Accuracy as Percentage
Mode 01	0.16m	8.18m	3	23.07%
Mode 02	1.13m	21.72m	0	0.00%
Mode 03	1.13m	14.87m	0	0.00%
Mode 04	0.52m	17.37m	1	7.69%
Mode 05	0.07m	2.42m	10	77.92%

CONCLUSIONS AND RECOMMENDATIONS

According to the results, most accurate results are given by handheld GPS in SBAS ON mode post-processing. The accuracy level of that approach is 77 % (Table 02). When it is compared with other four methods, handheld streaming mode is in front line and its accuracy level is 23%. Handheld GPS in SBAS OFF mode pre-processing, handheld GPS SBAS OFF mode post-processing and handheld GPS in SBAS ON mode pre-processing are not suitable in order to get acceptable results.

The importance of the accuracy level of the survey depends on the project. Specially for the project like Precise Leveling (to establish a benchmark), the high accuracy of the survey results is very important but there is no high importance of the accuracy level for the projects like water board pipeline projects. Even though the accuracy level of the Automatic Leveling is very high, costing side of implementing that type of method is not economical. It needs high manpower and time that is taken is also very high as well as the financial cost has to bear is also very high.

When comparing handheld GPS system with Automatic Leveling, the handheld GPS system is very cost-effective system. It does not need more people and with less timing it can do the survey easily. Other thing is that areas that are difficult to reach can be covered very easily. But there is little issue with accuracy level.

Even, the accuracy level of the handheld GPS survey increases with the SBAS on mode with DGPS correction. Because the results show that the survey with SBAS on mode improves the accuracy level for a certain level and from the DGPS correction mode increase for a certain level individually. But in the both combination method gives a best result for the height measurement. So, the combination of SBAS on mode with DGPS correction is the best method to improve the accuracy of the height measurement out of the others.

According to the recommendations given by the main surveyor of water board head office and chief engineer of Irrigation Department, height error of 1m is acceptable for an engineering project. So, out of these five methods, handheld GPS in SBAS on mode post-processing can be treated as most suitable method to do a survey especially for the engineering project like water pipe line, sewerage line, storm water line.

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