APPLICATION OF GPS IN PREDICTION OF POTENTIAL LANDSLIDE LOCATIONS

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ABSTRACT

This paper describes the application of the Global Positioning System (GPS) technology to predict landslide hazardous areas. Landslide is a general term used to describe a movement of a mass of rock, earth or debris down a slope under the influence of gravity. This occurrence causes property damage, injury, death and adversely affects a variety of resources in the disaster areas. With current GPS technology, it is possible to monitor sub-centimeter deformations of any ground movement. GPS requires no line-of-sight between stations. This enables GPS to function and monitor landslides even during unfavorable weather condition either in real time frame or post-processing mode. However, the attainable accuracy of a GPS based system is limited by the satellite geometry and systematic errors such as multi-path and weak satellite geometry. This paper highlights the investigation of landslide motions to produce a prediction map of mass movement using GPS mapping. The research investigation described was conducted at a small landslide area along a new road connecting Pos Selim to Kampong Raja.

Keywords: Landslide, Prediction, GPS survey, GPS mapping

1. INTRODUCTION

At least a landslide disaster will occur each year in Malaysia where the present weather and climate change is concerned. This is because a planner, developer, engineer or a geologist has failed to recognize the warnings from an existing landslide, initial slope movement or area of potential failure. Often landslide hazard is only thought to be significant from more rapid, violent events, which are recognized for their size, speed and devastation. The economic implications of these landslides are numerous. Among the direct effect to humans are the loss of life, damage to natural resources and delay of and damage to development projects such as roads, dams, communication lines, bridges and many more.

The measurement of landslide behavior is usually undertaken through a monitoring scheme. Usually, the measurement of superficial displacement is the simplest way to observe the history of a landslide and consequently to enable analysis of the kinematics of the movement. In all cases, measurements have to be made efficiently in terms of time, manpower and budget.

Various surveying techniques have been used in the past to detect the superficial movements of unstable area [Mikkelsen, 1996]. Global Positioning System (GPS) is used today as it is advanced and fully operational. GPS equipment is more reliable, cheaper, faster, and easier to use compared to conventional instruments [Kaplan, 1996]. New hardware, field procedures and software have also been developed to assist users in data collection and processing purposes. Thus, the development of GPS equipment has become more progressive and used for a wide range of monitoring applications [Gili, 2000]. This paper highlights the performance of GPS technology in landslide monitoring and mapping which discusses on the observations conducted, describes the process of data collected from a specific large surveyed area and analyzed the observations by producing a map to predict the mass soil movements using GPS mapping.

2. RESEARCH SCOPE AND OBJECTIVES

Natural instabilities and movement of material on the earth surface (landslide) have continued to be of special interest to government authorities and resource managers responsible for mitigating any hazards they may impose. In many occasions, landslides have been the cause for the shutting down of entire stretches of highway, swept away villages, buried families and reduced homes to rubble. Most landslides occur along a highway where slopes were made and cut to make way for the construction of the highway itself. In order to prevent unfortunate events such as landslides from happening, a landslide prediction map can be made with the aim to prevent the landslide from occur rather than to sit by and accept that things are all a matter of chance [Omar, 2004].

2.1. Scope of Research

In the development of the hazardous area map, GPS survey will be conducted to get the points and data required.

- This study is focused on the area along new road from Pos Selim to Kampong Raja.
- Most of the excavated cuts in the slope area along the new road from Pos Selim to Kampong Raja are prone to failure and very hazardous.
- The developed map will portray the surface of the area which have layers of different data input.

2.2. Objectives

The objectives of this study are:

(i) To create a landslide prediction map using GPS technology.
(ii) To determine the potential hazardous point in the research area through GIS mapping.

3. METHODOLODY

The methodology adopted in the research (figure 1) is to determine the potential hazardous point through GIS mapping. The level of risk of landslide is assessed. Rapid Static GPS differential surveying technique is used during the GPS survey [Kavanagh, 2003]. The data from the survey are subsequently analyzed using the appropriate software and compared with the previous data. Finally, combination of all the analyzed data contributes to the production of the landslide prediction map.

4. DATA ANALYSIS

During the static survey, data such as latitude, longitude, ellipsoid height and orthographic height are observed and recorded. From these parameters, the degree of present landslide activity and the depth to which the movement has occurred is ascertained and the mapping process will reveal the potential hazardous locations for landslide at the locations where the survey is conducted.

Out of all the parameters recorded, the orthographic height is the most significant and vital element in the evaluation of the hazard degree. The differential between the previous orthographic heights with the present orthographic height determined for a given location defines the movements which can be classified in accordance with the International Geotechnical Societies' UNESCO Working Party on World Landslide Inventory (abbreviated WP/WLI) requirements. The higher this difference greater will be the movement that will result with a higher risk of landslide occurrence.

4.1. Data Processing

There were a total of 12 locations (spots) where the static survey was conducted. Three different spot classifications have been adopted and these are:

- **Master** - with a site ID that bears a letter "C" in the coding **(C002, C001)**.
- **Safe area** - with a site ID that bears a letter "P" in the coding **(P002, P003, P004 and P005)**.
- **Landslide area** – with a site ID that bears a letter "S" in the coding **(S001, S002 and S003)**.

Ashtech Solutions was used to process the data from the site locations.

4.2. Mapping Process

After the survey data was processed and analyzed, the mapping process proceeded to determine whether movements occurred in the area of survey. In order to make a comparison, the area of study was divided into 2; the safe and stable area being one whereas the hazardous and landslide area was the other.

4.2.1. Safe area

The safe locations were identified by the presence in the area of safety features such as retaining structures, shallow slope angles of cut, appropriate vegetation cover that helps maintain slope stability. GIS survey was done on a total of 4 safety locations. The description of the locations of these is given in table 1 and illustrated in figure 2.

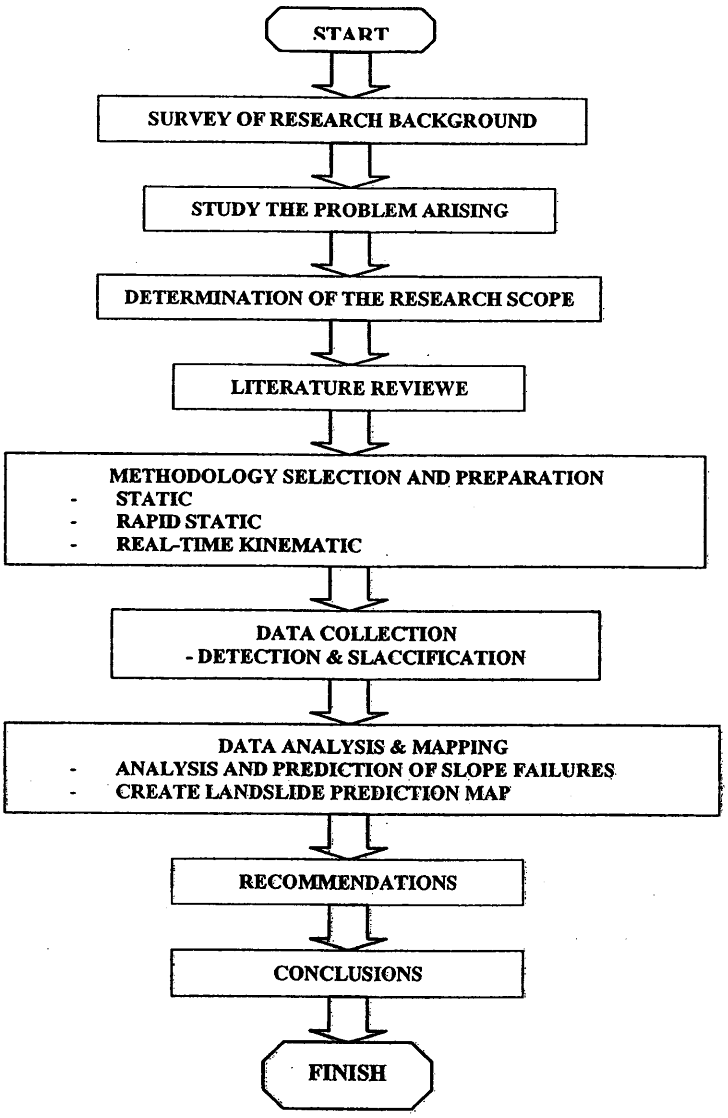

Figure 1: Methodology flow chart.

Site ID	Site Descriptions
P002	BM4051 / MS Kg. Raja 13 / Ipoh 57
P003	BM4053 / MS Kg. Raja 11 / Ipoh 59
P004	BM4055 / MS Kg. Raja 9 / Ipoh 61
P005	BM4057 / MS Kg. Raja 7 / Ipoh 63

Table 1: Site description of each point in the safe area

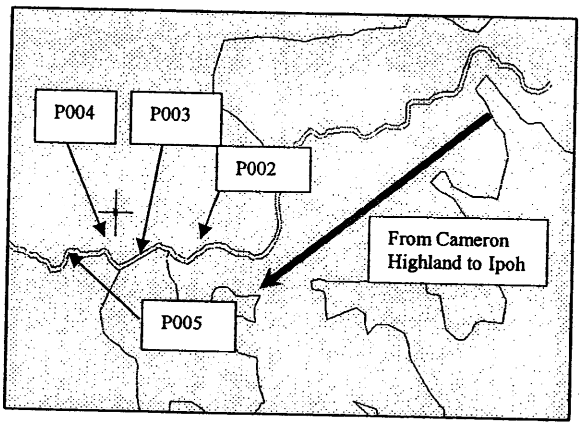

Figure 2: Map showing the safe area locations

4.2.2. Landslide area

The survey area as indicated in figures 3 & 4 were defined as landslide areas due to the condition of the slope which were potential danger to the surroundings with numerous numbers of landslide activities happened during the observation period.
There are total of 7 points including 1 master point where the static survey has been conducted. 3 points which bear the IDs J001, J002 and J003 are located on the road surface just below the slope surface. Meanwhile, the other 3 points which bear the IDs S001, S002 and S003 are located on the slope surface.

4.2.2.1. S001

S001 is located on chainage 23860.00 along the Pos Selim road to Kampong Raja road.

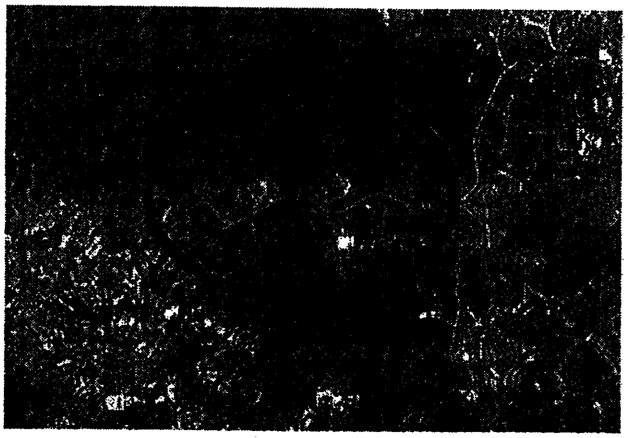

Figure 3: Map view of the landslide area using Quickbird Spatial Image.

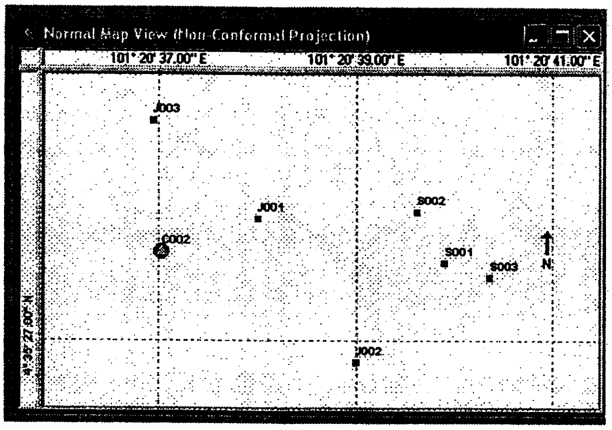

Figure 4: Normal map view of the landslide area using Ashtech Solutions

S001 has the latitude of 4° 35' 27.77347" N, longitude of 101° 20' 39.94523" E, ellipsoid height of 1346.809m and orthographic height of 1352.449m. From the January's data of S001, the orthographic height was 1356.929m. This showed that little movement occurred at point S001.

From figure 5, the difference of the orthographic height can be calculated and the class of the movement determined in accordance with WP/WLI (See also equations 1 & 2)

$$Velocity = \frac{Present\ Orthographic\ Height - Past\ Orthographic\ Height}{Time} \quad (1)$$

$$Velocity = \frac{1356.929m - 1352.449m}{1year} = 4.48 \, {}^{m}\!/_{year} \quad (2)$$

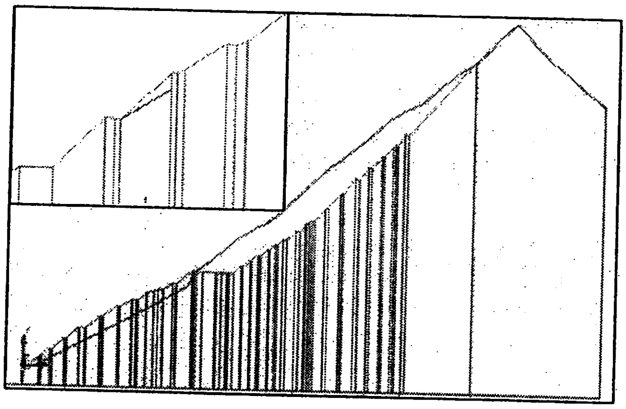

Figure 5: Movements that occurred at point S001

4.2.2.2 S002

S002 is located on chainage 23900.00 along the Pos Selim road to Kampong Raja road. S002 has the latitude of 4° 35' 28.29715" N, longitude of 101° 20' 39.66226" E, ellipsoid height of 1348.524m and orthographic height of 1354.164m. From the January's data of S002, the orthographic height was 1354.342m. This shows that little movement has occurred at point S002.

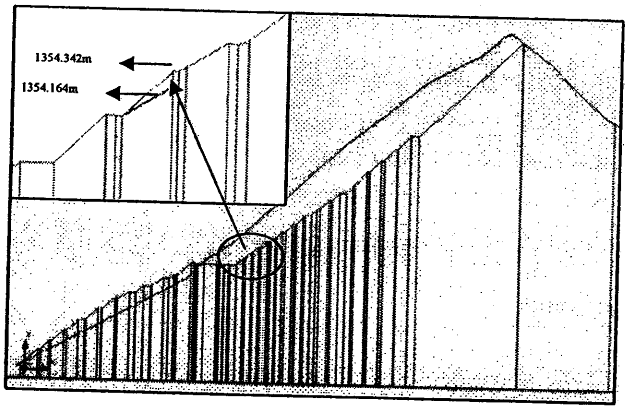

Figure 6: Movements that occurred at point S002

From figure 6 above the difference of the orthographic height is calculated and the movement class defined according to WP/WLI (See equation 3).

$$Velocity = \frac{1354.342m - 1354.164m}{1year} = 0.178 \, {}^{m}\!/_{year} \qquad (3)$$

4.2.2.3 S003

S003 is located on chainage 23860.00 along the Pos Selim road to Kampong Raja road. S003 has the latitude of 4° 35' 27.67709" N, longitude of 101° 20' 40.39308" E, ellipsoid height of 1351.778m and orthographic height of 1357.418m. From the January data of S003, the orthographic height was 1364.972m. This shows that some movement has occurred at point S003.

Similarly from figure 7, the difference of the orthographic height is calculated and the class of the movement determined according to WP/WLI (See equation 4).

$$Velocity = \frac{1364.972m - 1357.418m}{1year} = 7.554\,{}^{m}\!/\!_{year} \qquad (4)$$

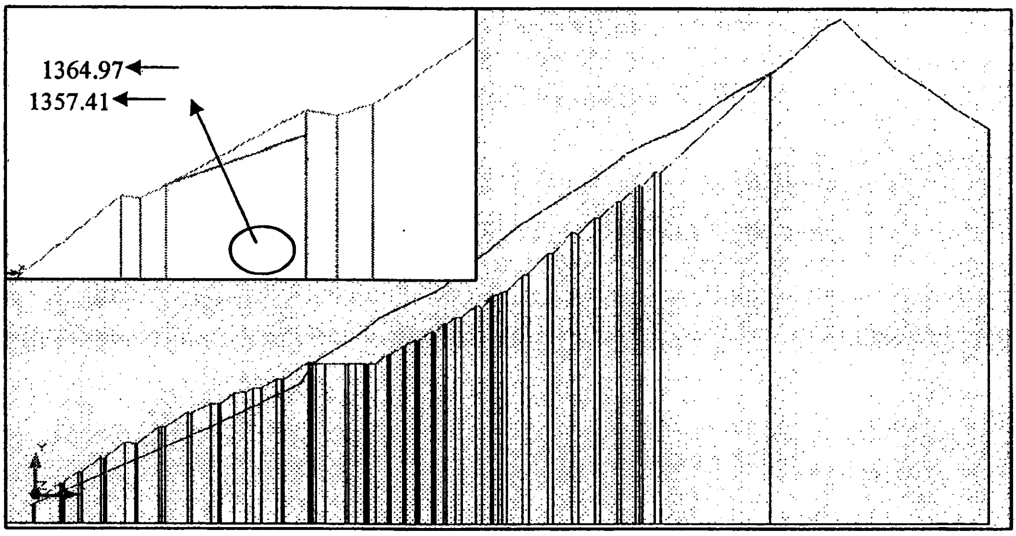

Figure 7: Movements that occurred at point S003

4.3. Results and Discussions

At the end of all the analysis, calculation and mapping, the velocity of each point in the landslide area is recorded in table 6 to define the classes of each movement according to classes of landslide. It is clear that the point S003 showed the highest velocity with 7.554 m/year, followed by S001 with velocity of 4.480 m/year and S002 with velocity of 0.178 m/year.

Table 6: Landslide classes for each point in the landslide area

Site ID	Velocity (m/year)	Classes for landslide (WP/WLI, 1994)
S001	4.480	Class 3 (Slow)
S002	0.178	Class 2 (Very Slow)
S003	7.554	Class 3 (Slow)

5. CONCLUSIONS

GPS is a very useful tool that is utilized for a wide range of scientific applications. This technology increases the accuracy, productivity, monitoring capability, rapidity and economy with respect to size of the study area and it is often better than classical geodetic survey techniques [6]. This paper evaluated the appropriate GPS technique in creating a landslide prediction map to determine the potential hazardous points along the new road from Pos Selim to Kampong Raja. The results indicated that the GPS modern techniques are very reliable for landslide monitoring survey and mapping whereby deformation of superficial displacement can be determined with another epoch of GPS data collections [7].

The data analysis demonstrated that the area which has been defined as the landslide area, chainage 23000 showed movement of the slope surface. Even though the velocity of 7.445 m/year is only classified as class 3 from the classes for landslide, the area showed the potential of larger velocity in an area near to the surveyed area.

Factors such as weathering, vibration of the working heavy machineries and moving heavy vehicles could cause the area become unstable and unsafe in due time and eventually larger movement will occur with higher velocity which in turn could trigger a landslide.

5.1 Recommendations

Some of the recommendations to increase the capability of the research are:

(i) More points should be observed or surveyed to acquire better and more accurate description of the area studied. The data will provide wider range of mapping capacity. Fewer points surveyed will limit the interpretation of the area involved.

(ii) A monitoring scheme should be implemented so that the data can be updated on real time and that the actual movement of the landslide can be detected on real time basis.

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