Establishment of New Control Point Network at Politeknik Merlimau Melaka (PMM): An Action Research Approach

Azrina Binti Zolkifli[1*], Ahmad Yusof Bin Sahdan[2], Norlydah Binti Othman Latpi[3]
[1,2,3] Department of Civil Engineering, Politeknik Merlimau, Melaka
azrina_zolkifli@pmm.edu.my

Abstract: The availability of sufficient and intervisible control points is essential for efficient and regulation-compliant field survey work, especially in academic environments. At Politeknik Merlimau Melaka (PMM), only six existing control points are available across the campus, resulting in students having to queue and wait their turn, which significantly delays their fieldwork progress during practical sessions. Moreover, these existing control points are not intervisible, making them unsuitable for cadastral survey applications and non-compliant with current regulations of the Department of Survey and Mapping Malaysia (JUPEM). This action research was conducted to establish a new network of control points that is not only sufficient in quantity but also meets visibility and spatial accuracy standards. The method involved GNSS (Global Navigation Satellite System) static observations to determine high-accuracy coordinates for newly proposed control points. The control points were carefully planned and distributed across the PMM campus to ensure intervisibility and practical accessibility for students during field exercises. The data were transformed into the GDM 2000 coordinate system and adjusted according to national geodetic standards. As a result, a complete set of accurate coordinate data and a reference control point layout plan were successfully produced. This updated control network now serves as a reliable datum reference for student survey tasks, improving the efficiency and quality of fieldwork in teaching and learning (T&L) processes, especially in the Engineering Surveying, Cadastral Surveying, and Geodesy course for Diploma in Geomatic students. The outcome of this study directly enhances survey education at PMM by reducing field congestion, increasing compliance with cadastral standards, and providing students with a real-world survey environment.

Keywords: Control Points, GNSS, Cadastral Survey, Spatial Reference, JUPEM Standards, Land Surveying, Accuracy, Field Measurement

1.0 INTRODUCTION

Control points are fundamental in all surveying and mapping activities, serving as fixed reference locations from which measurements are made. These control points, whether horizontal, vertical, or three-dimensional, provide the basis for establishing coordinates, aligning datasets, and ensuring the spatial integrity of survey work (Kavanagh, 2000). For any survey project to achieve precision, the availability of reliable and accessible control points is essential. In Malaysia, the standards for control point establishment, particularly for cadastral surveys, are governed by the Department of Survey and Mapping Malaysia (Jabatan Ukur dan Pemetaan Malaysia [JUPEM], 2009), which mandates that control points must be intervisible and referenced to approved geodetic datums. In parallel with international practices, universities and technical institutions have increasingly implemented campus geodetic control networks to simulate real-world survey conditions (Ibrahim, Rahim, & Zakaria, 2020).

At Politeknik Merlimau Melaka (PMM), practical fieldwork is a core component of the Diploma in Geomatics program. However, the existing geodetic infrastructure at the campus presents several limitations. Currently, there are only six established control points available across the institution. This limited number forces students to queue and share access during fieldwork sessions, resulting in inefficient use of time and delays in completing survey tasks. Furthermore, these existing control points are not intervisible, which violates cadastral surveying standards and restricts the application of surveying methods such as traversing and angular observations that require clear line-of-sight between control stations (JUPEM, 2009; Mustaffa, Sukor, & Badrul, 2007).

In response to these limitations, this study was designed as an action research project aimed at establishing a new network of GNSS-based control points that are well-distributed, intervisible, and compliant with national surveying standards. The objective of this study is to provide a reliable geodetic framework across the PMM campus to support student field activities. The purpose is to ensure that students can complete their practical surveying tasks efficiently and in a way that reflects real-world industry practices.

The significance of this study lies in its practical implications. By establishing a network of control points that meet technical, spatial, and educational needs, the institution not only enhances its academic infrastructure but also ensures that its survey training aligns with national standards. Students benefit from reduced field congestion, improved learning outcomes, and exposure to professional geodetic procedures. In addition, the new control network provides a long-term spatial reference framework that can support future engineering, cadastral, and geospatial projects at PMM.

2.0 LITERATURE REVIEW

2.1 Control Point Networks in Surveying

Control points are essential in providing reference positions for spatial measurements in both cadastral and engineering surveys. They serve as the foundational layer in geospatial data acquisition, ensuring all measurements are spatially consistent, traceable, and repeatable over time (Kavanagh, 2000). A robust control point network allows for the integration of different datasets, seamless transformation between coordinate systems, and efficient field operations.

In the Malaysian context, the Department of Survey and Mapping Malaysia (JUPEM) has defined strict regulations concerning the use and establishment of control points. According to JUPEM (2009), cadastral survey control points must be intervisible, well-marked, and referenced to national geodetic datums. The requirement for intervisibility is critical, especially in traversing and angular observations, which form the core of many traditional and modern surveying methods.

2.2 Establishment Control Networks using GNSS Technology

With the advancement of satellite-based positioning Global Navigation Satellite System (GNSS) has become the preferred method for establishing and verifying control point networks. GNSS allows for high-accuracy, three-dimensional coordinate determination using static or kinematic observation techniques (Hasan et al., 2010). Static GNSS observation, in particular, is widely used in control surveys due to its capability to deliver centimetre-level accuracy when sufficient satellite data and observation duration are maintained (Kavanagh, 2000).

In educational institutions, the application of GNSS to develop campus-scale control networks is increasingly common. Such networks serve as permanent spatial references for practical surveying exercises, enabling students to work in real-world scenarios while complying with national technical standards (Mustaffa, Sukor, & Badrul, 2007). Moreover, GNSS control stations can be easily integrated into national geodetic infrastructure, allowing seamless geospatial data exchange and alignment.

Recent studies emphasize that GNSS-based control networks, when properly integrated with national geodetic frameworks, significantly enhance spatial data integrity and field efficiency, especially within educational campuses (Abidin et al., 2017; Elnaga, 2022).

Several studies have highlighted the benefits of re-establishing campus control networks using modern methods such as GNSS, supported by traverse and leveling measurements for validation (Mustaffa et al., 2007; Abdul Kadir et al., 1994).

3.0 METHODOLOGY

This study involves existing equipment, such as GNSS sets, and does not involve large costs.

Table 1: Equipment used in the project to establish control points using GNSS

NO.	EQUIPMENT	SPECIFICATION
1.		Set GNSS: Model Trimble 5700 ● Antena dan GPS Receiver. ● Signals: GPS/QZSS L1C/A. L2C, GLONASS L10F, BEIDOU B1L, B2L, GALILEO E1-B/C, E5B
2.		Point marker (Monument) ● Cement and GI pipe (RM20 x 7 contol points)
3.		Software: Trimble Bussiness Centre ● Process Rinex data.
		TOTAL

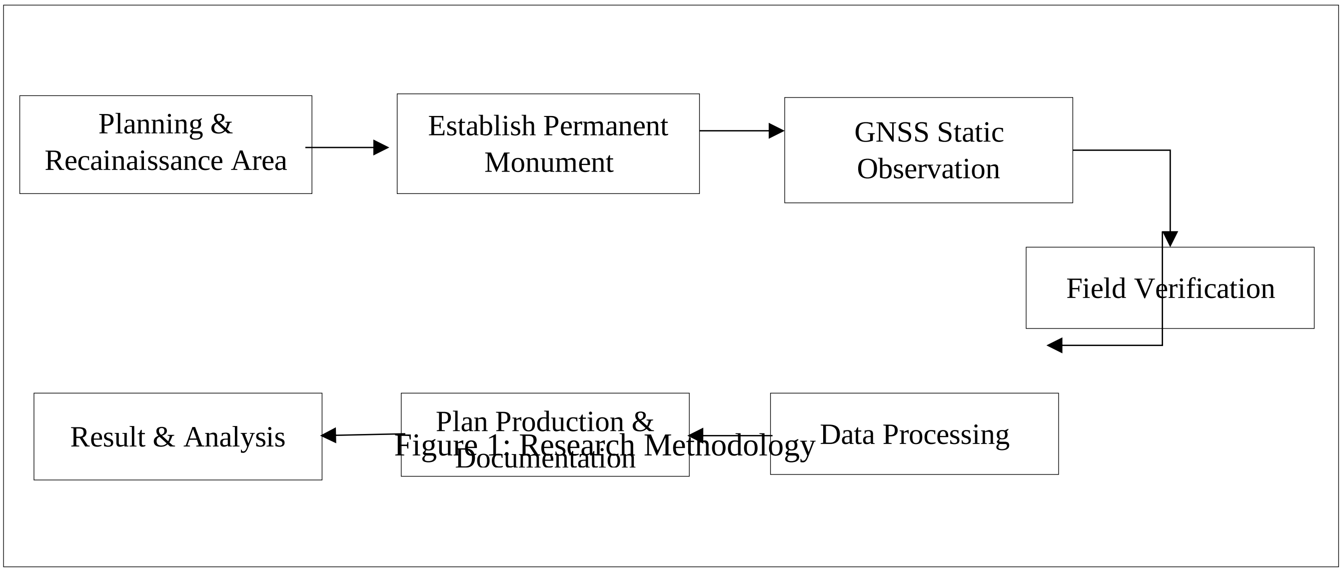

Figure 1: Research Methodology

3.1 Planning and Reconnaissance

To ensure that the study objectives are achieved, discussions with all parties were held. The selection of the location of the GNSS control point network was also made in agreement with PMM and its collaboration partner, the Department of Survey and Mapping of Malaysia (JUPEM), Melaka, after a site visit was conducted around the PMM area.

Figure 2: Planning and survey of the area by PMM and JUPEM Melaka officer

The selection of control point locations includes the following criteria:
i. Intervisibility.
ii. Stable and permanent location.
iii. Easy access.
iv. Physical protection and permanent marking.
v. Control points are distributed evenly or strategically to cover the entire project area.
vi. Tie in new control points to existing national reference systems.
vii. Safety and disturbance factors.

3.2 Establishment of Permanent Monument

Once the area has been selected and designated, a physical monument (a solid monument or marker) is planted at the location. In this project, cement mortar and GI pipe are used as markers for the permanent monument of each new control point.

Figure 3. The process of making a permanent monument

3.3 GNSS Static Observation

Data observations using the Global Navigation Satellite System (GNSS) method were statically made for seven (7) new monuments or control points for 1 hour using a Trimble 5700 GPS device. All GNSS observation data is in the World Geodetic System (WGS) 1984 projection. The data was then processed into the GDM 2000 projection. The three (3) GNSS control stations used as references are the HSR point located in the PMM, the station in Muar, and the station in Melaka.

The use of static GNSS techniques for campus control network establishment has been proven to deliver centimetre-level accuracy, aligning with best practices outlined by Teunissen and Montenbruck (2017) and Zulkifli and Hassan (2019).

Figure 4: GNSS observations being carried out by the project team

3.4 Verification and Mapping

Post-processed coordinates were verified for consistency and then plotted using CAD software to create a comprehensive control point layout plan. Intervisibility analysis was also conducted to ensure compliance with cadastral surveying requirements. To validate the control network, distance and bearing values between selected control points were computed and compared against theoretical values using Bowditch’s method of adjustment. Any control points that did not meet visibility standards were either re-positioned or excluded from the final network.

Verification is done to ensure that the location of the observed points is correct, not physically disturbed, and accessible for long-term purposes. This verification is done in collaboration with the PMM Diploma Geomatics program's collaborative partner, JUPEM Melaka.

Figure 5: Checkpoint checking carried out by JUPEM Melaka

4.0 RESULTS AND DISCUSSION

4.1 Establishment of Permanent Monument

The new control points have been successfully planted with permanent monuments, and their coordinates have been recorded. The following is a diagram of the positions of each control point:

GCP 01

Figure 6: Position of Ground Control Point 1 (CP01) near the corner next to the PMM Development and Instructional Unit (UPIM) building

GCP 02

Figure 7: Position of Ground Control Point 2 (CP02) near the PMM Development and Maintenance Unit (UPS) building

Figure 8: Position of Ground Control Point 3 (CP03) near the field next to the bus parking lot.

Figure 9: Position of Ground Control Point 4 (CP04) next to the PMM Dormitory Cafeteria.

GCP 05

Figure 10: Position of Ground Control Point 5 (CP05) near the student parking lot (road leading to the PMM Islamic Center)

GCP 06

Figure 11: Position of Control Point 6 (CP06) next to the Department of Electrical Engineering (JKE) building

Figure 12: Position of Control Point 7 (CP07) next to the PMM Sports Complex building.

4.2 GNSS Observation and Coordinate Results

The GNSS static observations were successfully conducted at all proposed control point locations across the PMM campus. Each observation lasted between 3 to 4 hours, ensuring a sufficient number of satellite signals for reliable post-processing. Using Trimble Business Center software, the raw GNSS data were processed and transformed from WGS84 to GDM2000 coordinate system as per JUPEM guidelines.

The following is the result of the observation coordinate data for the new control points that have been observed using the GNSS method.

Table 2: GNSS coordinates for base station

CP	Observed Coordinate (WGS 1984)			Observed Coordinate	(CAS-Geocentric)	Observed Coordinate (GDM 2000)		
	Latitude	Longitude	Height (m)	Latitude	Longitude	Latitude	Longitude	Height (m)
HSR1	2°10" 4.93226'	102°25" 29.82855'	17.26	2°10" 4.90251'	102°25" 29.82786'	2°10" 4.90251'	102°25" 29.82786'	17.715

Table 3: GNSS observation data for the new control points

CP	Observed Coordinate (WGS 1984)			Observed Coordinate	(CAS-Geocentric)	Observed Coordinate (GDM 2000)		
	Latitude	Longitude	Height (m)	Latitude	Longitude	Latitude	Longitude	Height (m)
CP01	2°10" 9.94903'	102°25" 56.9263'	25.393	-60013.142	54645.59	2°10" 9.51493'	102°25" 51.39152'	25.393
CP02	2°9" 57.05984'	102°25" 49.25693'	18.333	-60409.103	54408.767	2°9" 56.62664'	102°25" 43.72321'	18.333
CP03	2°9" 59.59537'	102°25" 39.76295'	11.713	-60331.322	54115.415	2°9" 59.16194'	102°25" 34.23049'	11.713
CP04	2°10" 3.36641'	102°25" 39.37992'	13.677	-60215.501	54103.543	2°10" 2.93270'	102°25" 33.84746'	13.677
CP05	2°10" 5.51215'	102°25" 36.60528'	16.679	-60149.634	53986.9	2°10" 5.07824'	102°25" 30.07332'	16.679
CP06	2°10" 4.78971'	102°25" 44.73262'	17.791	-60171.731	54268.906	2°10" 4.35592'	102°25" 39.19947'	17.791
CP07	2°10" 3.5436'	102°25" 48.32543'	19.38	-60209.968	54379.922	2°10" 3.10992'	102°25" 42.79181'	19.38

4.3 Layout and Network Design

The final output produced a complete list of X (East), Y (North), and Z (Height) coordinates for all new control stations. These coordinates were tabulated and compiled into a reference sheet for use in student fieldwork. All control points demonstrated a horizontal accuracy within ±0.02 m and vertical accuracy within ±0.03 m, aligning well with Class 1 geodetic control point requirements.

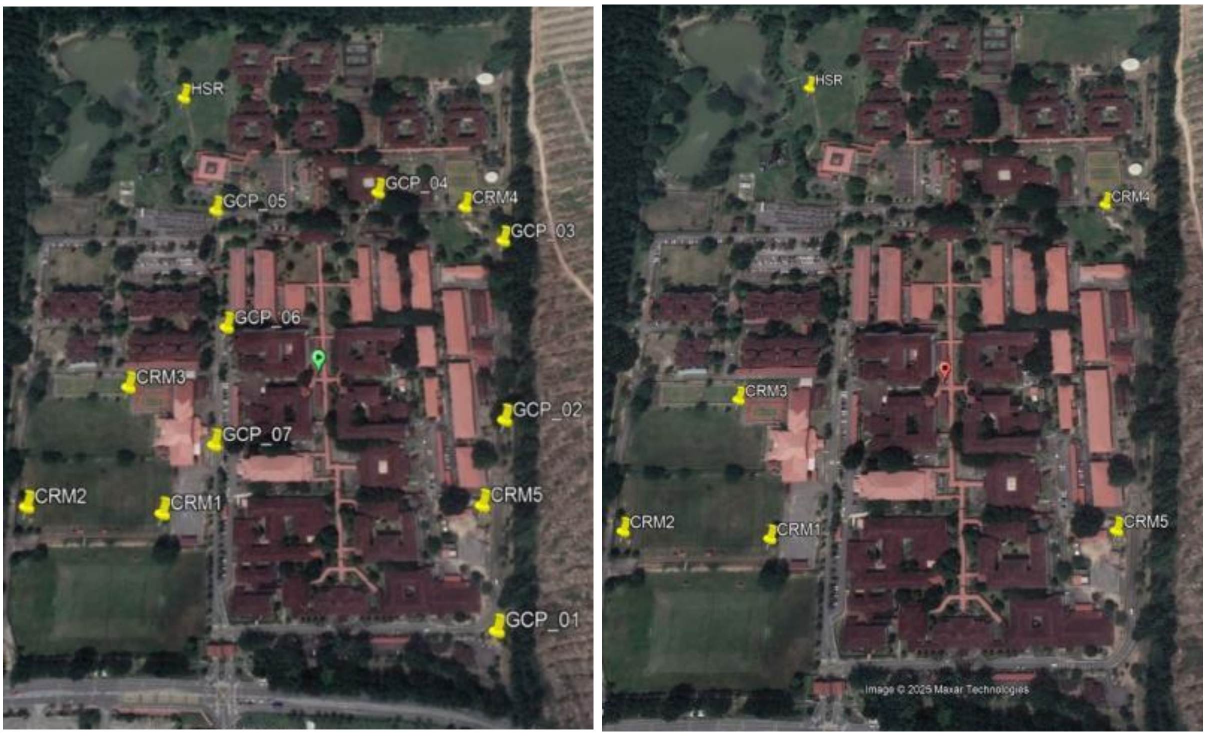

Figure 13: Existing control points (left) and new control points establish in PMM (right)

Figure 13 illustrates the initial configuration of the geodetic control network at Politeknik Merlimau, comprising six control points: CRM1 to CRM5 and HSR. While functional, this limited distribution posed constraints in terms of spatial referencing and survey precision across the campus area. In the enhanced configuration shown in the right image, an additional seven Ground Control Points (GCP_01 to GCP_07) were strategically established to densify the existing network. The incorporation of these new control stations improves geometric strength, reduces positional uncertainty, and provides a more robust reference framework for various surveying and geospatial applications, including topographic mapping, GNSS calibration, and remote sensing data alignment.

Figure 14 is a graphical representation of the control point network that has been constructed in the area of Merlimau Melaka Polytechnic (PMM). This network consists of two types of control points, namely the primary control points known as CRM (Example: CRM_01 to CRM_05) and secondary control points marked as CP (Example: CP01 to CP07). The layout of this network shows the comprehensive coverage of the campus area, and the positions of the control points have been strategically chosen to ensure stability, accessibility, and clear line of sight between the points.

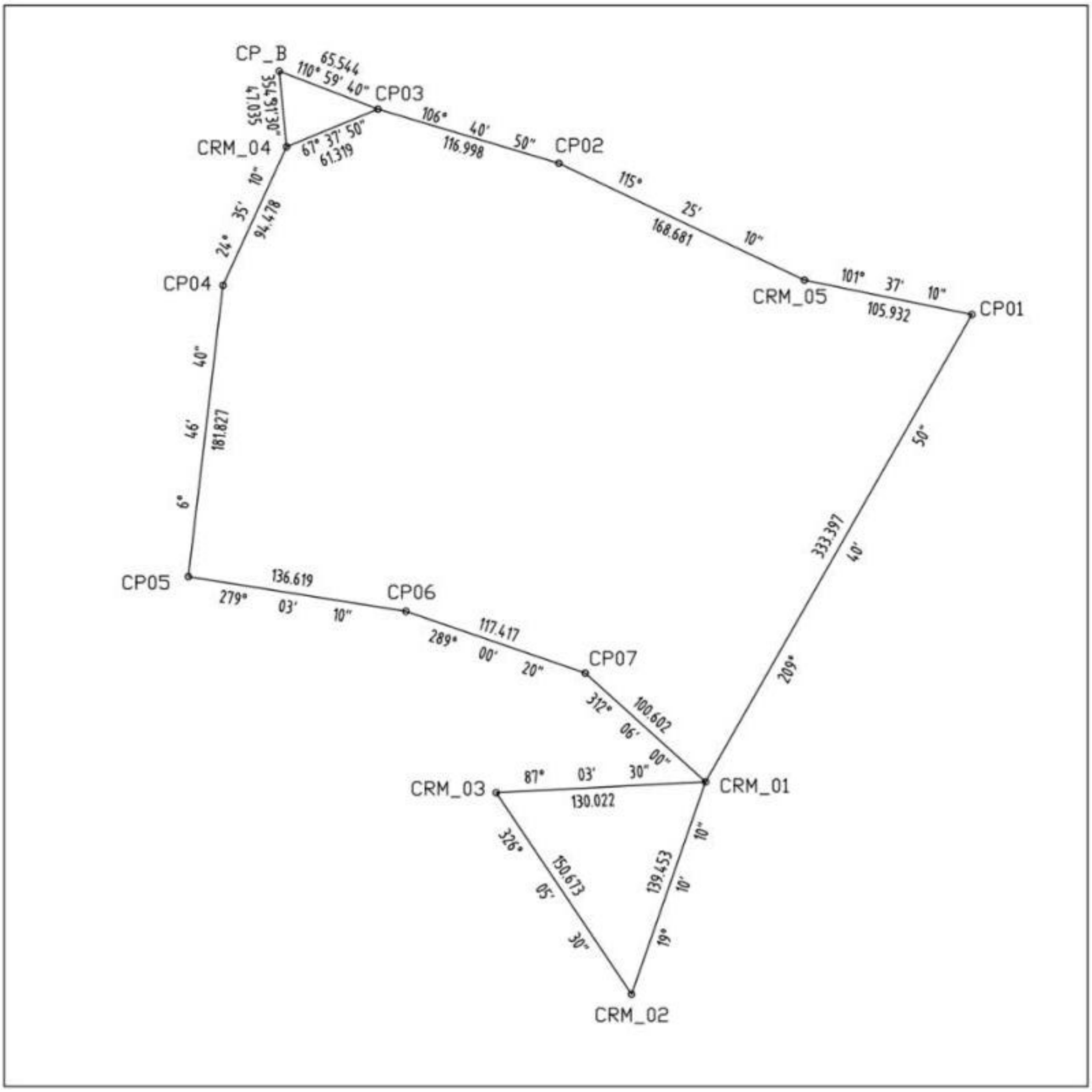

Figure 14: Plot of new and old control point positions at PMM

4.4 Comparison with the Previous Control System

The previous system relied on only six legacy control points, many of which were poorly marked, unverified, or non-intervisible. Students had to queue to access these limited stations, resulting in inefficiencies and inconsistent data. In contrast, the new network:

SITUATION BEFORE	SITUATION AFTER
The number of control points is limited and unsystematic/not visible to each other, making cadastral surveying difficult. Some of the old control points are not recorded properly.	Addition of systematic and complete control points with documentation.

The area coverage is not comprehensive, only involving selected areas, causing students to have to queue to use certain control points when practicing in the field.	Extensive coverage involves the entire PMM campus area.
There are no official records and it is difficult to trace back.	Has complete documentation including coordinates, sketches, pictures and metadata.

4.5 Discussion Summary

The findings of this action research clearly demonstrate that a GNSS-based control point network, when planned systematically and validated through academic fieldwork, can significantly improve the delivery of surveying education. It not only addresses operational inefficiencies but also enhances the quality of student output and engagement.

Moreover, the collaborative and iterative nature of action research allowed for real-time improvements and feedback integration: a model that could be replicated in other technical institutions facing similar geospatial challenges (Kemmis & McTaggart, 2005).

5.0 CONCLUSION

This action research successfully addressed the limitations of the existing control point infrastructure at Politeknik Merlimau Melaka by establishing a new, well-distributed, and intervisible network of GNSS-based control points. The previous system, which relied on only six non-intervisible points, was inadequate for the growing needs of the surveying program and failed to meet JUPEM cadastral standards (Jabatan Ukur dan Pemetaan Malaysia [JUPEM], 2009). The newly constructed network now comprises additional control points with high positional accuracy, all referenced to the national geodetic system and projected in RSO.

Through GNSS static observations, post-processing, and coordinated site planning, the research achieved its objective of enhancing the teaching and learning (T&L) environment for practical surveying activities. Students no longer face prolonged delays due to control point shortages, and instructors can now conduct practical assessments using standardized, reliable geospatial references.

Recommendations

Based on the findings and reflections throughout the research, the following recommendations are proposed:

1. **Institutionalise Control Point Usage**
   The control point network should be formally integrated into the surveying curriculum with clear SOPs for usage, maintenance, and record-keeping.
2. **Develop a Digital Reference Repository**
   A digital map and coordinate database should be created for student and staff access, including metadata, photos, and intervisibility charts of each control point.
3. **Regular Validation and Maintenance**
   Annual checks should be scheduled to validate the physical condition and positional accuracy of each point, ensuring long-term usability.
4. **Expand Network Coverage**
   Future phases could consider expanding the control point network to surrounding campus areas for

broader geospatial applications, including UAV mapping, infrastructure monitoring, and GIS-based planning.

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