UNDERGROUND UTILITY MAPPING AND ITS CHALLENGES IN MALAYSIA

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SUMMARY

Accurate information regarding the existing underground utilities is required in the planning, installation of new utilities and excavation of existing utilities. Lack of knowledge on this may result in fatality and catastrophic damages of existing underground utilities and disruption to utility services. Industries may suffer greatly, in terms of financial lost if utility services such as power supplies are interrupted because of accidents during excavation works due to inaccurate utility information.

Most utility agencies in Malaysia take the responsibilities of mapping and keeping their own utility network information for their internal use. The Department of Survey and Mapping Malaysia (JUPEM) have been given the mandate by the Government in compiling underground utility data from various utility agencies for the purpose of maintaining a single repository that would serve as a centre for utility data. However, there is no legislation to ensure underground utility data are being kept accurately and up-to-date.

Underground utility mapping presents a completely new field for land surveyors to diversify their expertise in positioning technology. Underground utility mapping which combines the use of detection and positioning technology, requires the land surveyors to acquire new skills, knowledge and technique.

This paper presents the role of JUPEM as a main driver in utility mapping, utility agencies, land surveyors and the land surveying profesion to meet the demand and challenges in executing the underground utility mapping in Malaysia.

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1. INTRODUCTION

Underground utility mapping is a process of identifying the position and labelling public utility mains which are located underground. These mains may include lines for telecommunication, electricity distribution, natural gas, water mains and wastewater pipes. In some location, major oil and pipe lines, national defence communication lines, mass transit, rail and road tunnels also compete for space underground.

Underground utility mapping refers to the detection, positioning and identification of buried pipes and cables beneath the ground. It deals with features mainly invisible to the naked eyes. While the determination of position can be obtained with conventional or modern survey equipment, the detection and identification of underground utilities require special tools and techniques. Principally, underground utility mapping is the combination or marriage between two major fields of knowledge namely; geophysics and geomatics.

Land surveyors in Malaysia, had always been associated with land and strata titles, geodetic surveys, engineering surveys, topographical surveys, hydrographical surveys and map making. In the recent years, land surveyors had also diversified into LIDAR technology, GIS and related fields. Underground utility mapping presents a completely new field for land surveyors to diversify their expertise in positioning technology. Thus, underground utility mapping which combines the use of detection and positioning technology, requires the land surveyors to acquire new skills, knowledge and technique.

In Malaysia, utility agencies are private entities or government linked companies (GLCs). Currently among the main players in this industry are: Gas Malaysia Sdn Bhd – with regards to the provision of gas and the laying of gas pipelines for its transmission; Tenaga National Berhad – pertaining to the provision of electricity and the laying of electricity cables; Telekom Malaysia Berhad – with regards to telecommunication and the laying of telephone lines; SYABAS – in the supply of water in the state of Selangor; Indah Water Konsortium Sdn Bhd – concerning the provision of sewerage facilities and the laying of sewerage pipes.

The Department of Survey and Mapping Malaysia (JUPEM) is a government agency responsible for cadastral survey and mapping in Malaysia. Being the national mapping agency for Malaysia and having vast experience in managing geospatial information, JUPEM have been entrusted by the Government to compile and manage information on all underground utilities.

2. THE ROLE OF JUPEM IN UTILITY MAPPING

JUPEM's involvement in utility mapping began with the directive from the Malaysian Cabinet to compile and manage information on all underground utilities for the country. This is due to the frequent disruption of water and electricity supplies caused by the damage of water pipes and electricity cables due to the excavation works carried out during installation of new utility facilities or during upgrading or widening of roads **(Figure 1)**. The damage is due to the unknown location and depth of the underground utilities.

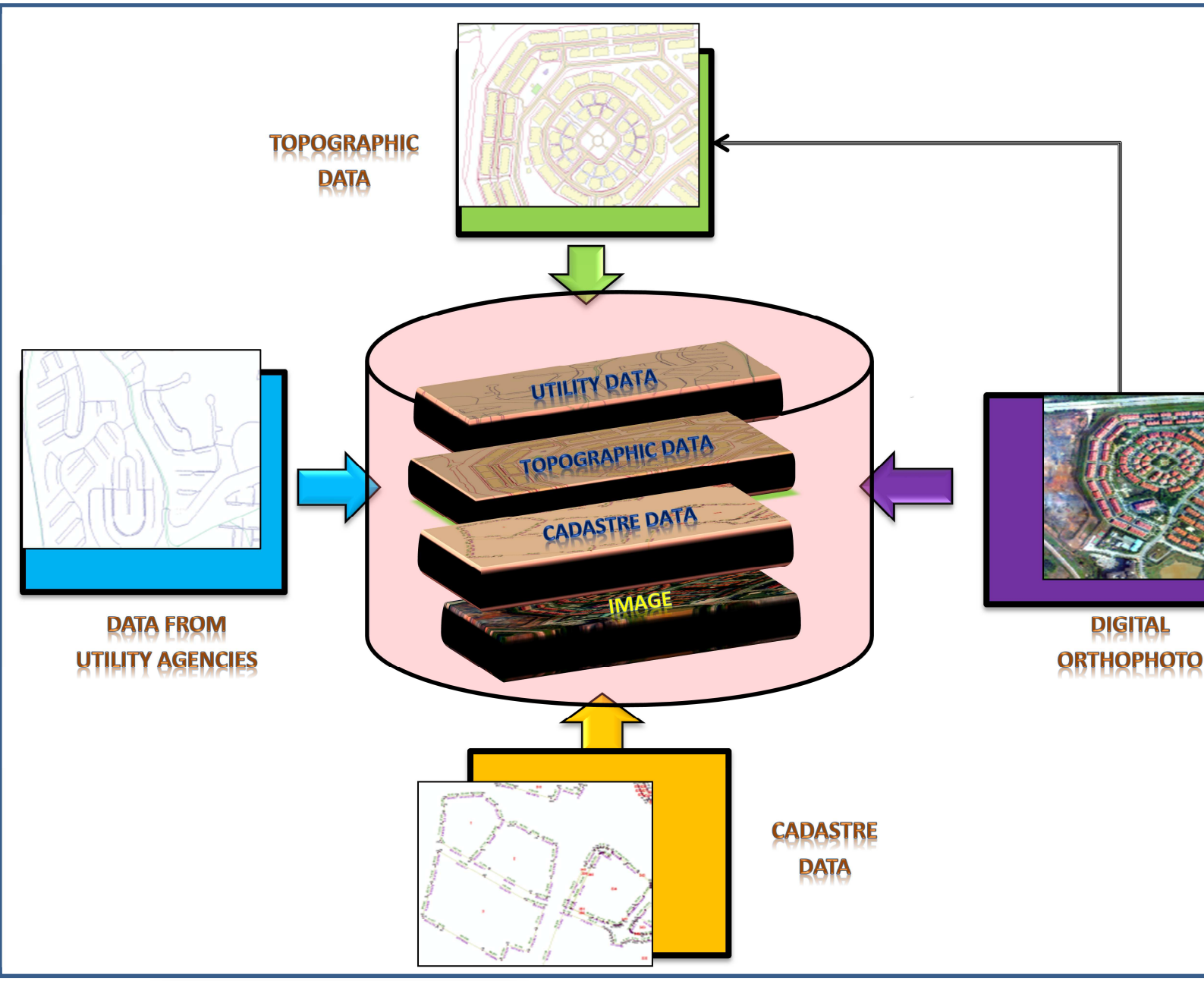
Figure 1: Damage utilities due to excavation works

In order to effectively undertake this task, JUPEM established a Utility Mapping Section under the Mapping Division in 2006 with fifty-five staff. JUPEM later acquired a Utility Mapping System and developed a national underground utility database called PADU. Its main objective is to act as a repository of reliable and accurate underground utility data comprising power and telecommunication cables, gas, water and sewerage pipes provided by the utility agencies in a systematic geographic information system (GIS) approach. The data submitted by the various utility agencies are subjected to various checks and verification processes before they are accepted into PADU. The database consists of four major components of information namely large scale photogrammetric base maps that are tied to the geodetic networks, cadastral overlays delineating all land parcels, topographic data and a series of utility layers, each containing utility features and attributes **(Figure 2).**

The underground utility and other geospatial data which form the core components of PADU are kept in a seamless geo-database format for efficient access, analysis and sharing purposes. The final products of the whole mapping process are maps presenting all the utility and geospatial information in a logical and easy to understand manner **(Figure 3).** These products are available on a print-on-demand basis allowing sharing of information amongst the relevant parties to be less hassle and more cost effective.

To ensure an orderly management of utility data between JUPEM and utility agencies requires the establishment of an agreed mechanism, procedures and specifications, and thus the need for a standard guideline for underground utility mapping. In 2006, JUPEM produced a Standard Guideline for Underground Utility Mapping (Director General of Survey and Mapping Circular 1/2006) with the aim to provide standard procedures for collection, compilation and presentation of underground utility data. This guideline is the culmination of

concerted efforts of the Underground Utility Mapping Technical Committee chaired by JUPEM comprising underground utility stakeholders functioning under the auspices of the National Committee for Mapping and Spatial Data, being the responsible body for the coordination of mapping activities in Malaysia.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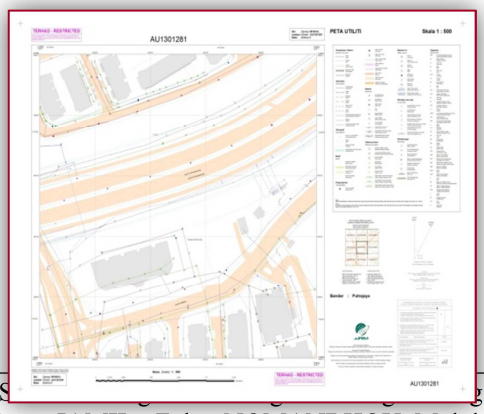

Figure 2: PADU Database Components Figure 3: Utility map produced by JUPEM

This guideline addresses issues such as the roles of stakeholders comprising utility agencies, land surveyors and JUPEM; utility quality levels which are categorized into quality level A, quality level B, quality level C and quality level D with quality level A being the most accurate and quality level D being the least accurate. This guideline also provides specifications on underground utility maps and creation and maintenance of underground utility database which stores related utility data that can be made available to utility agencies and all other relevant parties whenever underground information is required. These data can then be shared and utilized by various agencies involved in the re-development of the area.

3. CHALLENGES IN UTILITY MAPPING

3.1 Quality of Utility Data

Utility data from various utility agencies are collected and checked for their quality. Within a utility organization, data are sometimes collected and kept by different departments. They are usually kept for different purpose with different accuracy requirement such as for maintenance or planning. Most of the data provided to JUPEM are data from proposed plans rather than as-laid or as-built surveyed data. Comparison done by JUPEM with some of these data indicates large positioning difference which provides misleading information such as utility data being on the wrong side of the road **(Figure 4)**. During verification checks done in the field, JUPEM detected more utility data than what was indicated on the agencies utility plans.

Some utility agencies provides schematic maps/plans of their utilities rather than their actual locations. Moreover, to protect and safeguard their interest, agencies would usually claim the information to be of the lowest quality. Such claim would render the information unsuitable for excavation works but suitable only as a reference for planning. Thus, a more detail survey would have to be carried out before any excavation work could be done. Obviously, this defeats the real intention of the Government's directive for JUPEM to compile and keep data from all utility agencies. On top of that, it leads to unnecessary increase in costs, time and resources.

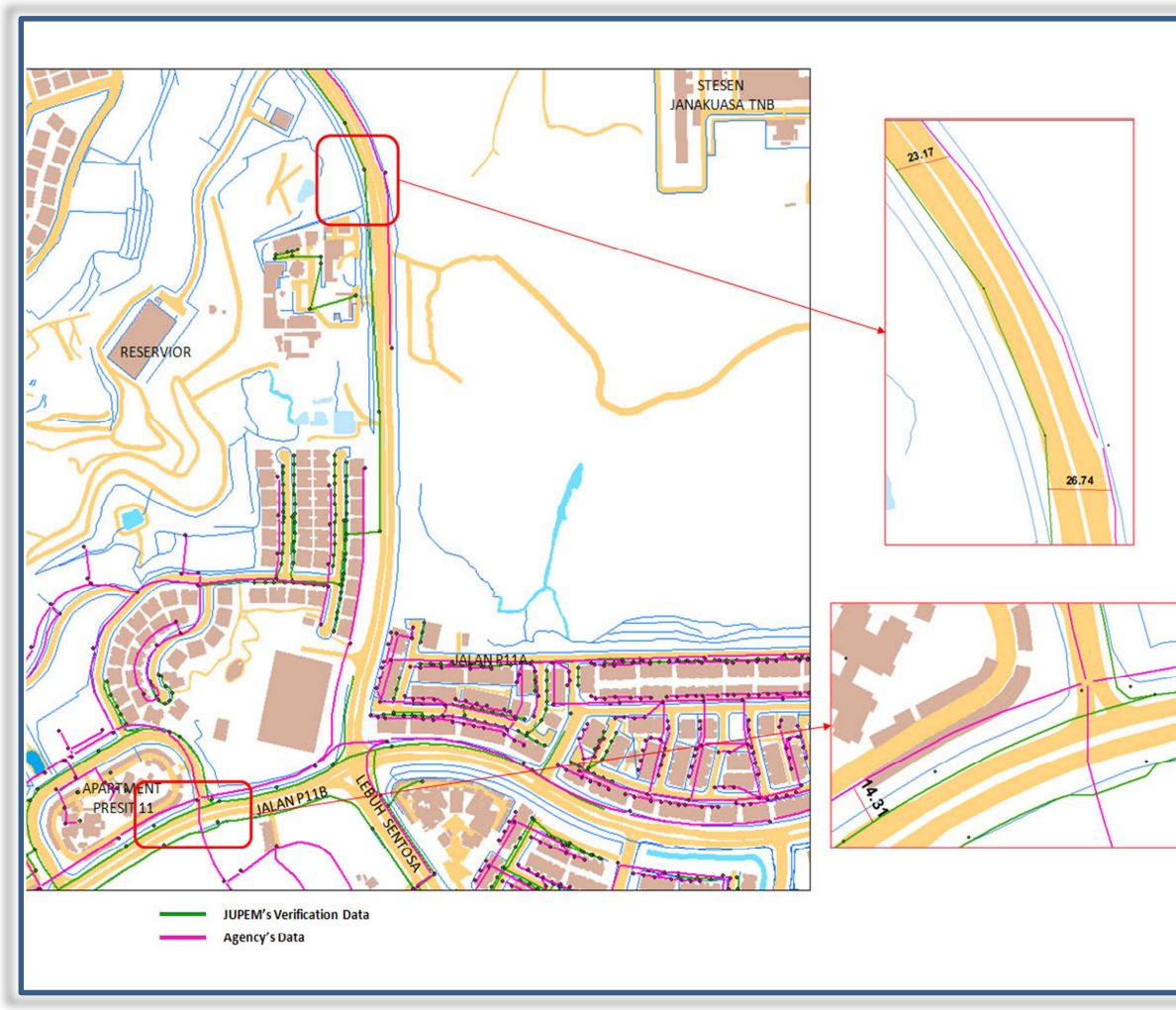

Figure 4: Comparison between agency's utility data and JUPEM's verification data

Usually utility mapping carried out by the utility agencies are for planning, installation of new utilities and also for asset management. The mapping specifications and accuracy requirements between the utility agencies vary depending on their purpose and budget. Administratively, most of the utility agencies are under the jurisdiction of different ministries. There are also regulatory bodies set-up to govern the utility agencies. The Malaysian Communication Multimedia Commission (MCMC) regulates telecommunication companies, while National Water Service Commission (SPAN) regulates the water companies. These commissions provide the necessary guidelines and advice in accordance to the law. However, this situation can become a hindrance in executing what is supposed to be a simple task in compiling data.

As-built information on underground utilities is usually not properly kept and updated. If the data is available, it is usually inaccurate. Currently, there is no requirement for any individuals or organization to provide an accurately surveyed endorsed as-built plan. Without

endorsement by land surveying professionals such as the licensed land surveyors, there is no guarantee that the utilities have been surveyed to a certain accuracies and standards. Also, this is unhealthy where no qualified person or bodies would and could be held responsible or accountable regarding the accuracy of the utility data.

In practice, certain municipalities engage land surveyors and contractors to execute underground utility detection before any re-development is carried out. However, deliverables would depend on what the client requires. They could be in any reference system such as Cassini or Rectified Skew Orthomorphic (RSO) with different datums. Problems may arise when overlaying information coming from different sources. Understanding of coordinate system and the accuracy of equipment and methodology for interpretation of data is critical in overcoming this problem. Most surveys are done in Cassini Soldner projection. The spatial data could easily be transformed if the data is GIS-ready and the transformation parameters are known. At present, the coordinate system used in JUPEM is in a new geocentric reference system based on the International Terrestrial Reference Frame (ITRF) known as Geocentric Datum of Malaysia (GDM). Currently, there are 3 epochs available, namely GDM 2000, GDM 2000 (2006) and GDM 2000 (2009) (Director General of Survey and Mapping Circular 1/2009). The last two epochs are derived from the study of tectonic movement due to the Sumatra earthquake in 2004. Thus, land surveyors need to be aware and educate themselves on these development.

Previously, utility maps were kept by the different utility agencies which had their own formats and standards. There is no central depository control or standards for utility mapping. Sometimes, utility pipes or cables are relocated during repairs or renovations, but not updated in their database. The result of digging or drilling in the presence of unknowns, unmarked, unmapped, or incorrectly located utilities can be a waste of excavation time, causing major damage, utility downtime, and worst of all – personal injury or death.

3.2 Equipment and Technology

Utility mapping is a relatively new task being undertaken by JUPEM, though underground utilities in Malaysia have already been emplaced for many decades. Going underground presents a new challenge to JUPEM, with the incorporation of geophysical elements to the established positional aspect in JUPEMs' work practices. Advanced geophysical tools such as Ground Penetrating Radar (GPR) as well as Electromagnetic Locator (EML) are largely used to detect underground facilities. Detection using GPR is done by pushing or towing the RADAR transmitter cum receiver across or along the facilities. Any buried utilities can be viewed and interpreted through GPR profiles or tomographic images **(Figure 5)**. EML on the other hand, allows the detection of metal pipes by detecting electromagnetic field created or inherently present in the facility **(Figure 6)**. In materializing the full potential of the available techniques, JUPEM's personnel have to undergo specific training and courses. This helps the field parties to efficiently and safely carry out their jobs.

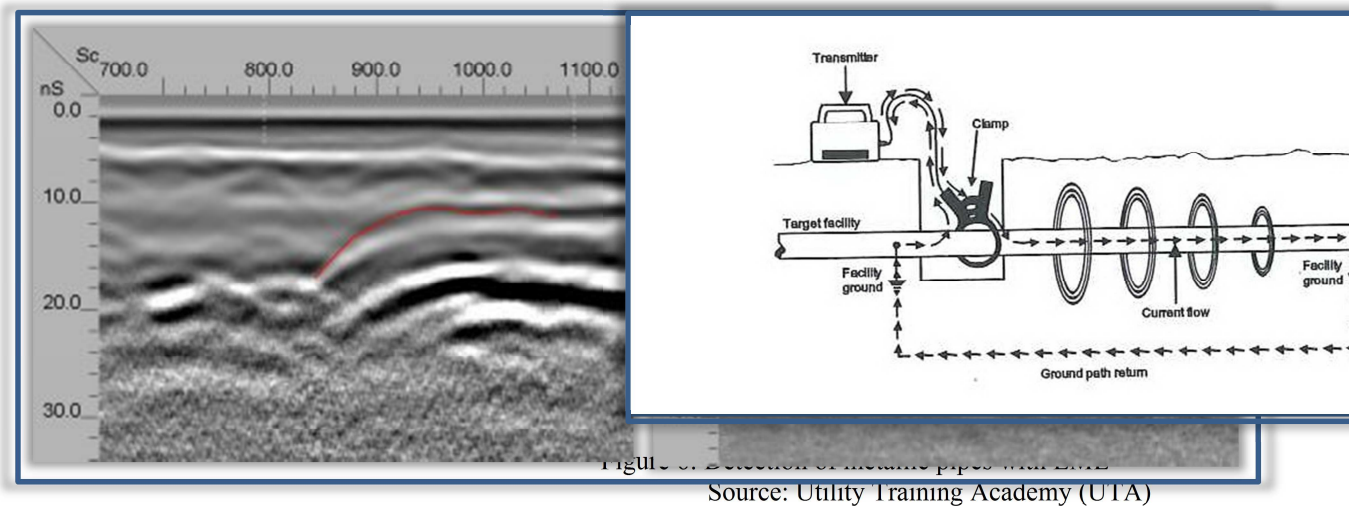

Figure 5: Left profile displays edge of excavation and right profile indicates presence of non metallic utility pipes

Source: Utility Training Academy (UTA)

In utility mapping, providing highly accurate surveying of markings is essential. The survey data is used to make utility maps or overlays for GIS. To establish control above ground, Ground Positioning Systems (GPS) and total stations are used. To map underground utilities, depending on the type of utility, electromagnetic (EM), magnetic, sonic/ acoustic, ground penetrating radar, live line detector, and robotic crawler techniques are used to detect, trace, and map buried utility lines.

Electromagnetic detection techniques are unable to detect non-metallic buried services including plastic, water and gas-pipes and clay drainage pipes. To overcome this potentially hazardous situation, land surveyors often combine the use of electromagnetic detection with GPR. The ground penetrating radar has the advantage of detecting virtually anything below the surface. It also gives an indication of the location and depth of buried utilities but does not identify them. The depth of investigation depends on the conditions of the site. In general, electromagnetic detection and ground penetrating radar techniques detect utilities up to 3 metres below the ground surface. The depth of penetration of the radar can be increased but often at the expense of resolution. All survey and surface geophysical detection equipment used to acquire quality level A data need to be appropriately calibrated to ensure accuracy as specified in standard guidelines.

Underground utility mapping is more complex than surface mapping. Although both involve 3D mapping, the former deals with invisibles that are underground. It needs different technologies, skills and expertise which involve land surveyors in collaboration with other related professionals. However, the main role of land surveyors is to focus on spatial data collection, management of utility information, and actual mapping of the utility network.

3.3 Populating The National Underground Utility Database (PADU)

The challenges faced by PADU is primarily in its data content. Most of the data compiled or provided by the utility agencies have low accuracy and not reliable or fit to be used as referenced for excavations works. This is to be expected as the utility agencies has no legal requirement to provide high quality data or as-built data to PADU. The reason maybe due to the utility agencies not having high quality data. As a result, JUPEM has to perform the detection and survey of underground utilities themselves to upgrade the accuracy of the data to level A or B in order to meet its objective. One of the steps to overcome this situation is to establish an Act whereby by law the utility agencies have to engage qualified land surveyors to execute detection and survey works of existing underground utilities as well as the installation of new utilities. A copy of the utility plan including digital data produced has to be certified and submitted to JUPEM for inclusion into PADU.

3.4 Legislation on Underground Utility Mapping

Utility facilities are usually located on land mainly own by government such as road reserve. By law these facilities are subject to local and federal government requirements in which it is situated. The only law available that governs utility facilities is the Street, Drainage and Building Act 1974 (Act 133) Section 40(1). The Act says that:

"No person shall lay or carry any line of rails, mains, pipes, conduits or electric lines along, through, across, over or under any street or any place laid out or intended for a street within any local authority area without the prior written permission of the local authority which permission may be granted or not at the discretion of the local authority and upon such terms as it thinks fit".

Utility agencies must adhere to the requirement stipulated in this Act during the installation of underground utilities. This Act is silent on mandatory requirement for utility mapping to be carried out. However, this Act gives the power to the government to impose any condition as it deems necessary in a utility project. One of the conditions set by the local government is the requirement to submit 'as-built plan' of the underground utility upon completion of the project. The as-built plan could be in any format i.e. hardcopy or digital format. This information is a good source for up-dating utility data. However, there is no requirement by law for this information to be channelled to JUPEM for safe keeping of future reference. The lack of legal requirement and certainty has inadvertently caused reluctance of parties in contributing data as well as difficulties in collecting and maintaining updated data.

3.5 Health and Safety Aspect

Another major challenge and problem but often being overlook by the industry is with regards to the health and safety aspect of the workers. Land surveyors dealing with utility mapping should be aware of hazard and danger posed by these utilities. As such, land surveyors must take into consideration and satisfy requirement as demanded by the Occupational Safety and Health Act (OSHA, 1994) as it may be a question of life and death for those involved. Failure to observe the necessary precaution would put land surveyors at risk as the employer and/ or employee are liable to be fined and/or imprisonment.

4. NEW DEVELOPMENT IN UTILITY MAPPING

4.1 Involvement of Land Surveyor

Currently, there is no mandatory requirement for licensed land surveyor to be involved from planning to completion of utility projects and up to the creation of as-built plan and to submit a copy of the plan to JUPEM. Introduction of a new law policy could be a viable option to allow qualified land surveyors and JUPEM to play a bigger role in utility mapping in this country. It is proposed that all newly laid utility data must be surveyed by a qualified land surveyor and an as-built plan drawn and the plan with its digital data submitted to JUPEM.

Also, at present, horizontal directional drilling or HDD techniques are used for the installation of underground pipes, conduits and cables along a prescribed bore path by using a surface-launched drilling rig. Steps are now being taken to ensure the location of both ends and underground facilities are being mapped with as-built drawing by land surveyors.

Companies dealing with underground surveying and mapping services are encouraged to engage land surveyor to carry out positioning services to ensure the location of the underground utilities being mapped are accurate and reliable.

4.2 Use of Standard Codes and Marking

Cooperation and sharing of utility data is essential between utility agencies and relevant authorities. Currently, there is no policy to allow the sharing of utility information which is considered a sensitive issue to some due to its business and legal implication. Furthermore, the use of independent features coding by different agencies add to the existing problem in data sharing. In addressing this issue, the Underground Utility Mapping Technical Committee with cooperation with Technical Committee 2 SIRIM has developed standards for feature and attribute codes and has become part of the Malaysian Standard MS 1759: Geographic Information/ Geomatics Feature and Attributes Codes. Hopefully, such action would positively encourage all concerned parties to follow and satisfy the standard requirements set therein. A standardized marking system is also being developed. In order to facilitate their use, all underground utility maps produced must be accompanied by appropriate metadata which complies with the Malaysian Standard Metadata specifications.

4.3 Training in Utility Mapping

The industry for underground utility mapping is relatively new in Malaysia. The tools and technology for underground utility detection were only available during the last decade. Detection tools with better capability and higher productivity are already being developed and are available. In any industry that involves the use of high technology equipment, knowledge and expertise is a major requirement. While knowledge can be obtained through tertiary education level, expertise can only be obtained through experience.

Knowledge in utility mapping is still lacking and need to be developed at the tertiary education level. Some universities in Malaysia such as University Sains Malaysia (USM) and University Technology Mara (UiTM) have introduced the subject into their undergraduate programmes. University Technology Malaysia has taken steps to introduce Master of Science in Utility Mapping. This is a good career development for future and potential land surveyors and those who are already in the industry.

Training should be an on-going process both for office and field personnel. The current focus by JUPEM is on-the-job training. Initially, its personnel works on relatively uncomplicated sites followed by verification work and subsequently on more difficult and densely populated sites. This will allow them to gain enough experience at an acceptable pace.

Most personnel attended short courses conducted in-house or by training centres such as the National Land and Survey Training Institute (INSTUN) and National Institute of Occupational Safety and Hazard (NIOSH). INSTUN is more focussed in disseminating technical knowledge on utility mapping, while NIOSH is concerned with the safety and occupational hazard aspects of the field. Both represent an expansion of career and extension of responsibilities for land surveyors that emerge and progress together with the advancement of technology. It is also intended to make the industry safer and enhances professionalism of the land surveyor.

3D underground mapping is an area that needs expertise. 3D utility mapping allows the depiction of underground utility from different perspective **(Figure 7)**. Such skills and knowledge would provide that extra edge to land surveyors. As such surveyors need to invest in education, in terms of attending courses and investing in hardware and software.

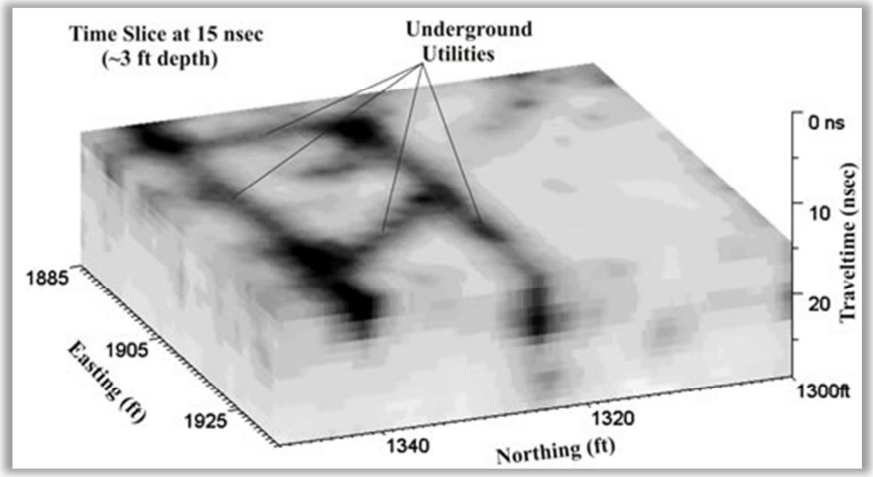

Figure 7: Position of underground utilities in 3D
Source : image obtained from Internet

4.4 Accreditation on Utility Mapping

To ensure competencies as well as enhancing and updating the practicing land surveyors with the latest technological knowledge, they should regularly undergo short professional courses.

At present, an accreditation course is being conducted with cooperation between JUPEM, the Authorised Land Surveyors Association (PEJUTA) and Land Surveyors Board (LJT). This course is conducted for a duration of six months and consists of three (3) main modules: (1) Fundamental and Basic Principal of Measurement – Principle of measurement and tools, fundamental of geophysics, data management, data processing and interpretation, limitation of data analysis; (2) System Operations and Applications – coordinate system, adjustment and transformation, datum conversion and projection, data loading, translation, coding and formatting; (3) Professional and Society - Utility mapping standards and safety requirements, underground utilities system design.

The course consists of lectures and practical assignments which includes reports and documentation of each module/dissertation/project documentation, competency test and skills and oral interview. A certificate will be awarded to participants who fulfil the accreditation prerequisite.

4.5 Standard Rate for Utility Mapping

Another important aspect for the licensed land surveyors is the official rate for utility mapping. At present, there is no standard rate available for underground utility detection work. This has resulted in unhealthy competition practice which can result in sub-standard and inferior results. To address this issue, JUPEM, PEJUTA and LJT have introduced an appropriate and viable rates for all jobs relating to utility detection and mapping and incorporated these rates into the existing rate schedule.

4.6 Studies on Legislation

Laying underground cables and pipelines in Malaysia is a complex matter in which various utility agencies and ministries are involved. Currently, there is no Act available regarding utility mapping. The only Act available that governs utility facilities is the Street, Drainage and Building Act 1974 (Act 133). In order to prevent catastrophic damages of underground utilities and disruption to existing utility services during excavation due to bad or insufficient information on the underground utilities, an efficient system of information exchange between all the parties involved is needed. This can only be achieve by having an Act where all utility agencies are obligated to provide accurate and current information on underground utility networks under their jurisdiction to PADU. JUPEM, on the other hand will have the responsibility to provide large scale accurate base maps where all underground utilities can be overlayed. Based on request, reliable, accurate and current information on underground utility networks will be provided to the excavator at a certain fee before any excavation works can be carried out. Studies are now being conducted to have a legislation for efficient system of information exchange between all the parties involved.

5. CONCLUSION

With the mandate given by the Government, JUPEM has developed a national underground utility database called PADU to act as a repository of reliable and accurate underground utility data comprising power and telecommunication cables, gas, water and sewerage pipes provided by the utility agencies in a systematic GIS approach. The data submitted by the various utility agencies are subjected to various checks and verification processes before they are accepted into PADU. However, these checks reveal data of low quality, inaccurate and insufficient to be used as a reference for excavation works.

Issues pertaining to data quality, lack of skill and knowledge and the requirement of legislation on underground utility mapping are some of the challenges faced with regards to underground utility mapping in Malaysia. Various initiatives are now being undertaken to overcome these challenges. Having an Act that stipulates the requirement for efficient system of information exchange between all the parties involved in the excavation chain will provide the biggest challenge as underground utilities is complex matter.

The land surveyors is the most appropriate profession to engage fully in underground utility mapping in Malaysia. In any projects that require installation of new utilities or relocation of existing utilities, the presence of qualified land surveyors should be required from design plan, pre-survey, setting-up and the laying of utility up to the production of as-built plan.

Having up-to-date information of all underground utilities will enable all parties concerned in making informed decision to carry out planning, installation and excavation activities with greater confidence.

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BIOGRAPHICAL NOTES

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