

Geo Environmental Study to Assess the Hazard of the Surface and Subsurface in Selected Construction Sites by Application of Combined techniques in (Kinta Valley) Perak, Peninsular Malaysia

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ABSTRACT:

This geoenvironmental case study focuses on the combination of geological, geophysical, environmental, aerial photographs, and satellite imaging techniques as identification techniques to assess the hazard of the surface and subsurface due to presence of various classes of carbonate karst environment contains solution features and it's extended. These techniques are coupled with the engineering surface and subsurface remediation techniques and performed across three selected construction sites for housing complex projects located in north and south of Ipoh city (Kinta valley) Perak state, Peninsular Malaysia.

The civil and geo environmental engineers in Perak state facing numerous and frequent problems in constructing the structures that situated over marbleized limestone karst regions, due to various class of karstic solution features such as sinkholes, caves, karstic voids or cavities, channel pipes, depressions, conduits, internal drainages system, solution-widened joints, intensely fractured zones and faults which directly exerts a negative impact on the use of the land for construction and the design of shallow foundation structure projects. Furthermore, it can also indirectly have the potential to cause catastrophic damages in the near future perhaps many years after the project has ended. The subsidence damages was result through the construction works will cause massive losses which maximize the project overall cost leading to enormous financial costs, to the developers and the lands.

In this study, geophysical site characterization technique was performed across (3) three selected construction sites. The Two-dimensional (2D) electrical resistivity tomography (ERT) was applied in order to acquire the images of the subsurface and locate evidence for near surface karstic features such as voids, cavities, channel pipe and sinkholes. Moreover, in order to estimate the depth of the marbleized limestone bedrock, it is applied to estimate whether geophysical techniques are capable of identifying such features. Numbers of Resistivity traverses or profiles were conducted along the survey area at each of the three construction sites. The orientation, extension and the degree of inclination of those profiles are shown in Google's satellite maps.

This study also demonstrated that high-resolution Electrical Resistivity Tomography (ERT) can be effectively applied in site characterizations to reflect and differentiate surficial soil, clay, weathered rocks, compact or intact rocks, and air-filled karstic voids or cavities. The appearance of many sinkholes in the area is mostly attributed to karstic activity.

Subsequently, an assessment to the geo environment situation was surmised from interpretations of the subsurface images sections. An estimation of the possibility of a collapse could occurring in some site area due to the presence of several of cover collapse sinkholes and lenses packed with non-stiff moisturized clay. These features were delineated in all sections and prepared for early planning of subsurface remediation technique to minimize the geoenvironment hazard of these karst features in these construction sites over karstic carbonate bedrock.

The geological model is clarified via the geophysical site characterizations data, consists of a basal marbleized limestone unit and constitutes the bedrock of the study area. This bedrock unit appears to have been effected by solution-widened joints process. Enclosed by overburdened layers consisting of sand, containing lenses of stiff, non- stiff moisturized clay and covered by soil with friable sand and rock fragments in certain places. Intervened by sinkholes and cavities in-filled with clay or sandy clay and sand; it is interpreted as a karstic process.

Interpretations of (ERT) inverse model sections can illustrate to the civil and geo environmental engineers the irregularity in subsurface karst topography of marbleized limestone bedrocks in Perak. Its shows that the depth

of limestone bedrock topography was uneven, containing many pinnacles and cutters. In construction site #1, marbleized limestone bedrock was visibly detected in the image with a depth various from 15.0m from the surface to maximum depth of > 39.4 m. In construction site#2, identified at a depth various from 20.0m from the surface to maximum depth of and >28.0m. In construction site#3, identified at a depth various from 13.0m from the surface to maximum depth of and >59.0m.

The geophysical site characterizations data also indicated that the different kinds of subsurface karst features were originated from geo-hazardous area in many locations along the study sites. The most harmful one is the sinkholes which geophysical image showed that it's originated in many locations.

The most geo-hazardous area was found in construction site #1(Bandar Baru Putra) extended beneath resistivity traverses no.4. Furthermore, it's extended beneath resistivity traverses no.5. Various types of sinkholes observed and identified. These features are harmful because some are in-filled with water, while others with thick clay and in-filled with sandy or silty clay, which could collapse when subjected to piping under load. Also, lenses with various depth. Some contain thick clay, while others are in-filled with sandy or silty clay.

The most geo-hazardous area in construction site #2(Taman Gunung Rapat view), were found beneath resistivity traverse no.1. Furthermore it's identified extended beneath resistivity traverse no.2 and in traverse no.3, 4 and traverse no.5 which affected in different places by various types of soil cover collapse sinkholes, soil pipes and lenses. These features are harmful because some were in-filled with water, while others with thick clay or with sandy or silty clay, which could collapse when subjected to piping under load of structures.

The most geo-hazardous area in construction site #3(Kampar - Taman Bandar Baru), were found beneath resistivity traverse no.1. Furthermore it's identified extended beneath resistivity traverse no.2, 3, 4, 5 and traverse no.6. This area is hazardous because of the presence of thick layer of stiff and non-stiff clay. Furthermore this layer affected in different places by various types of cover collapse sinkholes, lenses, depressions and channel pipes. These features are harmful because some were in-filled with non-stiff clay highly moisturized, while others with stiff clay silty or sandy. Interpretation of (ERT) inverse geo environment model sections can exposed to civil and geo environmental engineers the degrees of karst level, the reason after the appearance of the karst features and the deference in the appearance of the karst features along these sites. Then, can formulate the classification of these construction sites through applying of the engineering classification of karst ground conditions (Waltham & Fookes, 2005). The karst level in construction sites was classified and found mostly ranging between a youthful karst type KII, mature karst type KIII and complex karst type KIV.

As a result of operating a Permanent Geo-Hazard Incident Scale (PGHIS), many levels of geo-hazard incident record up from the normal values shown in the area have impact on the environment, people and animals. This scale have many levels which is determined on the basis of three factors and there is (7) seven levels in this scale to assess the geohazard of ground condition in any construction sites situated over cover carbonate karst and effected by its features in Malaysia.

Through the comparison between the boring data by auger and the geophysical data from the survey by ERT found that there is small deference in the depth between the depth from geophysical interpretation sections and the depth from the geological report of drilling by auger about 2.0m to maximum 5.0m if the ground surface is cover with sand and/or rock fragments. If ground surface is cover with thick layer of soil, no deference in the depth observed between the depth record from geophysical interpretation sections and the depth record from the geological report.

Early planning of applying subsurface remediation technique is needed to minimize the geoenvironment hazard of these karst features in these construction sites over karstic carbonate bedrock. Several techniques are available to repairing any construction site threatened by cover-collapse sinkholes, to transfer the load of the future building structure to recognizable bedrock. The best remediation technique of the sinkhole repair varies, depending on the size and stability of the hole.

An effective procedure can be rapidly used to fill the sinkhole by using of reverse graded filter technique. The purpose of using this technique is to make the hole stable and prevents any future collapse. In the case of great sinkholes the graded filter construction is essentially the same, but the final layers are fine gravel, coarse sand and fine sand. The uppermost layer is bentonite clay which blocks water seepage. Furthermore need of a new process of grouting method in the study areas as chemical grouting techniques to fill the channel pipes, conduits, cavities and voids. Besides, controlling of the surface and the subsurface water drainages. Uses of bentonite drilling mud and the rocks cutting from the oil and gas drilling operation after the water and other liquids are removed to refill the depression and small sinkholes in karst regions. Skin friction piles driven into the layers which containing of non-stiff materials (soil, clay, silt, sand). Finally, driven of long piles down to the sound bedrock due to difference in the depth of bed rock from one site to the other. Furthermore need in controlling of surface and subsurface water drainages must be put into operation in these relevant sites.

Furthermore, the survey include Phase I environmental site assessment, is generally considered as the first step in the process of environmental due wariness to know if the surface of these selected construction sites are

considered to be contaminated with industrial pollution affected the site or not. The final reports of survey shows that no potential or existing environmental contamination responsibilities in these construction sites. Moreover, in this study an assessment to the air quality were applied to understand if these selected construction sites effected by any Pollution or not. The study shows that Air Pollutant Index (API) reading in these sites about (51-100), its means the Air Pollution Level (APL) is goods with no health implications.

Keywords: Geoenviromental, assessthe hazard, surface and the subsurface, Construction sites, combined techniques, Perak- Peninsular Malaysia.

I. INTRODUCTION

The situation of construction site projects, the position and the condition of carbonate bedrocks such as limestone, dolomitic or marbleized limestone and its appearance is very important for the geo- environmental engineers in Perak state, such as housing complexes, condominium, shopping malls and roads, which overlays Kinta marbleized limestone. Many problems are attributed to the various classes of solution features that are congenital and are especially well developed in tropical karst regions.

The problem of foundations in carbonate regions namely ; the highly pinnacle bedrock topography, the extension of solution channels and cavities, the thin arches or roofs over cavities, the collapse of weak soil zone above the carbonate bedrock , Ting (1986), Tan ; Komoo (1990). Furthermore the overburden zones consist of many varieties of appearance such as young and old overburden soils. In the ex-mining regions most of the problematic were originated in construction project works wascreated due to existence of dumped tailings of mine, covering the overburden layers in theseregions.

The collapse in carbonate karst regions unusually occurred damages in the buildings with little warning. Because the groundwater moves rapidly from place to place in large cavern passageways, pollution and contamination of water supplies is a serious threat, Strahler (1981). Also Karst regions impose some unique environmental hazards to humans, particularly urban areas where heavy structures are built over cavernous limestone. Geotechnical engineering and environmental problems are increasing rapidly due to the presence of cavities and irregular buried karstic limestone subsurface. Mining and human activities, air and water high pollution, and heavy rain developed the karst features rapidly in this tropical area of Peninsular Malaysia.

Construction delays and stability problems was cause by sinkholes appearance in the site, which may increase the cost of the project some time due to the possibility of wall cracking, collapse of some buildings' foundations, or subsidence and cracking on paved roads. Sinkholes are the main crux of the geohazard issue in a limestone formation due to natural erosion processes. Sinkholes developed at both the surface and subsurface due to the dissolution related with the difference in composition and associated processes ,pose many problems, and was classified by Waltham A C ; FookesP G (2001), into six types, including the type of subsidence sinkholes that formed in the zone of cover soil within karst terrains. The formation or emergence of a sinkhole is usually very sudden and unpredictable. As such, its consequences can be catastrophic.

The natural of Karst features in the carbonate bedrock such as pinnacle topography, cavities and linear trenches all contribute and provide the geologic settings for the development of sinkholes. Man-made factors or activities such as changing the groundwater level by pumping for watering the farm and deep excavations to open-cast mining can generate the formation of sinkholes, occurrence of falling rock, soil erosion and subsidence. Excavating the land and removing of the trees, plants and bushes for the ongoing constructions projects works. Therefore, it is reasonable that sinkhole problems have become the common interest not only for geologists and engineers, but also city planners and even enterprise or project managers. Within karst regions, the design and execution will be expensive vis-à-vis the present and future structures. Moreover, borings that are drilled within karsts regions do not overlap areas of concern on the subsurface. Inappropriate and mismanaged borings are incapable of providing plenty subsurface data for analysis, and at the same time, can also misrepresent the subsurface system, which may lead to additional costs for corrective design or additional analysis.

Rapid geo environmental reconnaissance surveys via satellite images, surface environment and geophysical techniques incorporated with a boring plan are the best obtainable options that can be used to aid in suitable location of test borings in identifying or distinguishing the subsurface features related to karst development.

High resolution electrical resistivity tomography (ERT) geophysical technique were functional for sitecharacterizations at three selected constructions sites. Construction site #1 is located in the north Bandar Baru Putra, the main road to Tanjung Malim and north of Ipoh city. Constructions site#2 located south in Gunung Rapat-Taman Gunung view in the southeast of Ipoh city. Constructions site # 3 located in Kampar city, Taman Bandar Baru near Tesco Extra in the south of Ipoh city. Figure 1 highlights the locations of the studied construction sites in Kinta valley, north and south of Ipoh, Perak- Peninsular Malaysia.

The (2D) Tomography/imaging technique was preferred for subsurface investigations over other geophysical methods for its high contrast or disparity in resistivity values vis-à-vis the different types of

sediments, such as carbonate rock and clay or soil, air or water in-filled cavity or voids, compared to the bordering or surrounding limestone bedrock. These entire elements reflector reproduce the use of resistivity imaging method that outlines and delineate the boundary between bedrocks and overburden. Moreover, this method is manageable with respect to time for small-scale projects in both pre and post-ability processing steps, rendering it's the most appropriate for this type of investigations.

The survey include Phase I environmental site assessment, is generally considered as the first step in the process of environmental due wariness if the surface of these sites are considered to be contaminated with industrial pollution affected the site. This step include preparing the reports of environmental site assessment to construction site management.

Furthermore, in this study an assessment to the air quality of these selected construction sites and to understand if it's there effected by any Pollution in this survey practicable of (API) (Air Pollutant Index) or in Malay as (IPU) is a simple and generalized way to describe the air quality. It's calculated from several sets of air pollution data in Malaysia.



Figure 1: Google terrain, google normal satellite images viewing the locations of studied construction sites in Kinta valley, north and south Ipoh city, Perak state, peninsular Malaysia

II. OBJECTIVE OF THE STUDY

This study determine to reflect several objective:

- Determine the near surface environment karstic features such as, cavities, sinkholes, channel pipe and if air-filled karstic voids or cavities present in the deep subsurface and its effects in the geo environment of the study regions.
- Estimate the depth, shape, type and understand the origin of these environment karst features.
- Estimate the depth of the intact, weathered marbleized limestone bedrock and pinnacles in these construction sites.
- Produce the geo environment models to characterize the construction sites in the study regions.
- Engineering identify and classify to the levels of the subsurface Karst ground conditions.
- Assess the subsurface environment conditions that might compromise the reliability of any proposed future work and if these can result to any dangerous collapse or ground failures at construction sites that superimpose these features.
- Identify the best solution of engineering remediation techniques commonly used in the plan to minimize the risk of geo environment problem in the regions of these construction sites.
- Environmental site assessment to know if the surface of these sites are considered to be contaminated with industrial pollution or not.
- Assess the air quality of these selected construction sites.

III. LOCATION OF STUDY AREA

3.1 Construction site #1 (Bandar Baru Putra)

Construction site #1 is situated north of Bandar Baru Putra, which is itself north of Ipoh (Kinta Valley), Positioned approximately at latitude N4°40'37.10"- N4°41'17.48", longitude E101°07' 51.77"- E101°08'08.33", as shown in Figure 2. It is located to the west of the main series of Cameron Highlands. The project plan estimating construction housing complex include 150 two floor linked houses and its facilities.

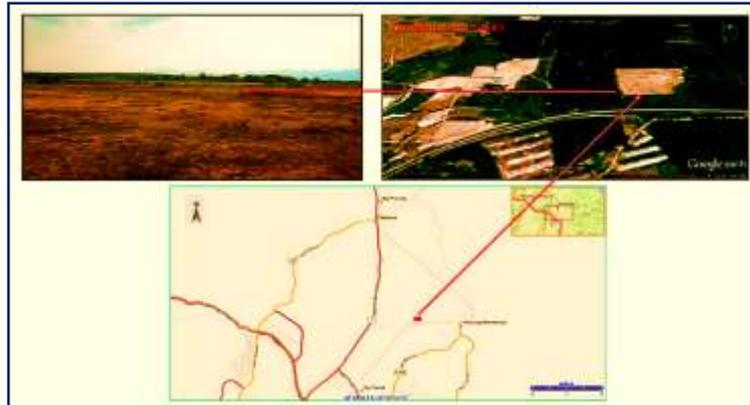


Figure 2: Location map, satellite image and land photograph viewing the location of the study region in construction site #1 on north of Bandar Baru Putra (Kinta valley), Perak state, peninsular Malaysia

3.2 Construction site #2 (*Gunung Rapat*)

Construction site #2 is situated at Gunung Rapat region, the site is visible from the express highway from Simpang Pulai to Ipoh, about 5.0 km south-east of city centre. The site under study located to the south of Taman Rapat Damai within (Kinta Valley). It's positioned with GPS coordinates at latitude $4^{\circ} 34' 17.34''$ N - $4^{\circ} 34' 25.5''$ N and longitude $101^{\circ} 08' 35.7''$ E - $101^{\circ} 08' 29.46''$ E, as shown in figure 3. The project plan estimating constructing housing complex include 100 two floor linked houses and its facilities.



Figure 3: Location map, satellite images and land photograph viewing the location of construction site #2 in Gunung Rapat, Taman Gunung view (Kinta valley), Perak state, peninsular Malaysia

3.3 Construction site #3 (*Kampar*)

Construction site #3 is situated in Kampar; it's a town in the state of Perak, the town within the Kinta Valley and located in the Kampar District near Tesco Kampar. It's positioned with GPS coordinates at latitude $4^{\circ} 19' 54.22''$ N - $4^{\circ} 20' 08.04''$ N $101^{\circ} 08' 29$ and longitude $46''$ E - $101^{\circ} 09' 10.53''$ E, as shown in figure 4. The project plan estimating constructing housing complex include 150 two floor linked houses and its facilities.



Figure 4: Location map, satellite images and land photograph viewing the location of the study area in construction site #3

IV. THE GEOLOGY OF THE STUDY AREA

4.1 Geomorphology and Topography of the study area

Kinta Valley is located in western Peninsular Malaysia, forms in a (Triangular-shaped) or a (V-shaped valley) open to the south, which is situated at 867 m above the mean sea level of Kinta Valley is bounded by the granitic massif of the Main Range on the east and Kledang Range in the west. The northern tip of the triangle starts around Chemore town in the north. The valley in this region broadens to about 7 km. In the south area around Kampar town the valley in this region broadens about 20 km. This valley is extended over a distance of 45 km from north to south. The first tower karst observed in Kinta valley is Gunung Kanthan in the north, and the last tower karst observed is Gunung Tempurung in the south. The alluvial plain is situated at about 60 m to 80 m above the mean sea level.

Major rivers originating from the granitic Main Range highland drains into most of the karstic land in the study area. The famous one drained to Kinta Valley is Sungai Kinta; extending from the northeast down to Bota in the southwest to meet Sungai Perak. Major tributaries of Sungai Perak that drains into the valley and run through the limestone towers from the east and northeast of the valley are Sungai Pinji, Sungai Raia, Sungai Dipang, Sungai Kinta, Sungai Tempurung and Sungai Kampar. Those tributaries transport alluvial deposits to the eroded marbleized limestone, creating a flood plain across the low-lying valley.

4.2 limestone of Kinta valley

Kinta Valley karst is made up of steep-sided limestone hills that stick out above enormous floodplain with moderate rolling hills of metasedimentary rocks. The granitic massif that forms the Ranges which bounded Kinta Valley has been dated to the Triassic age, (Cobbing et al., 1992).

The plain is enclosed by alluvium of varying thickness and underlain by rugged and jagged subsurface of limestone platform. The limestone hills are the remnants of extensive limestone beds, which are part of large Palaeozoic carbonate platform complexes that covered parts of South-East Asia. Palaeozoic limestone outcrops are scattered intermittently throughout Peninsula Malaysia. The original limestone beds of Kinta Valley, presumed to be Carboniferous, (Ingham & Bradford, 1960); (Hutchison, 2007), or possibly the original limestone beds of Kinta Valley of Permian age (Fontaine, 1995) have been severely eroded and karstified. Deposited more than 250 million years ago and buried to great depths, lithified and eventually brought to the surface by tectonic forces, presumably in the Mesozoic, the Palaeozoic limestone of the Kinta Valley was exposed to a humid tropical to equatorial climate for very long periods of time, which slowly dissolves the limestones. The hills are the only remaining visible part of the Palaeozoic limestone layers underlying the Tertiary to Recent alluvial deposits over the entire expanse of Kinta Valley and beyond.

The limestone of Kinta Valley overlay extensive younger granite bodies, which affects the texture and composition of the limestone via contact metamorphism at the time of granite intrusion, dated as originated from the Triassic age (Cobbing et al., 1992). Initial observations reveal that the degree of metamorphism of the limestone varies from hill to hill, from low (practically intact limestone) to high (limestone entirely turned to marble). Most of the Kinta Valley limestone has undergone contact metamorphism from Sungai Siput in the north to Tapah in the south. The less metamorphosed limestone is located in the northern part of Kinta Valley. The eastern part of the area is made up of limestone hills of Silurian to Permian age that mostly metamorphosed to marble. Limestone hills found are covered by a huge amount of vegetation. The outcrop of limestone hills can be found widespread on the eastern part of the study area. The geological map in figure 5 viewing the location of construction sites under studies in Kinta valley.

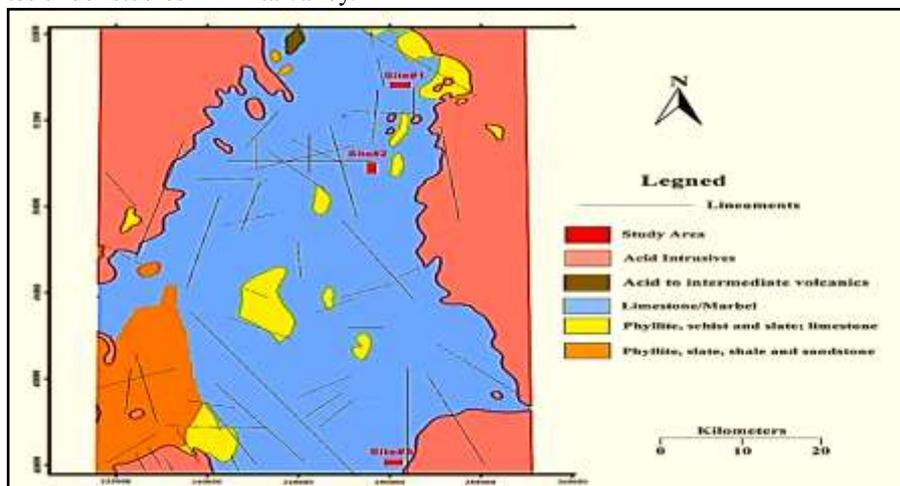


Figure 5: Geological map of Kinta valley viewing the location of construction sites under study

4.3 lithology of the study area

In Kinta valley, the lithology of the study area is made up of four main types, each resulting in a different landscape. They are:

- Carbonate rocks forming Kinta Limestone, where it has undergone tropical karstification to form steep sided and cockpit towers protruding across the enormous plain.
- Granite bodies of the Main Range and Kledang Range (series) that flank the plain in the east and west, respectively, forming rugged ranges of up to 1000 m above mean sea level.
- Other metasedimentary rocks such as Schist, which makes up the rolling landscape of the valley.
- Quaternary alluvial deposits that has been deposited across the valley and form an enormous plain.

Kinta Limestone was named after Kinta Valley in Perak. It is believed that the age of the Kinta Limestone is Silurian to Middle Permian, (Lee, 2004). The limestone in the study area is always calcitic, granular and homogeneous though some dolomite and mica do occur in some places.

The Silurian to Lower Devonian rocks mainly are pure cream-colored dolomite while the Lower to Upper Devonian rocks consist of massive grey recrystallized calcite limestone. The Carboniferous rocks consist of massive grey recrystallized calcite limestone. The Carboniferous rocks here mainly are thin-bedded grey recrystallized calcite limestone with dolomitic beds and also pyritiferous black shale’s and argillaceous sandstone. While the Permian rocks of Kinta Limestone consist of grey-black crinoidal limestone overlain by impure carbonaceous brachiopod-polyzoan limestone and also grey-white bioclastic and fusuline limestone overlain by biothermal limestone. Moreover the depositional environment of these Palaeozoic units is in shallow marine shelf carbonate build-up with shally flanks. The limestones found in this area are really restricted and most of it is metamorphosed to marble (Lee, 2004).

Geologically, most of the study area is underlain by the Kinta limestone which shows an age range from Devonian to Permian, (Suntharalingam, 1968). Most of the limestone is found beneath the general surface covered with the tin-ore bearing alluvium for which the Kinta Valley is famous for. The isolated residual limestone hills that are seen in the Kinta Valley rises above the alluvial plains to form limestone hills with steep to vertical slopes (mogote or tower karst), its constitute less than 10 % of the actual limestone bedrock (Ros FM,&Yeap, E. B.,2003). Schist found underneath as well as interbedded with the limestone its age is probably shorter and most of it could be older than Devonian. The limestone and schist were probably folded about the end of the Permian. These were also metamorphosed at the same time forming mainly the quartz-mica schists and the fine to medium to coarse-grained white to dark-grey calcitic marble and some minor black and reddish colored dolomites. The study area has limestone hills extend 20 km north of Ipoh and also 20 km to the south. There are many caves in these hills; cave temples are built in some of these caves. Tempurung cave is the largest and deepest one in Peninsula Malaysia.

The subsurface geology is particularly important for a construction sites, especially for high rise buildings in Ipoh city. Numerous construction projects in the area either through data from numerous boreholes or actual excavations have discovered the typical subsurface geologic features and soil profiles of the urban area (Yin, 1976) ;(Ingham, &Bradford 1960). For example, limestone bedrock and its associated karstic or solution features are major concerns to the local construction engineering projects. Highly irregular bedrock topography, solution channels and cavities, arches, steep cliffs and overhangs, floaters, etc. are of major concern to the foundation engineers. Table 1 below summarizes the geology and stratigraphy of the Ipoh areas after (Yin, 1976).

Age of sediment		Type of sediment in the study area
1	Quaternary	Alluvium (Young and old alluvium)
2	Triassic	Granite & Allied Rocks
3	Palaeozoic	- Kinta Limestone (dominant) -Basal Schist

Table 1: Geology/stratigraphy of the Ipoh areas (Yin, 1976)

This geologic setting has given rise to alluvial deposit rich in tin content – hence, the growth and development of the area as “mining town” since the last century. The subject of foundations in limestone was one of the main subject matter on many studies. A review of borehole data by (Tan, 1988) showed that the depth of limestone bedrock in the Ipoh area is generally less than 20 m. The review of the borehole data showed the size of the cavities in the limestone bedrock, were mostly < 3 m across.

Yassin R. R. (2009;2010), applied Electrical Resistivity Tomography (ERT) geophysical technique in site characterizations of several construction sites of housing complex and shopping mall projects in Perak state, pointed out that the depth of marbleized limestone bed rock was uneven and it contains numerous pinnacles and cutters ranging between 3.0m to more than 28.0m in one site. Furthermore, pointed out that the overburden layer was comprised of alluvium covered with thin beds of rock fragments deposits and/or with tailings of mines in some locations(Yassin, R. R., Hj- Taib, S., &Muhammad, R. F. 2013).

V. IDENTIFYING SINKHOLES BY EMPLOYING OF AERIAL PHOTOGRAPHS AND SATELLITE IMAGES TECHNIQUE

In this current work, usage of satellite images (five layers spot image of Perak state) is on the scale 1/5000 of year (2010), figure6. Additionally, Global Position System (GPS) and Geographic Information System (GIS) technologies have massively improved the investigations. The remote sensing provides updated information on land by using these methods instead of the common methods of mapping land and utilizing changes are typically high in cost and low in accuracy. Natural events and human activity features can observe by using current photograph and archived clearly identified data. The key limitation of aerial photographs and satellite images is that, depending on the scale and explanation of the images, it may not be feasible to pinpoint small or shallow sinkholes.

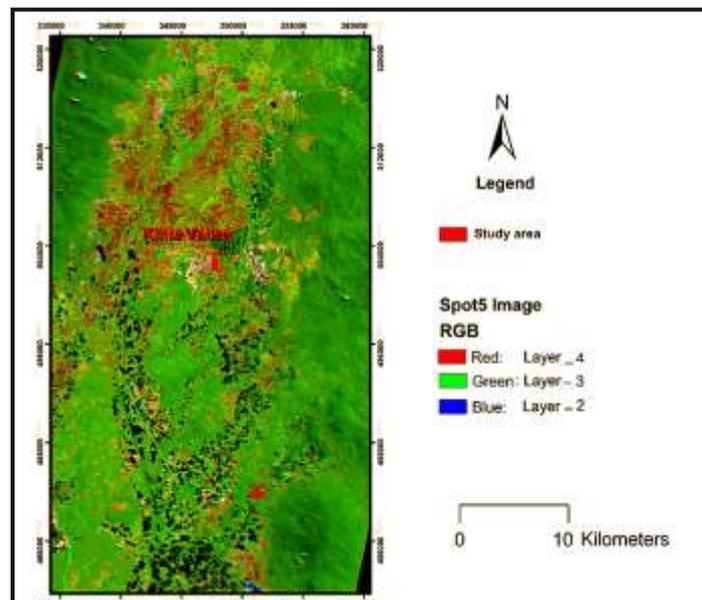


Figure 6: Five layers spot images of Perak state (2010) presenting the location of construction site #1, site #2 and site #3 north and south of Ipoh city (Kinta valley).

The interpretation of the aerial photographs of the study area and its surroundings to determine the fracture system, topography, and drainage pattern was conducted. These old aerial photographs were operational in 1965 under the Colombo Plan, possessing a scale of about 1: 25,000. Table 2 shows the list of aerial photographs used in this study. This old aerial photographs are usually very helpful in detecting the surface karst features such as sinkholes, depressions that are enclosed by buildings or man-made structures. The technique for this aerial photographic interpretation of the karstic features, limestone isolated residual hills (mogotes) and the cliffs, and also the lineaments, forests, and plantations. The significance of the karstic features and their possible origin in relation to the geological features are concluded as well. Also, the interpretation showed that the orientation of lineaments from the Main Range and Kledang Range is far from asymmetrical, but shows the dominant strike of northwest to southeast, with a subsidiary set striking east-northeast to west-southwest. It was concluded that these lineaments were also observed to be clearly cutting the marbleized limestone of Kinta valley and the hills above it. The drainage in this study area is rather straight and angular, and aerial photographs show that stream courses are controlled by the direction of lineaments (joints, fractures and fault systems) in the marbleized bedrock.

Location	Roll no.	Line no.	Print no.
Ipoh - Perak	C10	L35N	215-235
	C109	L34N	162-150

	C24	L33S	45-60
	C-12-A	L32N	35-20
	C-6	L31N	60-40
	C-5	L30N	30-20
	C-5	L29S	80-100
	C-5	L28N	130-110
	C-4	L27N	170-190
	C-4	L26N	80-70
	C-4	L25S	40-55

Table 2: Presenting the list of aerial photographs employed in this study

In addition, the aerial photographs show that the area of construction site #1 was covered by oil palm plantations; some of it was removed for construction project. Moreover, some isolated residual limestone hills were determined distributed in the south and south west of the construction site. The aerial photograph also shows that the area of construction site #2 large areas with organic grey clay shown over the ground surface along the site, also in the satellite image of the area which shown as one large-size black spot extended widely with more than 200 m. this indicate that the area before was swampy and was covered with bushes, plants and some Ex-mining activity observed separated in the west side of the construction site. Furthermore, the aerial photographs and the satellite images' shows that construction site #3 was Ex-mining project, most of region including large pit of mines due to excavation operations in the area such as open cast mining which is a process of digging the tin-bearing material from a surface with mechanical shovels, then using of gravel Pump is the most common method of extracting alluvial tin deposit. This technique involves spraying high-pressure jets of water on the sediments that containing tin ore and breaking them up. These pits now a day is in-filled with water due to old hydraulic activity and precipitation.

VI. RECONNAISSANCE FIELD SURVEYS

Direct ground inspections in the three construction sites resulted in the discovery of environmental karst features such as several types of sinkholes that were not visible in aerial photographs and satellite images due to many factors. For example, the area may be enclosed by vegetation, sinkholes with definite size, or their depth is too small to be detected. The recorded include the description of each sinkhole, including a diagram of the sinkhole and its access geometry, orientation, dimensions, age and continuation degree. These features supply information on the activity and the age of the sinkholes, and act as indicators of probable location of future sinkholes in proximity to human constructions. The existence of features such as muddy areas, or the expansion of vegetation and holes crammed with materials may help detect shallow subsidence depressions. Generally, the application of geophysical surveys is desired to determine whether these irregular characteristics are interconnected to sinkholes.

Ground inspection at site#1 reveals that there were several of cover soil collapse sinkholes with different size was distributed in the south of this site. This give a consideration that might be many small channels in undetermined depth connected to one or more of larger channel in the subsurface could threaten the reliability of this construction site. On the other hand, the area it's made up of palm oil plantation and some of its remove for construction projects.

During the ground inspection at site #2, large areas with organic gray clay shown over the ground surface along the site, this indicate that the area before was swampy covered with bushes and plants. Several varieties cover collapse sinkholes was discovered but not recognized in aerial photographs and satellite images, as adjacent small plants enclose it. One of these sinkholes has a diameter from ~3m to less than ~10m, a few with water in-filled, visually undetermined depth, are recognized and proven as a sinkhole with a narrow showing throat, positioned in the south and south west section of this site is littered with soil cover collapses flank of this site. Some was in-filled with moisturized clay and other material of sediments due to karst activity, raised a question that this sinkhole might be linked in the subsurface to one or more of the large tabular conduits or channels, and the presence of cavities or voids of undetermined depth. Clay, or air in-filled karstic sinkhole or cavities were present, which could compromise the veracity of this site.

During the ground inspection at site #3, it showed that this region was part from the Ex-mining area. A group of different size of pools separating on surface formed due to effect of heavy rain were recognized in this site and describe as small to medium size with~ 1.5 m - ~15.0 m in diameters. Also found a number of cover soil collapse sinkholes with a depth about few meters and with a diameter from ~1m to less than ~5m, some pack with vegetation and others with sand or water infill. Only one subsidence sinkhole determines in the south east of this site is filled with vegetation's with ~50.0 m in diameter. A number of sinkholes that identified as water in-fill, empty and covered with vegetation was determined as small and narrow in construction site#1, #2 and site#3viewing in Figure 7.



Figure 7 :Land Photographs viewing a number of sinkholes that identified as water in-fill, empty and covered with vegetation was determined as small and narrow in construction site#1, #2 and site#3

The survey include Phase I geo environmental site assessment which is generally considered as the first step in the process of environmental due wariness. This step will demonstration if the surface of these selected construction sites are considered to be contaminated with industrial pollution affected the site or not. This step include preparing the reports of environmental site assessment to construction site management which identifies if there is potential or existing environmental contamination responsibilities. However, the techniques applied in a Phase I is never include real collection of physical samples and nor chemical analyses was done of any kind. Examination of the land includes examination of potential soil contamination, groundwater quality, and surface water quality. The examination of a site may include only definition of any chemical residues within the land or not. In addition to the record of hazardous substances could store or used on site. Furthermore, if any industrial activity were near sites or not.

Furthermore, in this study an assessment to the air quality of these selected construction sites and to understand if it's there effected by any air pollution or not. In this survey practicable of (API) (Air Pollutant Index) or in Malay as (IPU) is a simple and generalized way to describe the air quality. It's calculated from several sets of air pollution data in Malaysia. The range of the Air Pollutant Index is divided into five bands: Low (0 to 25), Medium (26 to 50), High (51 to 100), Very High (101 to 200) and Severe (201 to 500).An API is calculated from comparing concentrations of five air pollutants (sulphur dioxide, ozone, nitrogen dioxide, carbon monoxide, breathable suspended particulates).

VII. ENGINEERING CLASSIFICATION OF KARST GROUND CONDITION

In this study two type of engineering classification to environmental karst ground condition for construction sites was applied:

7.1The first engineering classification by (Waltham & Fookes, 2005)

An engineering classification of karstic ground conditions present by (Waltham& Fookes, 2005) which characterize simplified guidelines to the potential variation in landforms and ground cavities that may be come upon in civil engineering works on karst terrains. This classification divides the Karst terrains into five classes. The five classes confer the basis of an engineering classification that characterizes karst in terms of the difficulty and complexity and to be encountered by the foundation engineer. The geomorphologic characteristics of the five classes summarized as follows:

- K I: Only in deserts and periglacial zones, or on impure carbonates, rare sinkhole, rockhead almost uniform; minor fissures; low secondary permeability, Caves is rare and small; some isolated relict features.
- K II: Minimum in temperate regions, small suffusion or dropout sinkholes; open stream sinks, many small fissures, Fissures are widespread in the few meters nearest surface, Caves are many and small (size less than 3m across).
- K III: Common in temperate regions; minimum in the wet tropics, many suffusion and dropout sinkholes; large dissolution sinkholes; small collapse and buried sinkholes extensive fissuring; relief less than 5m, loose blocks in cover soil, extensive secondary opening of most fissures, caves are many (size less than 5m across at multiple levels).
- KIV: Localized in temperate regions and normal in tropical regions, with many large dissolution sinkholes; numerous subsidence sinkholes; scattered collapse and buried sinkholes, Pinnacles relief of 5-20m, loose pillars, extensive large dissolution openings, on and away from major fissures, caves are with several size greater than 5m across at multiple levels.

- KV: Only in wet tropics, very large sinkholes of all types, soil compaction in buried sinkholes, tall pinnacles, relief of greater than 20 m, remnant arches, loose pillars undercut between deep soil fissures abundant and very complex dissolution cavities, numerous complex 3-D cave systems which cave size greater than 15m across, with chambers and galleries).

7.2 The second engineering classification by (Yassin R.R. & Hj- Taib, S., 2013)

In this study operating a new scale named as Permanent Geo-Hazard Incident Scale (PGHIS), completed by (Yassin R.R. & Hj- Taib, S., 2013). This scale have many levels to show the geo-hazard incident record up from the normal values and if the area have impact on the environment, people and animals. This scale have many levels which is determined the construction sites on the basis of three factors and there is seven levels in this scale to assess the geohazard of ground condition in any construction sites situated over cover carbonate karst and effected by its features in Malaysia.

VIII. SITE CHARACTERIZATION FOR VARIOUS SUBSURFACE ENVIRONMENTAL KARST FEATURES BY APPLYING OF GEOPHYSICAL TECHNIQUE

The application of verity types of geophysical techniques in site characterization proposed to reduce the hazard of environmentalkarst features which generally require detectionof the existing unique featureswhich most likely to occur in the near future.

Generally, features may have a very fine geomorphic appearance, as the collapse produced by the underground processes may have yet to reach the ground surface. Many sources of surface and subsurface information need to be examined to gather sufficient data regarding the past and existing subsidence movement in the study area. In order to partially address these difficulties, the geophysical examination techniques can be used to detect the changes in the physical properties and the anomalies of the ground that is connected with air-filled, water-filled or sediment-filled cavities, channel pipes, subsidence zones, irregularity of rock head topography and covered sinkholes.

There are a large numbers of advances geophysical techniques thatcan applyfor mapping the subsidence damage. The appropriateand strength of the technique depends largely on the investments available, type of necessary deposits, geological situation of the area, the over covering and inter layers of the karsts, the topography of the area and the probable type of structures dissolution. The best option is to apply two or more geophysical techniques, and compare the results to each other. It is wise to apply the geophysical techniques on the sites earlier before drilling as one of the phased progression of investigation. The area with irregularity and the normal areas not including abnormality can recognize and delineated, and planned for construction projects.

Electrical Resistivity survey is an extensively used method in geophysical surveys for investigation of various subsurface geomorphological features and structures. In this study a Two-dimensional electrical resistivity tomography (ERT) survey was performed across thethree construction sites in Perak state, Malaysia. The survey was carried out to imaging the subsurface andto locate evidence for near surface karstic features such as voids, cavities, channel pipes and sinkholes as primary objective.Also to discover the reliability of electrical resistivity method if can identify such karst features or not as secondary objective andto Evaluate the subsurface karst ground conditions which based on features that occurring in the intact carbonate rocks and its level and asses if this would result to potentially dangerous collapse or ground failures at construction sites which superimpose these features as the final objective.

Resistivity traverses were conducted along the studied sites. The orientation, extension and the degree of inclination of those profiles are shown in the location map. The correct resistivity data was interpreted using res2dinv.Version 3.54 software. Interpretation of geophysical data indicated that the area has been exaggerated by several karst features.

Geophysical ERT technique can be used to detect the changes in the physical properties and the anomalies of the ground connected with air-filled, water-filled or sediment-filled cavities, channel pipes, subsidence hang down zone, irregularity of bed rock topography and covered sinkholes. The best option is to apply two or more geophysical techniques and then evaluate the results with each other. It is wise to apply geophysical technique on the sites prior to drilling as one of the phased sequences of investigation. The area with abnormality and the normal areas are recognized then delineated and the normal areas wereplanned for construction projects.

Evaluation of the geophysical techniques used in karst areas have been presented by (Hoover et al., 2003); (Waltham et al., 2005). A number of previous geophysical studies in karst terrain were mentioned in applying (ERT) technique to map the bedrock surface, (Zhou W. et. al., 2000), in a site in southern Indiana where limestone is covered by about 9 m of clayey soils. Forty-nine profiles were conducted over an area of approximately 42,037 m². The repeatability of ERT technique was evaluated by comparing the previous drilling

section with interpreted ERT section from pairs of transects where they crossed each other. To identified the depth of mud-filled void and its extension by (William E. D. et al., 2002), by applied geophysical surveys at a site on the Oak Ridge Reservation (ORR), Tennessee, USA. The data suggest that an optimal scheme for detailed karst mapping might consist of multi electrode resistivity survey followed by joint inversion of gravity and seismic Travel time data. The resistivity results could be used to produce an initial model for the seismic and gravity inversions. To identify buried sinkholes and other karst features in zone of karst terrain (Kachentra & Tanad, 2007) applying of 2D and 3D electrical resistivity imaging(ERI) survey at Ban Pakjam in Huaiyod district, Trung province, in southern part of Thailand. The (2D) resistivity surveys clearly show the central depression as well as resistivity contrasts between the cover sediments, delineating the in- filled sinkholes, underlying weathered bedrock and mapped the locations of sinkholes in this covered karst terrain.

8.1 Instrumentation and measurement procedure

The survey was conducted using a SAS1000 resistivity meter, which has an inherent microprocessor that automatically selects the appropriate four electrodes for each measurement. The two dimensional (2D) - electrical imaging/tomography surveys (ERT) are typically carried out by employing a large number of electrodes; 41, 61 and 81 electrodes along a straight line, coupled to a multi-core cable (Griffiths & Barker ,1993), commonly at a constant spacing of 5m or 10m between the adjoining electrodes. When the succeeding measurements were taken, they were configured in a Wenner array and other survey parameters, such as the electrical current and its usually converted into a text file, which can be read by a computer program. After reading the control file, the computer program then automatically detects the suitable electrodes for each quantity. A laptop computer was utilized to set the RES2DINV inversion software for the purpose of developing the resistivity model.

In a distinctive survey, most of the fieldwork involves laying out the cables and electrodes. After doing that, the measurements are taken automatically and stocked into the computer. This resistivity procedure usually gives a better grouping of spatial resolution and depth of study in karst terrain than any other geophysical technique. Figure 8 viewing the instrument used in this survey.



Figure 8: viewing the instrument type SAS1000 applied in geophysical survey

Through applied ERT technique can imaging the shallow subsurface from a depth of less than 10.0 m, to a maximum depth of 60.0m in the karstified carbonate regions as a function to investigated karst features such as sinkholes, cavities, depressions and channel pipes . Also it was applied due to it requiring less effort and more time effective.

Several studies were done in numerous construction sites containing of geo environmental problems due to karst terrains located in Kinta valley by (Yassin,R.R., Hj- Taib, S., & Muhammad, R. F. 2010, 2011, 2013, 2014). These studies applied of (ERT) site characterization geophysical techniques.

8.2 Controlling of (ERT– traverses) and data collection in the construction sites projects

8.2.1 Controlling of ER Traverses and data collection in construction site #1 (North Bandar Baru Putra)

Electrical resistivity tomography (ERT) were applied and Six (6) electrical resistivity traverses, named Traverses-1 to Traverses-6, were controlled over and along the survey area in construction site #1, located in the North of Taman Bandar Baru Putra. The directions of these profiles are in (N90°W), and the levels of those lines are shown in the satellite image, illustrated in figure 9. Electrical resistivity data were acquired and accumulated for the purpose of mapping the subsurface of this site along the two dimensional (2-D) electrical resistivity

profiles, using an 81-channel array in Winner configuration. The measurement length of each profile was 400 m, with an electrode spacing of 5m, on average, spaced at 25 m intervals between each profile. The total length of total traverses at this site was 2400 m, covering an area of 80000 m², with 340 data points composed for each (81-electrode) in one profile. On average, about 2040 data were collected from a total six profiles at this site.

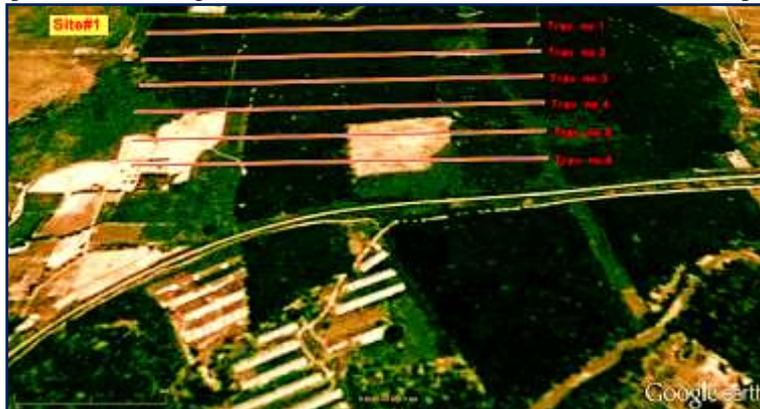


Figure 9: Satellite Image viewing the location of resistivity traverses in site #1 (north Taman Bandar Baru Putra)

8.2.2 Controlling of E.R. Traverses and data collection in construction site #2 (Gunung Rapat –Taman Gunung View)

Electrical resistivity tomography (ERT) were applied in five (5) electrical resistivity traverses, traverse no.1 to Traverse #5 were controlled over and along the survey area in construction site #2 located in Gunung Rapat region, Taman Gunung View. These traverses oriented in the direction of (NW10°SE) in this construction site. The length of each profile is 200 m, with space interval of 25m between each traverse. The electrodes space of 5m between each. The levels of those traverses are shown in the satellite image illustrated in figure 10. The survey was completed by using a 41-channel array in winner configuration. In average, 190 data points were collected for each (41-electrode) in one Traverse and about 950 data points in average were collected for total of five traverses in this site. The total length of traverses at this site was 1000 m, covering an area of 30000 m²

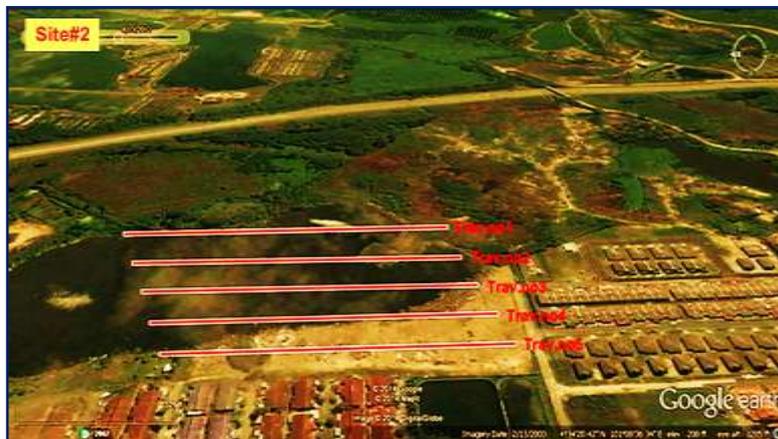


Figure 10: Google satellite image map (2002) viewing the locations of resistivity traverses which controlled in construction site #2 (Gunung Rapat –Taman Gunung View)

8.2.3 Controlling of ER Traverses and data collection in construction site#5 (Kampar-Taman Bandar Baru)

Electrical resistivity tomography (ERT) were applied in six electrical resistivity traverses, traverse no.1 to traverse no.6 were controlled over along the survey area in construction site #3 located in Kampar-Taman Bandar Baru near Tesco Kampar by using 81-channel array in winner configuration. The direction of these traverses in (NE86°SW) and the level of those lines are shown in the satellite image illustrated in Figure 11. The length of each traverse is 400 m and the spaced interval between each traverse is at 25 m and with electrode spacing of 5.0m. About 340 data points were collected for each (81-electrode) in one traverse, and on average about 2040 data were collected for total of six traverses in this site. The total length of total traverses at this site was 2400 m, covering an area of 60000 m².

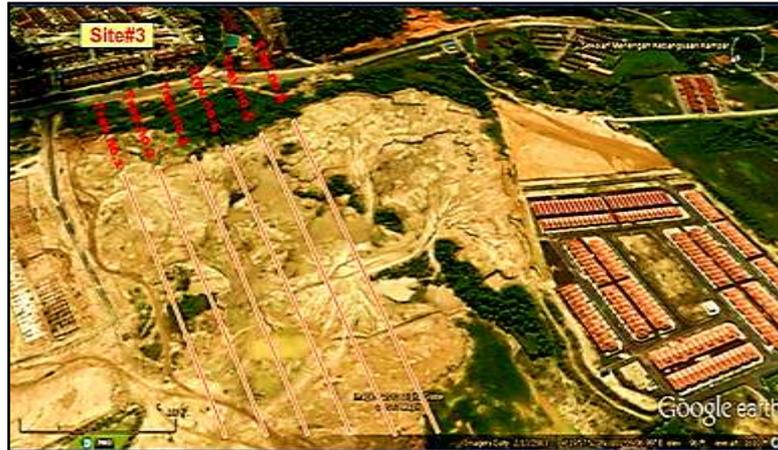


Figure 11: Google satellite image map (2003) viewing the locations of resistivity traverses which controlled in construction site #3 (Kampar-Taman Bandar Baru)

IX. DATA PROCESSING

After completing the field survey, the resistance measurements were regularly converted to apparent resistivity values. The data were developed to produce two-dimensional resistivity model of the subsurface. This step converts the apparent resistivity values into a resistivity model section that can be used to explain geological occurrences. The data were readily obtained in the RES2DINV formats, while the conversion program was outfitted with the system. The Root Mean Square (RMS) error statistics enumerate the distribution of the percentage differentiation between the logarithms of the calculated resistivity values, and those calculated from the true resistivity model (calculated apparent resistivity values). Data points containing errors of more than 30 % and above are usually omitted. In this survey, a small RMS value is indicative of the fact that less than 10% are defined by the convergence limit.

The average default RMS error value in construction site#1 is 6.75 %, and the change in the RMS error between iterations was a minimum of 3.4 %, and a maximum of 9.7 %. The average default RMS error value in construction site#2 is 4.50 %, and the change in the RMS error between iterations was a minimum of 4.0%, and a maximum of 6.3%. The average default RMS error value in construction site#3 is 4.60 %, and the change in the RMS error between iterations was a minimum of 5.0 % and a maximum of 7.3%. To get a good model, the data must be of uniformly of good quality.

X. INTERPRETATION OF ERTOMOGRAPHY/ IMAGE SECTIONS IN CONSTRUCTION SITES

The E.R. Tomography technique applied in this geo environment technical survey to imaging the shallow subsurface from a depth of less than 10.0 m, to a maximum depth of 60.0m in the karstified carbonate regions as a function to investigated karst features such as sinkholes, cavities, depressions and channel pipes .Through the survey found that this tool is suitable for differentiating surficial soil, clay, sand, weathered marbleized limestone bed rocks, intact marbleized limestone bed rocks and water-air-filled cavities. Also it was applied due to it requiring less effort and more time effective. It is based on the application of electric current into analysed bedrock and measuring the intensity of electric resistivity to its conduit. Basically, it gives information of electric resistivity properties through the analysed material towards electrical current passage.

Formerly, several reports, papers and researches of geo environmental studies were examined for several countries round the world. These studies of applying of geophysical techniques in many constructionsites containing of geo environmental problems due tokarst terrains. These reports and researches are done by (Anderson et al., 2007). Additional research was done by (Ioannis, et al., 2002). Other researches were completed by (Almashikyand Yassin, 2001), (Yassin, 2002) and (Zhouet al., 2000). Finally, an earlier research was completed by (Yahia et al., 1992).These reports and researches supported the interpretations, made based on the variations in electrical resistivity values that associated with the nature of sediments in the study regions.

Lately, Yassin,R.R. (2009-2010) practical all the studies former in Kinta valley construction sites of Kinta valley.These studies applied of (ERT) site characterization geophysical techniques. Several studies were doneby (Yassin,R.R., Hj- Taib, S., &Muhammad, R. F. 2010, 2011, 2013, 2014) in numerousconstruction

sites containing of geo environmental problems due to karst terrains located in Kinta valley. All these studies give a suitable images for investigating of karst features and its deposits within karst terrains area.

The classifications of the variables in the electrical resistivity values that associated with the nature of sediments were made. Hence, electrical resistivity values were determined for each rock unit. The results are tabulated in Table -3. This table was suitable for investigating karst features and its deposits within karst terrains. Also in the same time was suitable for detecting any mineral deposits within the sediments in the area but need experience for that.

Clay

Are usually distinguished by low apparent resistivity's and variables, which are dependent on moisture, mineral content, purity, and unit shape/size, usually from 5 ohm-m to less than 60 ohm-m. In this case, the clay is divided into many types with different colours, which is used in this resistivity section as:

- Highly moisturized soft clay is usually distinguished by insufficient low apparent resistivity with water filled porosity or very high mineralized. And is typically given pink colour.
- Soft clay with ponded water content is usually distinguished by extremely low resistivity and very high conductivity or highly mineralized. And is typically given dark blue colour.
- Moderate moisturized soft clay is usually distinguished by very low apparent resistivity and very high conductivity or moderate mineralized. And is typically given light blue colour.
- Clay very low-moisturized and stiff is usually distinguished by low apparent resistivity or with low mineralized content. And is typically given yellow colour.

Sand

It's usually typified by medium apparent resistivity and variables, depending on the moisture content, purity and unit size, usually from 70 ohm-m to less than 160 ohm-m. The sand is also divided into many types; its colouring scheme described below:

- Sand, distinguished by medium apparent resistivity, is typically dark green colour.
- Sandy clay, distinguished by its low medium apparent resistivity, is typically given light green colour.

Weathered limestone rock

Comparatively weathered limestone rock is typified by high apparent resistivities, typically more than 200 ohm-m to less than 400 ohm-m, is typically given gray colour.

Intact limestone rock

Is distinguished by higher apparent resistivity, naturally from more than 400 ohm-m to more than 3000 ohm-m, and varies depending on thickness of the layer, its impurities and moisture content. It's given a light purple colour.

Intact pure marbleized limestone or dolostone rocks

It's distinguished by higher apparent resistivity, naturally from more than 4000 ohm-m to more than 8000 ohm-m, and varies depending on thickness of the layer, its impurities and moisture content. It's given a dark purple colour.

Air-filled cavities or voids

Are generally characterized by very high apparent resistivity, usually more than 3000 ohm-m to less than 6000 ohm-m, but varies depending on the conductivity of the nearby strata and size/shape of void or cavity. Classically, it takes a black colour.

Hence, electrical resistivity values were resolute for each rock unit. The results are tabulated in Table - 3. This table was suitable for investigating karst features and its deposits within karst terrains. Also in the same time it was suitable for detecting any mineral deposits within the sediments in the area but need experience for that.

No.	Range of resistivity values	Expected geological units deposits	Color of Res. units in ERT model
1.	0 Ω -m – 5 Ω -m	Insufficient low resistivity, Soft clay with water filled porosity, very high mineralized.	Red
2.	5 Ω -m – 10 Ω -m	Extremely low resistivity and very high conductivity, soft clay with ponded water, highly mineralized.	Blue
3.	10 Ω -m – 20 Ω -m	Very low resistivity and very high conductivity, Clay moderate mineralized.	Cyan
4.	20 Ω -m – 50 Ω -m	Clay low mineralized, low resistivity and very high conductivity.	Yellow
5.	50 Ω -m – 70 Ω -m	Below average resistivity, soil, silty or sandy clay.	Orange
6.	70 Ω -m – 100 Ω -m	Average resistivity, clayey or silty sand.	Light Green
7.	100 Ω -m – 160 Ω -m	Above average resistivity, sand friable, coarse grain.	Green
8.	160 Ω -m – 200 Ω -m	Mostly high resistivity, transitional zone consists of rock fragments and sand.	Brown
9.	>200 Ω -m – 400 Ω -m	high resistivity, weathered limestone, probably consisting of wet joints or fractures and/or clay in-fill, higher resistivity	Light Blue
10.	>400 Ω -m – >3000 Ω -m	Very high resistivity, Compact or intact limestone.	Purple
11.	>3000 Ω -m – 6000 Ω -m	Extremely high resistivity, Voids or cavity, air in-fill.	Black
12.	>4000 Ω -m – 8000 Ω -m	Extraordinarily high resistivity, Intact pure marbleized limestone or dolostone rocks.	Dark Purple

Table 3: Describes the range of resistivity values with the expected geological unit's deposit.

10.1 The interpretation of ER Image sections in construction site #1(Taman Bandar Baru Putra)

This site is normally situated over a high topography area above sea level and a flat terrain of marbleized limestone bedrocks. The electrical resistivity data were collected in this construction site and built up in electrical resistivity tomography sections. The interpretations of Tomography or image sections were clarified in the deficiency of borehole control, by utilizing data posited in table 3. The interpretation confirms that a variety of sinkholes that are present in this site, mainly the soil cover collapse type and unmitigated, can clearly be seen between resistivity traverse #3 and traverse #6. The inverse model of electrical resistivity section from traverses no.1 to traverses no.6 in figure 12 (A-F), viewing the interpreted location of shallow karst features (sinkholes and cavities) in Taman Bandar Baru Putra view.

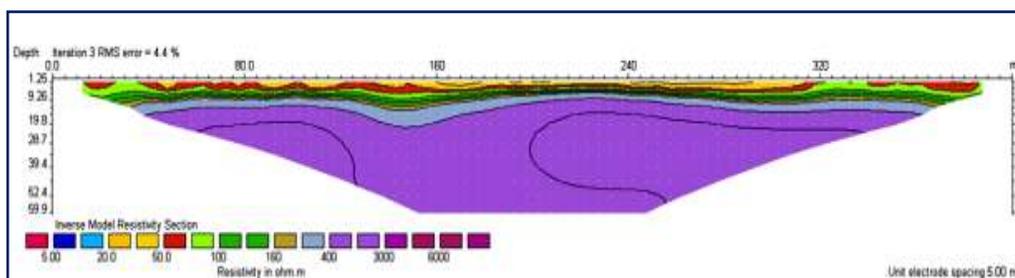


Figure (12 - A) Inverse model of electrical resistivity section for traverse no. 1 (Taman Bandar Baru Putra)

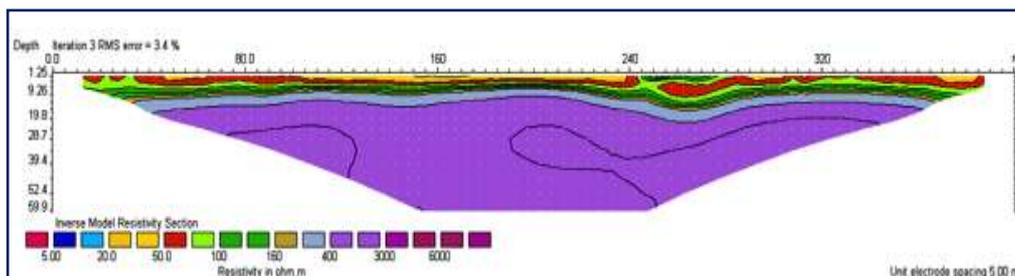


Figure (12- B) Inverse model of electrical resistivity section for traverse no. 2 (Taman Bandar Baru Putra)

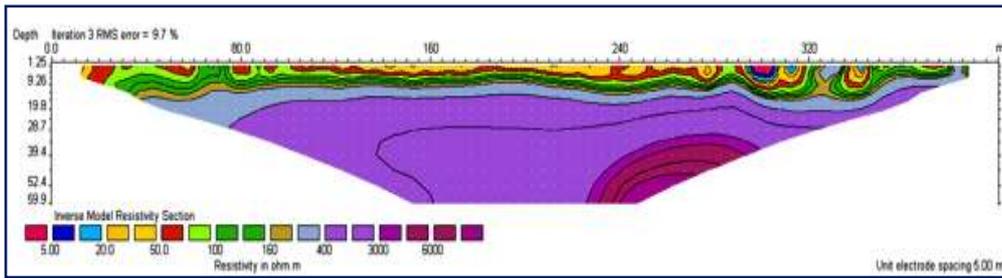


Figure (12- C) Inverse model of electrical resistivity section for traverse no. 3 (Taman Bandar Baru Putra)

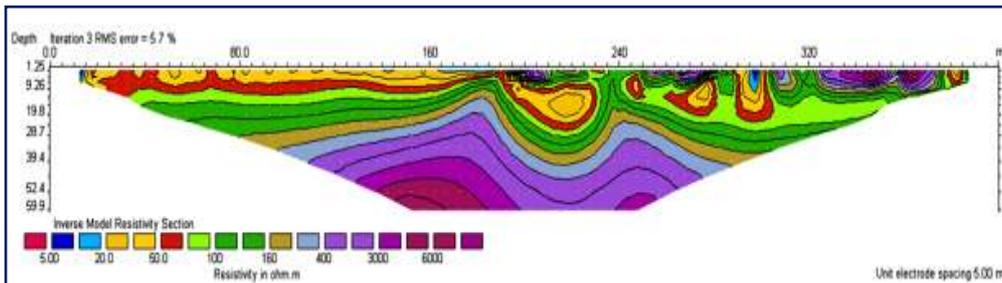


Figure (12- D) Inverse model of electrical resistivity section for traverse no. 4 (Taman Bandar Baru Putra)

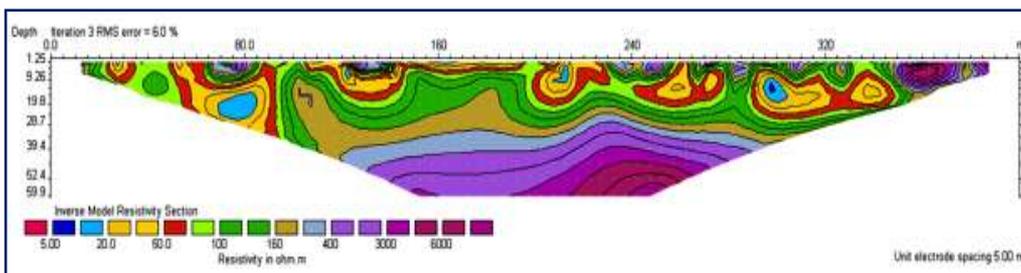


Figure (12 - E) Inverse model of electrical resistivity section for traverse no. 5 (Taman Bandar Baru Putra)

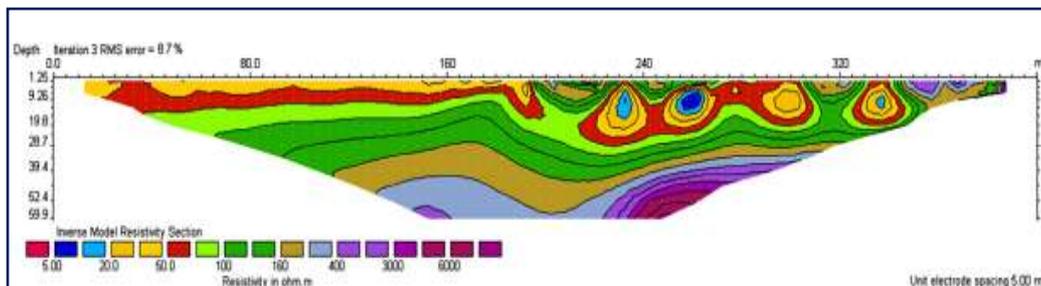


Figure (12 - F) Inverse model of electrical resistivity section for traverse no. 6 (Taman Bandar Baru Putra)

Figure 12(A-F): Inverse model of electrical resistivity section from traverse #1 to traverse #6, viewing the interpreted location of karst features (cavities and sinkholes) in Construction site #1 (Taman Bandar Baru Putra)

All the data base of the Karst features, which were detected through the 2D electrical resistivity image sections in construction site#1, was described in Table 4 below.

Data base of karst features from (2-D) E. R. Tomography sections in construction Site #1 (Taman Bandar Baru Putra)						
Traverses No.	Karst Features	Quantity	Location	Size	Approximate Depth	Descriptions
Trav.#1	Depression	1	E25 - E38	Length ~65.0m	7.5m - 15.0m	In-fill with stiff and silty clay.
Trav.#2	Depression	1	E49 - E64	Length ~75.0m	7.5m - 15.0m	In-fill with stiff and silty clay.
Trav.#3	Depression	1	E3 - E27	Length ~120 m	3.5m - 16.0m	Rain water activity.
	Depression	1	E49 - E65	Length ~80.0m	3.0m - 16.0m	Rain water activity.
	Sinkhole	1	E61 - E65	Diameter ~20.0m	0.0m - 17.5m	Soil covers collapse.
	Sinkhole	1	E68 - E70	Diameter ~10.0m	0.0m - 16.0m	Soil covers collapse.
Trav.#4	Sinkhole	1	E38 - E47	Diameter ~45.0m	3.25m - 37.0m	Karst processes.
	Soil pipe	1	E50 - E51	Diameter ~5.0m	0.0m - 15.0m	Soil covers collapse.
	Soil pipe	1	E57 - E58	Diameter ~5.0m	0.0m - 17.0m	Soil covers collapse.
	Soil pipe	1	E59 - E61	Diameter ~10.0m	0.0m - 19.8m	Soil covers collapse.
	Soil pipe	1	E77 - E78	Diameter ~5.0m	0.0m - 7.50m	Soil covers collapse.
Trav.#5	Soil pipes	1	E66 - E68	Diameter ~10.0m	0.0m - 9.7m	Soil covers collapse.
	filled depress	1	E14 - E18	Diameter ~20.0m	0.0m - 19.0m	Sand in-fill
	Soil pipes	1	E53 - E54	Diameter ~5.0m	0.0m - 19.0m	Soil covers collapse.
	Multi lenses	1	E59 - E70	Width ~55.0m	9.0m - 19.0m	Stiff & non-stiff clay.
	Empty depress	1	E12 - E30	Diameter ~40.0m	0.0m - 19.8m	Rain water dissolution.
	full-size lens	1	E11 - E19	Width ~80.0m	9.25m - 28.7m	Stiff clay with ponded water.
Trav.#6	Sinkhole	1	E66 - E69	Diameter ~15.0m	~19.8m	in-fill with rain water
	Multi lenses	3	E46 - E61	Width ~75.0m	~22.0m	clay with ponded water
	Depression	1	E7 - E42	length ~210.0m	~19.0m	in-fill with non-stiff clay

Table 4: Database of karst features from the inverse model sections in construction site#1(Taman Bandar Baru Putra)

10.2 Interpretation of ER Image sections in construction site #2(Gunung Rapat view)

This site is normally situated over a flat terrain of marbleized limestone bedrocks. The electrical resistivity data were collected in this construction site and built up in electrical resistivity tomography sections. The interpretations of tomography or image sections were clarified in the deficiency of borehole control, by utilizing data posited in table 3. The interpretation confirms that a variety of karst features that are present in this site, mainly the soil cover collapse sinkholes and lenses type and unmitigated, can clearly be seen along all resistivity traverses.

The inverse model of electrical resistivity section from traverses no.1to traverses no. 5 in figure 13 (A-E) viewing the interpreted location of shallow karst features (sinkholes and cavities) in Gunung Rapatview

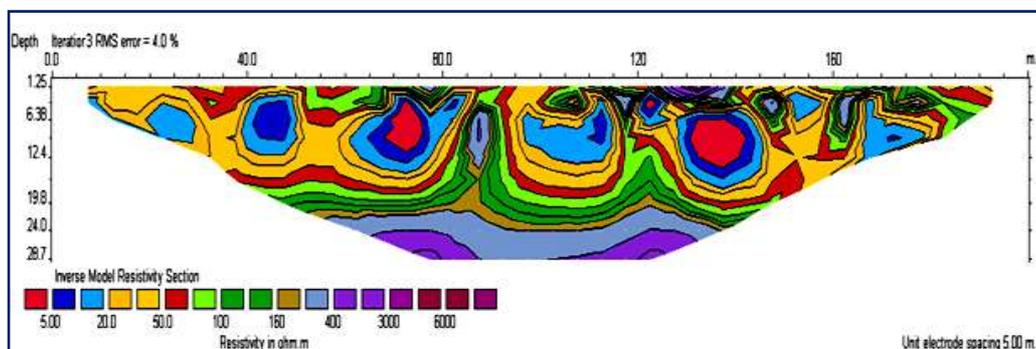


Figure (13 - A) Inverse model of electrical resistivity section for Traverse no.1 (Gunung Rapat view)

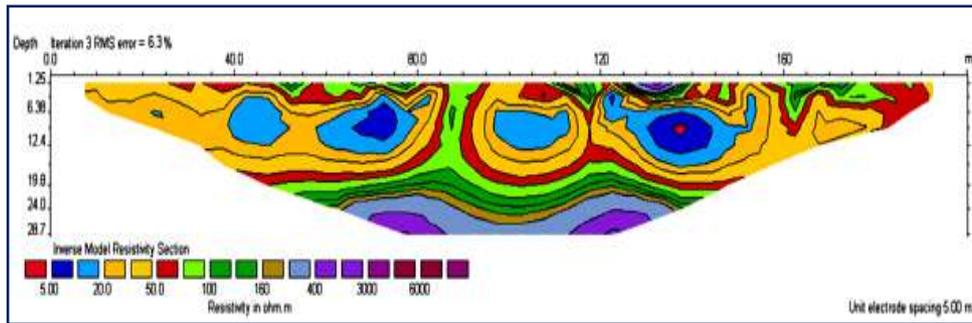


Figure (13 - B) Inverse model of electrical resistivity section for Traverse no.2 (Gunung Rapat view)

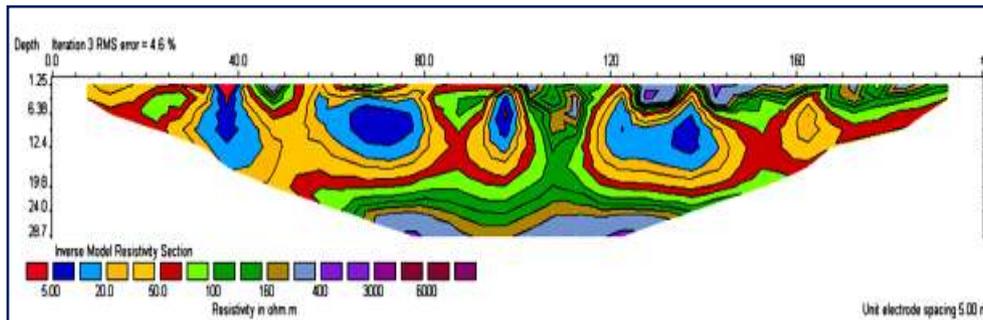


Figure (13 - C) Inverse model of electrical resistivity section for Traverse no.3 (Gunung Rapat view)

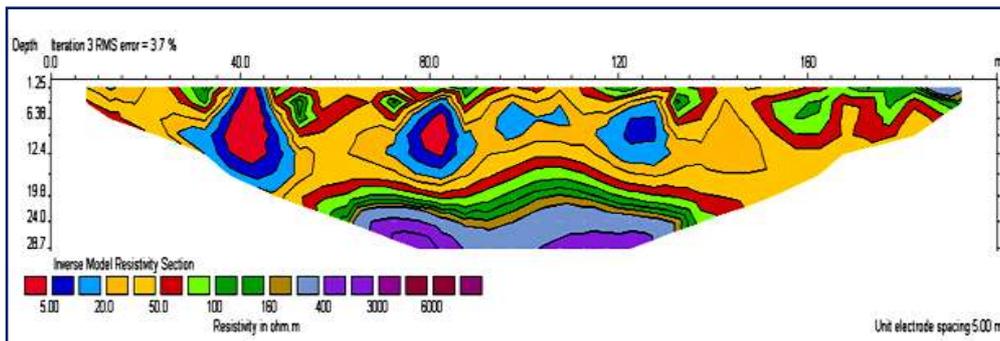


Figure (13- D) Inverse model of electrical resistivity section for Traverse no.4 (Gunung Rapat view)

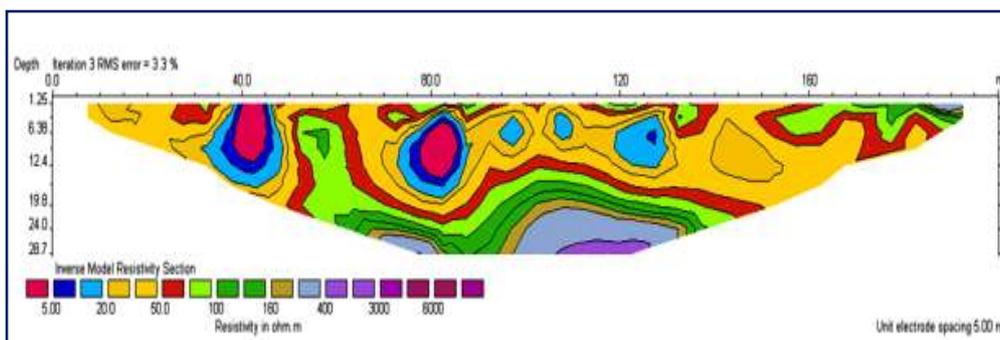


Figure (13- E) Inverse model of electrical resistivity section for Traverse no.5 (Gunung Rapat view)

Figure13(A-E): Inverse model of electrical resistivity section form traverse #1 to traverse #5, viewing the interpreted location of karst features (cavities and sinkholes) in Construction site #2(Gunung Rapat view)

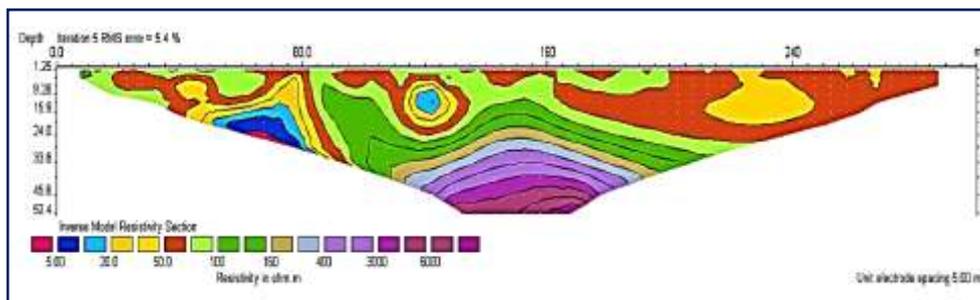
All the data base of the Karst features, which were detected through the 2D electrical resistivity image sections in construction site#2(Gunung Rapat view), was described in Table 5 below.

Data base of karst features from (2-D) E. R. Tomography sections in Construction site #2 (Gunung Rapat –Taman Gunong View)						
TRAVERSE NO.	KARST FEATURES	QUANTITY	LOCATION	SIZE	APPROXIMATE DEPTH	DESCRIPTIONS
Tras.#1	Semi round Lens	1	E7 - E11	Width ~ 20.0m	0.0m - -17.0m	In fill with extremely non-stiff moisturized clay
	Irregular Lens	1	E16 - E23	Width ~ 35.0m	3.0m - -14.0m	In fill with extremely non-stiff moisturized clay
	Semi round Lens	1	E25 - E27	Width ~ 10.0m	3.0m - -14.0m	In fill with extremely non-stiff moisturized clay
Tras.#2	Multi lens	1	E9 - E17	Length ~ 40.0m	2.5m - -12.4m	In fill with extremely non-stiff moisturized clay
	Mature sinkhole	1	E21- E24	Width ~ 15.0m	0.0m - -17.0m	In fill with stiff and extremely non-stiff moisturized clay
	Mature sinkhole	1	E25 - E32	Width ~ 50.0m	0.0m - -17.0m	In fill with stiff and extremely non-stiff moisturized clay
Tras.#3	Soil cover collapse sinkhole	1	E8 - E10	Diameter ~ 10.0m	0.0m - -15.0m	In fill with meteoric water and nonstiff clay
	Soil cover collapse sinkhole	1	E12 - E17	Diameter ~ 25.0m	0.0m - -14.0m	In fill with meteoric water and nonstiff clay
	Soil cover collapse sinkhole	1	E19 - E21	Diameter ~ 10.0m	0.0m - -17.0m	In fill with meteoric water and nonstiff clay
	Soil cover collapse sinkhole	1	E25 - E30	Diameter ~ 25.0m	0.0m - -19.0m	In fill with meteoric water and nonstiff clay
	Lens	1	E33 - E34	Diameter ~ 5.0m	2.5m - -15.0m	In fill with stiff clay
Tras.#4	Soil cover collapse sinkhole	1	E9 - E11	Diameter ~ 15.0m	0.0m - -18.0m	In fill with meteoric water and nonstiff clay
	Full-size Lens	1	E16 - E18	Width ~ 10.0m	1.5m - -17.0m	In fill with very non-stiff moisturized clay
	Normal Lens	1	E25 - E27	Width ~ 10.0m	3.0m - -14.0m	In fill with stiff and extremely non-stiff moisturized clay
Tras.#5	Soil cover collapse sinkhole	1	E8 - E11	Diameter ~ 15.0m	0.0m - -19.0m	In fill with meteoric water and nonstiff clay
	Full-size Lens	1	E16 - E19	Width ~ 10.0m	2.5m - -17.0m	In fill with very non-stiff moisturized clay
	Minute Lens	1	E20 - E21	Width ~ 5.0m	3.0m - -7.0m	In fill with non-stiff moisturized clay
	Minute Lens	1	E22 - E23	Width ~ 5.0m	3.0m - -7.0m	In fill with non-stiff moisturized clay
	Normal Lens	1	E25 - E27	Width ~ 10.0m	2.5m - -12.5m	In fill with non-stiff moisturized clay

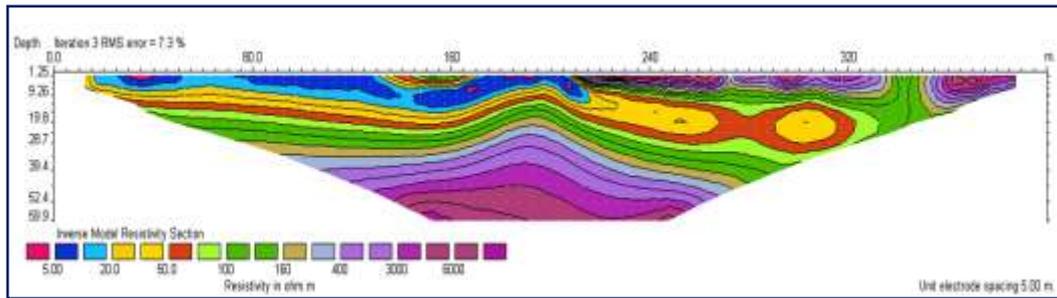
Table 5: Data base of karst features from (2-D) E. R. Tomography sections in construction site#2 (Gunung Rapat view)

10.3 Interpretation of ER Image sections in construction site#3 (Kampar- Taman Bandar Baru)

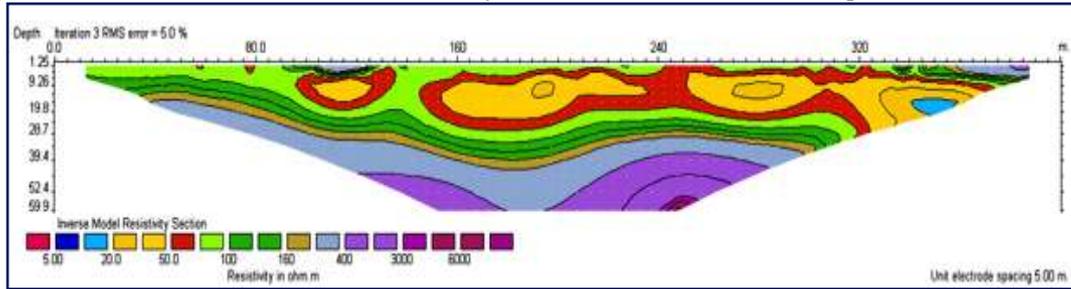
This site is normally situated over a flat terrain of marbleized limestone bedrocks located near huge pit of Tin mine. The electrical resistivity data were collected in this construction site and built up in electrical resistivity tomography sections. The interpretations of Tomography or image sections were clarified in the deficiency of borehole control, by utilizing data posited in table 3. The interpretation confirms that a variety of karst features that are present in this site, mainly the soil cover collapse sinkholes, depressions, surface pools and lenses type and unmitigated, can clearly be seen along all resistivity traverses. The inverse model of electrical resistivity section from traverses no.1to traverses no. 6 in figure 14 (A-F), viewing the interpreted location of shallow karst features (sinkholes and cavities) in 1 (Kampar- Taman Bandar Baru).



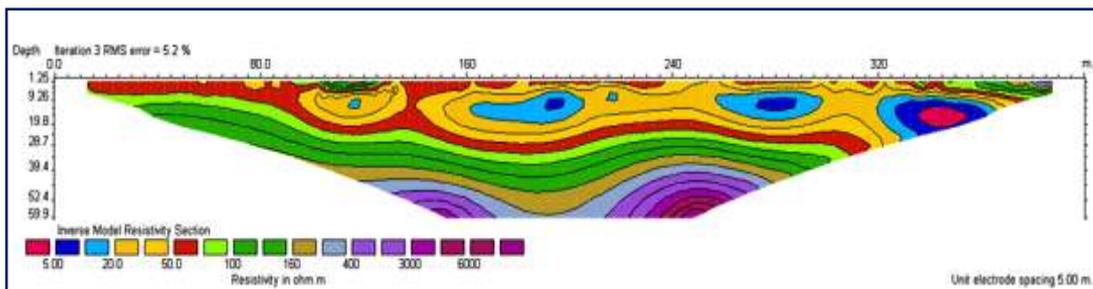
(Figure - A) Inverse model of electrical resistivity section for Traverse no. 1 (Kampar- Taman Bandar Baru)



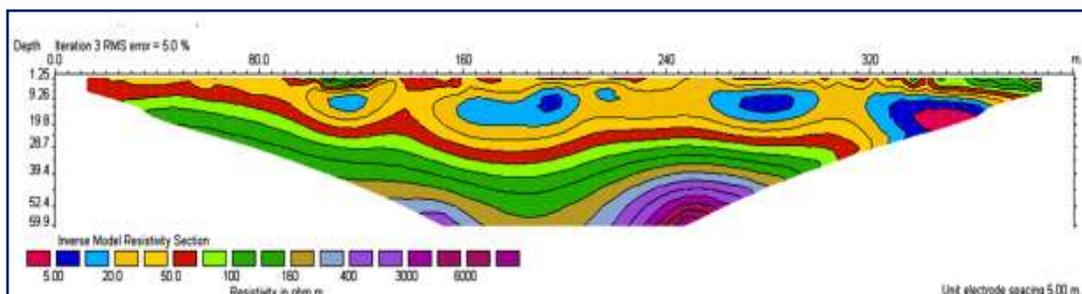
(Figure - B) Inverse model of electrical resistivity section for Traverse no. 2 (Kampar- Taman Bandar Baru)



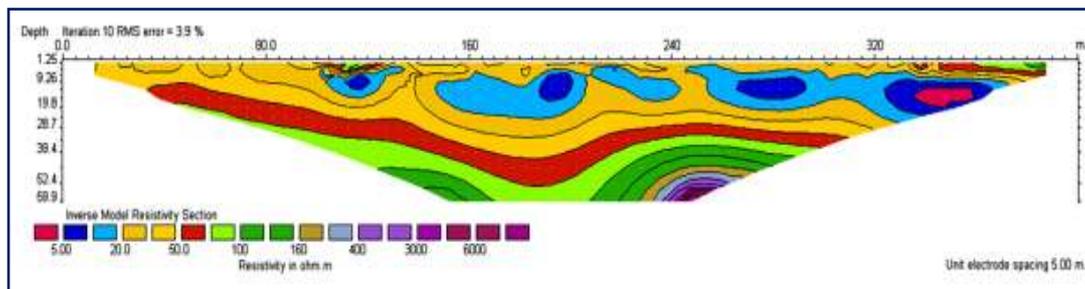
(Figure - C) Inverse model of electrical resistivity section for Traverse no. 3 (Kampar- Taman Bandar Baru)



(Figure - D) Inverse model of electrical resistivity section for Traverse no.4 (Kampar- Taman Bandar Baru)



(Figure - E) Inverse model of electrical resistivity section for Traverse no.5 (Kampar- Taman Bandar Baru)



(Figure -F) Inverse model of electrical resistivity section for Traverse no. 6 (Kampar- Taman Bandar Baru)

Figure 14(A-F): Inverse model of electrical resistivity section from Traverses no. (1 -6), viewing the interpreted location of shallow karst features (sinkholes and cavities) in ((Kampar- Taman Bandar Baru))

All the data base of the Karst features, which were detected through the 2D electric electrical resistivity image sections in construction site#3(Kampar - Taman Bandar Baru) was described in Table 6 below.

Data base of karst features from (2-D) E. R. Tomography sections in construction site#3 (Kampar - Taman Bandar Baru)						
Traverses No.	Karst Features	Quantity	Location	Size	Approximate Depth	Descriptions
Tran.#1	Irregular shape Lens crammed in the sand	1	E8 - E19	55.0m diameter	1.50m -- 39.0m	Comprised of stiff , non-stiff highly moisturized clay, with ponded water
	Circle shape Lens crammed in the sand	1	E23 - E28	25.0m diameter	2.50m -- 24.0m	Comprised of stiff, non-stiff clay with ponded water
Tran.#2	Surface pool	1	E6 - E11	25.0m wide	1.50m -- 5.0m	In-fill with non stiff clay highly moisturized clay and water
	Surface pool	1	E36 - E42	30.0m wide	1.50m -- 9.0m	In-fill with non stiff clay highly moisturized clay and water
	Irregular longitudinal channel pipe	1	E4 - E71	385.0m extend	1.25m -- 35.0m	In-fill with stiff soil clay, silty clay and moisturized water in some places
	Conduit	1	E69 - E71	12.0m diameters	1.25m -- 35.0m	Crammed with sand
	Regular semi- circular shape Cavity	1	E59 - E65	30.0m diameter	12.0m -- 26.0m	Comprised of stiff clay and silty clay
Tran.#3	Subsidence sinkhole	1	E20 - E29	45.0m wide	-1.25 - - 15.0m	The upper part consists of sand and rock fragments. The lower part consists of stiff clay
	Horizontal tabular channel contain multi lenses	1	E31 - E75	100.0m extend	1.25m -- 35.0m	In-fill with stiff and silty clay with moisturized clay in some places
	Lens	1	E32 - E48	45.0m diameter	-2.5m -- 18.0m	In-fill with stiff and non-stiff clay with ponded water
	Lens	1	E51 - E62	55.0m diameter	2.0m -- 25.0m	In-fill with stiff and non-stiff moisturized clay
	Lens	1	E62 - E77	40.0m wide	3.0m -- 9.62m	In-fill with stiff and non-stiff clay with ponded water
Tran.#4	Horizontal tabular channel contain multi lenses	1	E31 - E76	225.0m extend	3.0m -- 28.0m	In-fill with stiff clay and non- stiff in some part
	Lens	1	E34 - E42	40.0m Diameter	4.0m -- 18.0m	In-fill with stiff and non-stiff clay with ponded water
	Lens	1	E53 - E62	45.0m Diameter	-3.0m -- 17.0m	In-fill with stiff and non-stiff clay with ponded water
	Lens	1	E65 - E75	40.0m Diameter	-7.0m -- 19.5m	In-fill with stiff and non-stiff clay with ponded water
Tran.#5	Cave collapse sinkhole	1	E21 - E27	30.0m wide	1.25m -- 17.0m	In-fill with stiff clay, silty clay and sand
	Extensive lens	1	E33 - E42	45.0m wide	3.0m -- 19.8m	In-fill with non-stiff clay
	Semi oval lens	1	E53 - E61	40.0m wide	3.0m -- 15.0m	In-fill with non-stiff clay
	Large lens	1	E65 - E78	40.0m wide	5.0m -- 28.7m	In-fill with non-stiff highly moisturized clay
Tran.#6	Cave collapse sinkhole	1	E21 - E28	35.0m wide	1.25m -- 13.0m	The upper part consists of silty sand and rock fragments. The lower part consists of moisturized clay
	Longitudinal lens	1	E31 - E42	40.0m wide	2.0m -- 15.0m	Contains of non -stiff moisturized clay
	Small Longitudinal lens	1	E42 - E49	35.0m wide	1.5m -- 16.0m	Contains of non -stiff moisturized clay
	Longitudinal assembly with multi lenses	1	E50 - E79	155.0m wide	1.5m -- 19.8m	Contains of non -stiff highly moisturized clay

Table 6: Data base of karst features from (2-D) E. R. Tomography sections in construction site#3(Kampar - Taman Bandar Baru)

XI. DEPTH OF MARBLEIZED LIMESTONE BEDROCKS IN THESELECTED CONSTRUCTION SITES

Normally, constructing structures immediately over carbonate karst terrains or environment of will create problems for engineers, due to development of limestone rocks karsts morphology, which create various difficulties that made the area complex to understand. Frequently, only engineers who are familiar with the characteristic of soluble rock can understand the problems that are associated with it.

The three tables below present an outline or portrayal of some selected points regarding the limestone bedrock depth of the three construction sites that will be favourable for engineers, for them to recognize the

depth of limestone in the three construction sites under study. However, these tables can only provide common suggestions of projected ground conditions, despite the possibility of ending up with enormous discrepancies regarding the depth of the local features. The surveys showed that the depth of marbleized limestone bedrock in these three construction sites was uneven, and possesses many pinnacles and cutters.

In construction site#1, the uneven marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 17 to electrode 65. It began with a zone of weathered limestone and/or highly widened jointed marbleized limestone bedrock, overlooking upper layers deposits with a depth varies from 15.0 mfrom the surface to maximum depth of >39.4 m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 15.0m then tumbling down to reach a maximum depth of >52.4 m in the left flank of the profile. The depth of pinnacles was varied between 11.0 m beneath electrode 37 in traverse # 4 and with a depth of 39.4 m beneath electrode 33 in traverse #6. The depth of weathered, un-weathered or intact marbleized limestone bedrocks and pinnacles in construction site#1 was presented in Table 7.

Description of the approximate depth of weathered, intact marbleized limestone bedrock and pinnacles in construction site#1(Bandar Baru Putra)							
No.	Traverse No.	Electrode No.	Approximate depth of weathered limestone	Electrode No.	Approximate depth of intact limestone bedrock	Electrode No.	Approximate depth of pinnacle
1	Res Trav. #1	17	9.26m	17	16.0m	-	-
		33	15.0m	33	20.0m	-	-
		49	10.0m	49	10.0m	-	-
		65	14.0m	65	15.0m	-	-
2	Res Trav. #2	17	14.0m	17	17.0m	-	-
		33	9.62m	33	18.0m	-	-
		49	12.0m	49	18.0m	-	-
		65	9.0m	65	15.0m	-	-
3	Res Trav. #3	17	16.0m	17	19.8m	-	-
		33	15.0m	33	17.0m	-	-
		49	17.0m	49	19.8m	-	-
		65	16.0m	65	21.0m	-	-
4	Res Trav. #4	17	-	17	-	37	11.0m
		33	19.8	33	27.0m	49	22.0m
		49	20.0m	49	27.0m	-	-
		65	-	65	-	-	-
5	Res Trav. #5	17	-	17	-	46	20.0m
		33	34.0m	33	42.0m	-	-
		49	27.0m	49	29.0m	-	-
		65	-	65	-	-	-
6	Res Trav. #6	17	-	17	-	33	39.4m
		33	39.4m	33	52.4m	56	32.0m
		49	32.0m	49	42.0m	-	-
		63	29.0m	63	34.0m	-	-

Table 7: described the approximate depth of weathered, intact marbleized limestone bedrock and pinnacles in construction site#1

In construction site#2, marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 12 to electrode 29. It began with a zone of weathered limestone and/or highly widened jointed marbleized limestone bedrock, overlooking upper layers deposits with a depth varies from 20.0 mfrom the surface to maximum depth of >28.0m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 21.0m then tumbling down to reach a maximum depth of >28.7 m. The depth of pinnacles was varied between 19.8 mbeneath electrode 22in traverse %5and 27.0mbeneath electrode 26 in traverse #1, as shown in table 8.

The approximate depth of Weathered, Intact marbleized limestone bedrocks and Pinnacles in construction site#2(Gunong Rapat Veiv)							
No.	Traverse No	Electrode No	Approximate depth of weathered marbleized Lst. Bedrock	Electrode No	Approximate depth of Intact marbleized Lst. bedrock	Electrode No	Approximate depth of pinnacles
1	Res Trav. #1	9	>28.7m	9	>28.7m	15 26	23.0 m 27.0 m
		17	23.0m	17	26.0m		
		25	25.0m	25	>24.0m		
		33	>28.7m	33	>28.7m		
2	Res Trav. #2	9	>28.7m	9	>28.7m	17 26	21.0 m 20.0 m
		17	21.0m	17	22.0m		
		25	20.0m	25	21.0m		
		33	>28.7m	33	>28.7m		
3	Res Trav. #3	9	>28.7m	9	>28.7m	16 23	23.0 m 26.0 m
		17	24.0m	17	26.0m		
		25	25.0m	25	27.0m		
		33	>28.7m	33	>28.7m		
4	Res Trav. #4	9	>28.7m	9	>28.7m	16 23	23.0 m 24.0 m
		17	21.0m	17	23.5m		
		25	24.0m	25	26.0m		
		33	>28.7m	33	>28.7m		
5	Res Trav. #5	9	>28.7m	9	>28.7m	15 22	24.0 m 19.8 m
		17	26.0m	17	28.0m		
		25	22.0m	25	25.0m		
		33	>28.7m	33	>28.7m		

Table 8: Described the approximate depth of weathered, intact marbleized limestone bedrock and pinnacles in construction site#2

In construction site#3, marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 12 to electrode 29. It began with a zone of weathered limestone and/or highly widened jointed marbleized limestone bedrock, overlooking upper layers deposits with a depth varies from 13.0m from the surface to maximum depth of >59.0m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 25.0m then tumbling down to reach a maximum depth of >59.0 m. The depth of pinnacles was varied between 27.0 m beneath electrode 51 in traverse #3 and 49.0m beneath electrode 29 in traverse #5, as shown in table 8.

Description of the approximate depth of weathered , intact marbleized limestone bedrock and pinnacles in construction site#3 (Kampar- Taman Bandar Baru)									
No.	Traverse No.	Electrode No.	Approximate depth of weathered marbleized limestone bedrock	Electrode No.	Approximate depth of intact marbleized limestone bedrock	Electrode No.	Approximate depth of pinnacles		
1	Res Trav. #1	17	>33.0m	17	>40.0m	E31	24.0m		
		33	25.0m	33	39.0m				
		49	>33.0m	49	>40.0m				
		65	-	65	-				
2	Res Trav. #2	17	13.0m	17	25.0m	28	31.0m		
		33	27.8m	33	36.0m	50	27.8m		
		49	44.0m	49	>59.9m				
		65	-	65	-				
3	Res Trav. #3	17	18.0m	17	>40.0m	28	28.7m		
		33	37.0m	33	45.0m				
		49	28.7m	49	37.0m			51	27.0m
		65	>35.0m	65	>44.0m				
4	Res Trav. #4	17	>45.0m	17	>52.0m	30	42.0m		
		33	35.0m	33	40.0m				
		49	34.0m	49	39.4m			50	34.0m
		65	>59.0m	65	>59.0m				
5	Res Trav. #5	17	>45.0m	17	>52.4m	29	49.0m		
		33	50.0m	33	55.0m				
		49	38.0m	49	41.4m			51	37.0m
		65	>59.9m	65	>59.9m				
6	Res Trav. #6	17	>59.9m	17	>59.9m	51	46.0m		
		33	>59.9m	33	>59.9m				
		49	47.0m	49	52.0m				
		65	>59.9m	65	>59.9m				

Table 9: described the approximate depth of weathered, intact marbleized limestone bedrock and pinnacles in construction site#3

XII. 12. DESCRIPTIONS OF BOREHOLES FROM THE GEOENVIRONMENTBORING REPORTS

The boring report by auger clarified that the auger was penetrated till maximum depth of 12.0m of layers described as; Soil, clay, silty clay, silty sand, sand, rock fragments, and marbleized limestone. Sometimes was penetrated faster in layers described as soil and very non stiff clay which is highly moisturized. Also the boring report by auger clarified that the auger was terminated in a Boulders many times and fragment of marbleized limestone rocks or floater of it.

Through the comparison between the boring data by auger and geophysical data from (ERT) geo environment image section, found that there is small deference in the depth between the depth from the interpretation of (ERT) geophysical sections and the depth from the geological report of drilling by auger about 2.0m to maximum of 5.0m, if the ground surface is cover with sand and/or rock fragments. If the ground surface is covered with thick soil and /or with thick clay there is very small deference in depth cooperation and was found about 0.0m to maximum of 1.0m. The description of boreholes which drilled by Auger in construction site #1, site #2 and site #3 were presented in table 10, table 11 and table 12.

Description of boreholes which drilled by Auger in construction site#1 (Taman Bandar Baru Putra)						
Borehole no.	Traverse No.	Drilling Point	Depth (m) from drilling by auger	Depth (m) from ER Tomography sections	Description	Check point
1	1	E-33	10.0m	10.5m	Stiff clay, silty clay, silty sand and sand.	Depth of sand layer
2	2	E-17	8.0m	8.5m	Soil, silty sand and sand.	Depth of sand layer
3	3	E-63	10.0m	10.0m	Soil, clay stiff, non-stiff and moisturized, Silty clay, silty sand.	Depth of sand layer
4	4	E-33	10.0m	10.0m	Soil, stiff clay, silty clay, sandy clay.	Depth of sand layer
5	5	E-45	10.0m	10m.	Clay stiff, silty clay, sandy clay.	Depth of sand layer
6	6	E-60	10.0m	10m.	Soil, stiff clay, silty clay, sandy clay.	Depth of sand layer

Table 10: Description of boreholes which drilled by Auger in construction site#1(Taman Bandar Baru Putra)

Description of boreholes drilled by Auger in construction site #2 Gunung Rapat –Taman Gunong View						
Borehole no.	Traverse no.	Drilling point	Depth from drilling by Auger	Depth from ERT sections	Descriptions	Check point
1	1	E-9	16.0m	16.0m	Cover soil, stiff clay , highly moisturized non stiff clay and silty sand	Layer of silty sand
2	2	E-17	20.0m	20.50m	Sand, silty sand, silty clay, non-stiff clay, very non stiff highly moisturized clay, silty sand, sand, rock fragment	Boundary of carbonate bedrock
3	3	E-8	16.5m	17.0m	thick clay, highly moisturized clay, silty clay, silty sand	Depth soil clay
4	4	E-17	17.5m	19.0m	Silty sand, silty clay ,non-stiff clay, very non stiff highly moisturized clay	Depth soil clay
5	5	E-21	20.0m	19.0m	Silty sand, silty clay, non-stiff clay, very non stiff highly moisturized clay, silty sand, sand, rock fragment	Boundary of rock fragment between sand and carbonate layer

Table 11: Description of boreholes which drilled by Auger in construction site #2(Gunung Rapat – TamanGunongView).

Description of boreholes drilled by Auger in construction site #3 (Kampar-Taman Bandar Baru)						
Borehole no.	Traverse no.	Drilling position	Depth(m) from drilling by Auger	Depth(m) from ER Tomography sections	Description	Check point
1	1	E- 25	9.5m	9.0m	Thin crust of soil, silty sand, stiff clay, highly moisturized clay.	Center of lens is fill with water.
2	2	E- 40	17.5m	17.5m	Thin crust of soil, silty sand, sand, rock fragments.	Boundary of rock fragments.
3	3	E- 24	18.0m	19.0m	Rock fragments, sand, silty sand, clay.	Depth of sinkhois.
4	4	E- 49	21.0m	21.0m	Thin crust of soil, stiff clay, silty clay.	Depth of clay.
5	5	E- 21	22.0m	22.0m	Soil, stiff clay, silty clay.	Depth of clay.
6	6	E- 71	15.0m	15.0m	Soil, stiff clay, non - stiff clay highly moisturized, accumulate water.	Accumulate water in the subsurface.

Table 12: Description of boreholes which drilled by Auger in construction site #3(Kampar –Taman Bandar Baru)

XIII. PLANNING TO MITIGATE THE RISK IN CONSTRUCTION SITES DEVELOPING OVER THIS ENVIRONMENT CARBONATE KARST TERRAIN

The variety of foundation which functional for this construction sites over environment carbonate karst region depends upon two criteria, first to assume foundation loading, second the degree of maturity of the karst features. The most dangerous site was the occupied foundation over sinkholes which affected by two controlling factors, the first factor is the overloading and second the water seep through the cover soil.

If the level of engineering classification of karst ground conditions in these carbonate regions are known and classified, the mostly economical point of view in developing this site is to minimize the risk of structures that are founded over the area by determining the safest route in changing the plan’s location far from the problem site over the karst features. If possible, the most important part with great size and type of constructions structures has to be placed in the safest region, while the problem areas can be allocated for non-critical facilities, such as grass field, parking lots, golf courses, roadways etc.

13.1 Three solution methods are most frequently used in the plan to diminish or minimize the risk of problem areas in construction site#1(Taman Bandar Baru Putra)

13.1.1. First solution method is to minimize the risk of the problematic areabysinkhole remediation by using the reverse graded filter technique is one of engineering subsurface remediation technique

Preparing the land for future development of construction project consists of many stages. First stage is cleaning the land from the plants and bushes. Second stage, small sinkholes remediation by using the reverse graded filter technique would be the ideal solution. To fill the small sinkholes, first excavate the hole. Bottom of the hole

must be plugged with larger rocks, followed by coarse gravel, then fine gravel, (if possible spray with geopolymer chemical solution to fill the caps between filling material), coarse sand, and finally fine sand. In the third stage, the most upper or a final layer completed with bentonite clay to prevent water seepage from occurring. Then the ground surface will be covered with soil. Surface soil needs improvement in this construction site by rolling and compaction processes to increase the stiffness of the soils. Sinkhole remediation by using the reverse graded filter technique is presented in figure 15.

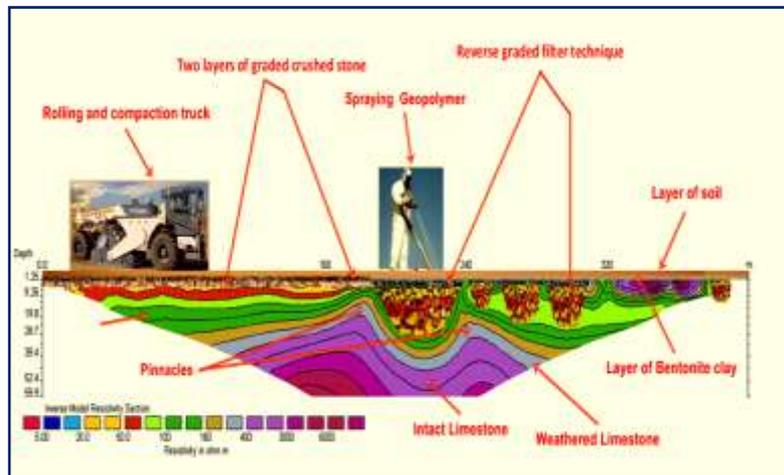


Figure 15: Sinkhole remediation by using the reverse graded filter technique is one of engineering subsurface remediation technique

13.1.2 Second solution method is to minimize the risk of the problematic areas by using chemical grouting technique is one of engineering subsurface remediation technique

Chemical grouting, which is a form of penetration grouting, it's a cost effective professional grouting technique that uses grouts to fill small sinkholes, cavities and voids found in the subsurface unconsolidated material with chemical solutions. The solution grouts that are commonly used include geopolymer (urethanes) these will strengthen the ground and prevent excessive movement. Chemical grout is injected through the joints and gaps in the surrounding soil, where it will solidifies with the soil to appear it's relatively impermeable and hard. The deep grouting by injection of chemical solution is one of engineering subsurface remediation technique as presented in figure 16.

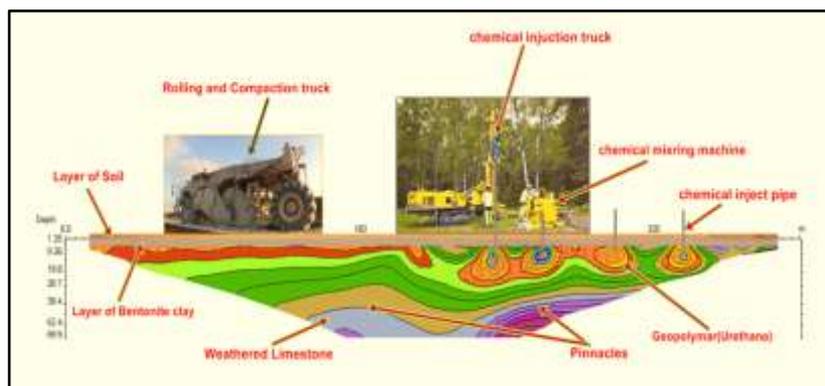


Figure 16: The deep grouting by injecting of chemical solution is one of engineering subsurface remediation technique

When the construction sites have difficult conditions such as, it contains a thick layer of soil and having a low bearing capacity. Choosing long skin friction or end bearing piles will not be economically the ideal solution. Because long piles are need to be driven along at a depth between 19.8m and 28.7m as shown in figure 17.

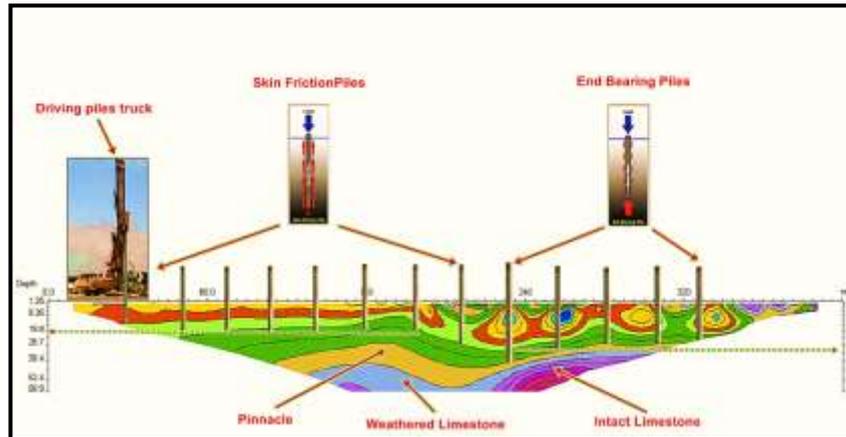


Figure 17: applying long skin friction or end bearing piles will not be economically the ideal solution

13.1.3 Third solution method is to minimize the risk of the problem areas by using of Raft foundation also this type is known as floating foundation

Raft foundations, also known as floating foundations and are made of concrete so that they can float over weaker soils. When the construction site with difficult conditions as the soil having a low bearing capacity, an economical solution raft foundations types can provide support to structural loads. Raft foundation is the economical solution in this site where the deep piles foundations will be used with length more than 29.0m become possible and not economical. When the piles foundation cannot be used constructively an independent column footing becomes unworkable. The type of Raft foundations which is convenient in construction site #1 are presented in figure 18.



Figure 18: Raft or floating foundations which is convenient in construction site #1

13.2 The following are three solution methods used most frequently in the plan to mitigate or minimize the risk of problem areas in construction site # 2 (Gunung Rapat)

13.2.1 First solution method is to minimize the risk of the problem areas by remediation of small sinkholes using a Bentonite drilling mud and the rock cutting

Preparing the land for future development construction project consists of many stages. First stage is cleaning the land from the plants and bushes. Second stage, small sinkholes remediation by using Bentonite drilling mud and the rock cutting from the drilling operation as one of the steps of environmental management in oil and gas exploration, after the water and other liquids are removed to refill the small sinkholes in this construction site would be the ideal solution. To fill these small sinkholes, first excavate the holes, then filling it with bentonite drilling mud and the rock cutting. After that if possible to spray the filling sinkholes with geopolymer chemical solution to fill the gaps between the rocks fragments. The third stage, the upper most of the sinkhole area completed with bentonite clay about 4.0/5.0 inches to prevent water seepage from occurring. After that the final layer of the ground surface will be covered by soil about 6.0/7.0 inches. Surface soil needs improvement in this construction site by rolling and compaction processes to increase the stiffness through decreasing the permeability in this construction site. Small sinkholes remediation by using of Bentonite drilling mud and the rock gutting from the drilling operation presented in Figure 19.

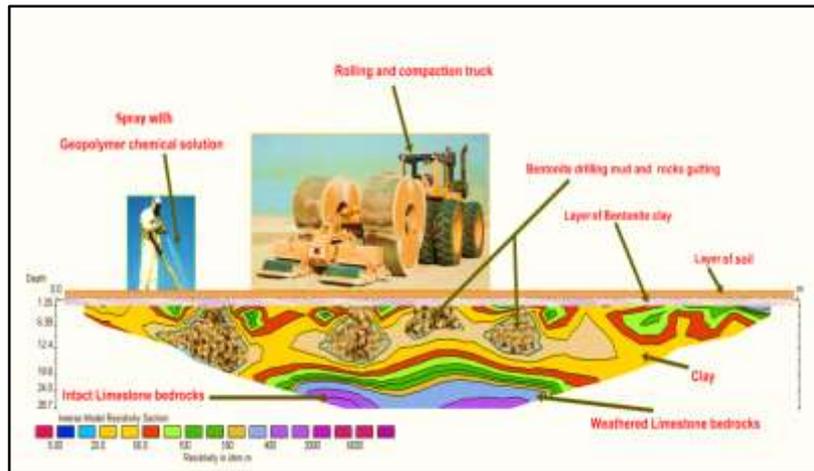


Figure 19: Small sinkholes remediation by using Bentonite drilling mud and the rock cutting from the oil and gas drilling operation

13.2.2 Second solution method is to minimize the risk of the problem areas by using of deep grouting chemical solution

Deep grouting by using of geopolymer chemical solution grouts (urethane) is a form of penetration grouting. It is a process that uses chemical solution forms to fill the small sinkholes, cavities, voids and fissures in the soil. The best type of soils suited for this technique are granular soils, with significant fine sand content, that strengthen the ground and prevent excessive movement. Chemical grout is injected through the joints and a gap in the surrounding soil, where it solidifies with the soil making it appear relatively impermeable and hard. The deep grouting by injection of chemical solution is one of engineering subsurface remediation techniques as presented here below in figure 20.

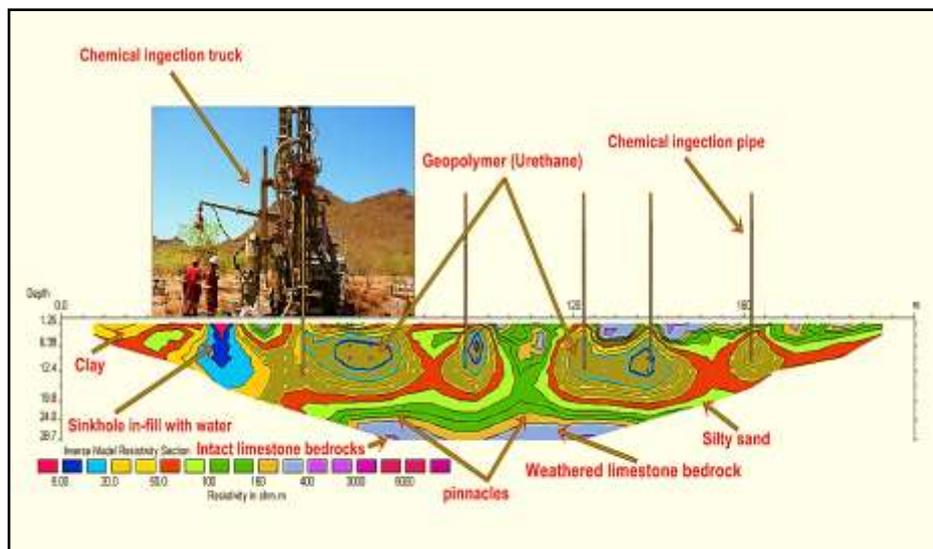


Figure 20: The deep grouting by injection of chemical solution is one of engineering subsurface remediation techniques

13.2.3 Third solution method is to minimize the risk of the problem areas by using of Raft foundation also this type is known as floating foundation

Raft foundation (also known as floating foundation) is required and necessary where soils have low bearing capacity and have to hold up heavy structural loads on swampy land, soft clay, and unconsolidated soil material. Raft foundation is necessary where an area that subsidence may occur from different reasons such as, due to the presence of soil cover collapse sinkhole. The changes in the ground water level especially in this area with extended soil. Raft foundation is the economical solution in this site where the deep pile foundations are not possible and not economical. The type of Raft foundations which is convenient in construction site #2 are presented in figure 21.

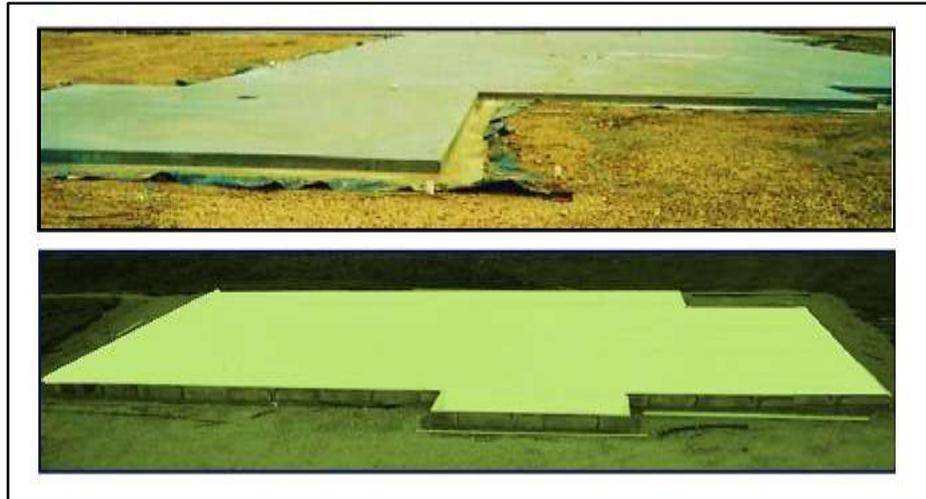


Figure21: Raft foundations or floating foundation which is convenient in construction site #2

13.3The following are three solution methods used most frequently in the plan to mitigate or minimize the risk of problem areas in construction site# 3 (Kampar- Taman Bandar Baru)

13.3.1First solution method is to minimize the risk of the problem areasbyusing of deep grouting chemical solution

Deep grouting by using of geopolymer chemical solution grouts (urethane) is a form of penetration grouting used to fill the small voids and fissures in the soil. The best type of soils suited for this technique is to strengthen the ground and prevent excessive movement. Chemical grout is injected through the joints and a gap in the surrounding soil, where it solidifies with the soil making itappearsrelatively impermeable and hard and pushes the water from the hole. The deep grouting by injectingchemical solution is one of engineering subsurface remediation technique as presented here below in figure 22.

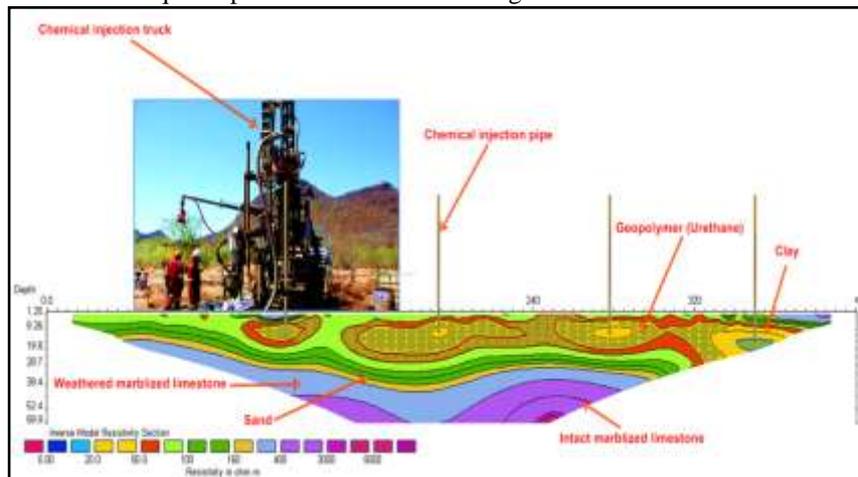


Figure22: Deep grouting by injection of chemical solution is one of engineering subsurface remediation technique

13.3.2Second solution method is to minimize the risk of the problem areasbyusingBentonite / Cement grouting compaction technique

Soil stabilization by using Bentonite / Cement grouting compaction technique can be utilized to correct soil settlement problems and to fill the small voids and fissures in the soil and torepairsinkhole.

The process is done byinjecting a low mobility Bentonite / Cement grout mixture under high pressure, through a number of angled and vertical injection to theland around the projects area. The purpose is to fill the voids beneath and increase the density of the soil layers which supports the housing project in the futureand remediate the sinkhole and blocked its activity.

The first step is using a drilling rig to install the steel grout casings to the maximum treatment depth by usingthe rotary wash method. Once all the injection pipes are installedand ensure a clear path for the grout to flow, each point will flushed. The grout is ready to be pumped by connecting the pump to the pipesthen through the steel casing .The casing is slowly pull out in controlled augment lifts, usually two to five feet every one

time. The casing is lifted up and pumping recommence grout again at the new level until pumping has reached higher pressures. Then the casing is lifted up more and pumping continues at the subsequently level. The process will create an impenetrable zone and compact the soil /clay or sand around it and increasing the density in the targeted treatment until the area is fully stabilized. As injection points are finished, the grouting process moves on to the next point and continues there. Point by point till all the injection points will completely pumped. Soil stabilization using Bentonite / Cement grouting technique is one of engineering subsurface remediation technique in construction site # 3 as presented in figure 23.

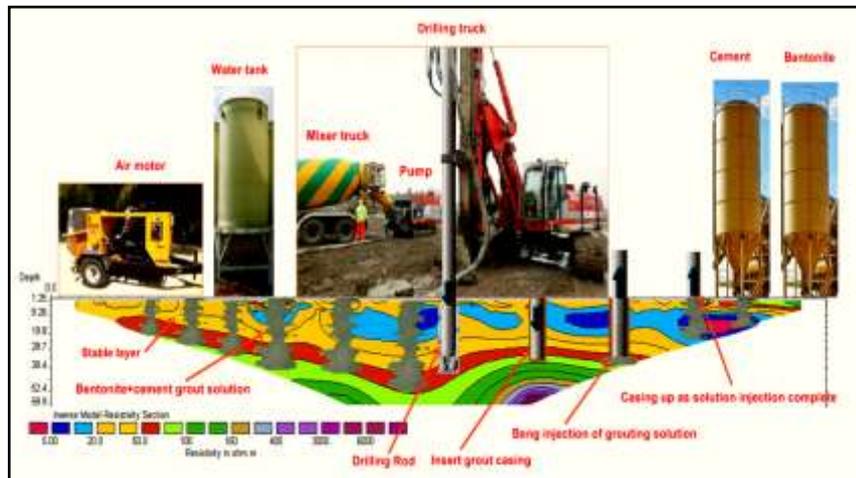


Figure 23: Soil stabilization using Bentonite / Cement grouting technique is one of engineering subsurface remediation technique in construction site # 3

13.3.3 Third solution method is to minimize the risk of the problem as by using of Raft foundation

Raft foundation or floating foundation is required and necessary, because in this area the thickness of soil is very high and contains unconsolidated material with low bearing capacity. Raft foundation is necessary where an area that subsidence may occur from different reasons such as due to the change in the climate especially in area of mining activity which lead to the alteration in ground water level. Raft foundation is the economical solution in this site where the deep pile foundations will be use with length more than 29.0 m become possible and not economical.

XIV. RESULTS AND DISCUSSION

1. The current geo environmental case study focuses on the combination of geological, geophysical, aerial photographs, and satellite imaging techniques as identification techniques for geohazard assessment of the subsurface geological carbonate karst features including sinkholes, channel pipes, karstic voids or cavities, and the subsurface geological structures such as solution-widened joints, intensely fractured zones and faults. These techniques are coupled with engineering subsurface remediation techniques and performed across three selected construction sites for housing complex projects located in north and south of Ipoh city (Kinta valley), Perak, Peninsular Malaysia. An assessment of the situation was surmised from the subsurface image sections.
2. These techniques were performed across three selected construction sites in north and south of Ipoh city (Kinta valley), Perak, Peninsular Malaysia. An assessment of the situation was surmised from the subsurface image sections.
3. This case study also displayed the reliability ON application of high resolution Electrical Resistivity Tomography (ERT) technique to reflect the bedrocks and the overburden layers in these karsts regions. The (ERT) technique used in this study was completely very favourable for differentiating surficial soil, clay, and weathered limestone rocks, compact or intact limestone rocks. Also useful to delineate karst features such as underground air-filled karstic voids or cavities and intensely fractured rocks. Also sinkholes and water channels due to the dissolution of fractured zones. These karst features effect many construction site locations in regions extended over carbonate rocks, causing disturbance in construction works, which can increase the overall cost of the projects.
4. The interpretation of aerial photographic and satellite image techniques observed clearly that the orientation of lineaments (fractures and fault systems) from the main series and Kledang series was cutting the marbleized limestone of Kinta valley and the hills above it. These give a consideration that there is a significant relation between the geologic features and the origin of the karstic features and the possibility of its development in the study area. Also the interpretation showed that the drainage in the study area is rather

straight and angular and the stream courses are controlled by the direction of lineaments (fractures and fault systems) in the marbleized limestone bedrock.

5. Through direct ground inspections in the three construction sites, various types of sinkholes were found distributed on the surrounding of the study area that were not observed in the satellite images because it contained modest evidence in the study area with regards to the presence of sinkholes; this might be due to various factors such as the very small size of the sinkholes or their depth is too small to be detected in the satellite images, or it might be covered by concentrated plants, or its formation and development occurred after the satellite images were taken.
6. The geological model is clarified via the geophysical data, consists of a basal marbleized limestone unit and constitutes the bedrock of the study area. This bedrock unit appears to have been effected by solution-widened joints process. Enclosed by overburdened layers consisting of sand, containing lenses of stiff, non-stiff moisturized clay and covered by soil with friable sand and rock fragments in certain places. Intervened by sinkholes and cavities in-filled with clay or sandy clay and sand; it is interpreted as a karstic process.
7. The geophysical data indicated that the depth of limestone bedrock topography was uneven, containing many pinnacles and cutters. In construction site #1, marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 8 to electrode 74 in traverses no. 1, 2, and 3. Extended between electrodes 25 and electrode 63 in traverses no. 3, 4, and 5. The depth of weathered limestone bedrock overlooking upper layers deposits with a depth varies from 15.0m from the surface to maximum depth of >39.4m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 15.0m then tumbling down to reach a maximum depth of >52.4 m in the left flank of the profile. The depth of pinnacles was varied between 11.0m beneath electrode 37 in traverse # 4 and with a depth of 39.4m beneath electrode 33 in traverse #6.

In construction site #2, marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 9 to electrode 28 in traverses no.1 and 2. Additionally it's extended between electrodes 11 and electrode 28 in traverses no.3, 4, and 5. It's began with a zone of weathered limestone and/or highly widened jointed marbleized limestone bedrock, overlooking upper layers deposits with a depth varies from 20.0m from the surface to maximum depth of and >28.0m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 21.0m then sink down to reach a maximum depth of >28.7m. The depth of pinnacles was varied between 19.8m beneath electrode 22 in traverse #5 and 27.0m beneath electrode 26 in traverse #1.

In construction site #3, marbleized limestone bedrock was visibly detected in the image extended on the subsurface between electrodes 25 to electrode 50 in traverses no.1. Additionally it's expanded between electrodes 8 and electrode 60 in traverses no.3, and decline between electrodes 46 and electrode 55 in traverses no.6. It began with a zone of weathered limestone and/or highly widened jointed marbleized limestone bedrock, overlooking on the upper layers of deposits with a depth varies from 13.0m from the surface to maximum depth of >59.0m. Intact or unweathered marbleized limestone bedrock, with very high resistivities were detected on the subsurface beneath the weathered bedrock, with a depth varies from 25.0 m then sink down to reach a maximum depth of >59.0 m. The depth of pinnacles was varied between 27.0m beneath electrode 51 in traverse # 3 and 49.0m beneath electrode 29 in traverse #5.

8. The interpretation of inverse model section of construction site #1 (Bandar Baru Putra) showed an area that has been affected by several karst features in the form of soil cover collapse sinkholes and soil pipes, thus containing stiff, non-stiff clay and sandy clay, and are sometimes in-filled with meteoric water. These features are harmful which could collapse when the clay is subjected to piping under load of structures. The interpretation of inverse model section of construction site #2 (Gunung Rapat) indicated that the area have been affected by thick cover of alluvium deposits contain several cover soil collapse sinkhole and lenses, those containing both stiff and non-stiff clay which is highly moisturized. This making the area hazardous and it need mitigation for any construction project. The interpretation of inverse model section of construction site #3 indicated that the area have been affected by thick cover of alluvium deposits contain several cover soil collapse sinkhole and lenses contain both stiff and non-stiff clay which is highly moisturized, making the area hazard.
9. The geophysical data also indicated that the different kinds of subsurface karst features originated from geo-hazardous area in many locations along the study sites. The most harmful one is the sinkholes which geophysical image showed that it's originated in many locations. The most hazardous area was found in construction site #1 extended beneath resistivity traverses no.4, in between electrode no. 38 and electrode no.49. Furthermore, extended beneath resistivity traverses no.5, in between electrode no. 22 and electrode no.70. Various types of sinkholes observed and identified, some of it extending to about 15.0m to 20m, with a maximum depth of ~19.0 m. These features are harmful because some are in-filled with water, while

others with thick clay and in-filled with sandy or silty clay, which could collapse when subjected to piping under load. Also, lenses with various depth and size are extended between 15.0m to 75.0m, with a maximum depth of ~22.0m. Some contain thick clay, while others are in-filled with sandy or silty clay.

Although, the most geo-hazardous area in construction site #2, were found beneath resistivity traverse no.1, between electrode no. 7 and electrode no. 29. Furthermore it's found beneath resistivity traverse no.2, between electrode no. 7 and electrode no. 32. Also in traverse no.3, 4 and traverse no.5 which affected in different places by various types of soil cover collapse sinkholes, soil pipes and lenses. Several of these features reaching a depths range between 12.0m to 15.0m, while others reaching the maximum depth of ~19.0 m. These features are harmful because some were in-filled with water, while others with thick clay or with sandy or silty clay, which could collapse when subjected to piping under load of structures.

Finally, the most geo-hazardous area in construction site #3, were found beneath resistivity traverse no.1, between electrode no. 4 and electrode no.71. Furthermore it's found beneath resistivity traverse no.2, 3, 4, 5 and traverse no. 6, between electrode no. 17 and electrode no.75 because of the presence of thick layer of clay and this layer affected in different places by various types of cover collapse sinkholes, lenses, depressions and channel pipes. Several of these features reaching a depths range between 15.0m to 18.0m while others reaching the maximum depth of >28.0 m. These features are harmful because some were in-filled with non-stiff clay which is highly moisturized, while others with stiff clay, silty or sandy.

10. These analyses led to the conclusion that the origin of The karst features such as cover collapse, subsidence sinkhole and cavities in construction site #1 is due to the initiated development of small voids at a depth of a few meters in the soil or in the unconsolidated cover overlying karstic bedrock and enlarged by the loss of cohesion and the loading of the arch-forming material, which is in turn caused by either a saturation of the soil due to rainwater precipitation or by the rapid draining of a submerged void which also increases pore pressure. While, the karst features in construction site #2 appears to be a new. The early stages of a soil-cover collapse may appear as a soil-piping feature; most soil cover collapse sinkholes locations are soil materials dominated by porous layers, with thickness of > 9.0m, highly weathered condition of underlying karstic carbonate bedrock, with positions adjacent to a main active sinkhole.

Finally, the karst features in construction site #3 appears to be new and due to thickness of >15.0m of cover overlying highly weathered condition with karstic carbonate bedrock, the sudden appearance and development of small voids at a depth of a few meters in the unconsolidated cover overlying highly weathered condition of karstic carbonate bedrock. Then enlarged and in-filled by soil and other material which is in turn caused due to running of heavy rainwater on the surface and rapid draining the material in a submerged void.

11. In accordance to the characteristics of the morphological features of karstic ground conditions by (Waltham & Fookes, 2005);

The karst level in construction site #1 found between traverse no. 1 and traverse no. 2 is a youthful karst type KII. Then the karst level observed in traverse no.3 are varied to older, mature karst type KIII. After that the karst level observed in between traverse no.4 and traverse no. 6 are complex karst type KIV. While the karst level in construction site #2 found between traverse no. 1 and traverse no.2 is a mature karst KIII. Then the karst level observed in between traverse no.4 to traverse no.6 are varied to complex karst type KIV. Finally, the karst level in construction site #3 found between traverse no.1 to traverse no.3 is a mature karst type KIII. Then the karst level observed in traverse no.4 to traverse no.6 are varied to complex karst type KIV.

12. As a result of operating a Permanent Geo-Hazard Incident Scale (PGHIS) completed by (Yassin R.R. & Hj-Taib, S., 2013) to assessing the geo-hazard in construction sites situated over the cover carbonate karst areas in Malaysia. This scale have many levels which is determined on the basis of three factors. There are 7 levels in this scale to assess the geohazard in construction sites as described below:

In construction site #1, three level of scale have shown in this site. Level 0: Neutral hazard found between traverse no. 1 and no.2, no incident record are shown in this area and no evidence on the surface of Karst features such as surface pool, small depression. The geophysical survey not display any karst features in the subsurface such as sinkhole or cavity. Level 2: very low hazard, found in traverse no.3, some record found of serious accident up from the normal values for civilian and animals due to presence of many soil cover collapse or subsidence sinkholes. The geophysical survey display karst features extended few meters in the subsurface. Level 5: high hazard incident, found in traverse no.4, the site suddenly passing to with wide-ranging consequences and have impact on people and the environment. The geophysical survey shown large karst features extended in the subsurface deep and wide tenth to meters such as buried sinkhole or uneven rock bed topography containing pinnacles and cutters. Level 4: medium hazard incident with local results found in traverse no.5, and no.6. Geophysical survey shown medium karst features extended in the subsurface, with tenth of meters.

In construction site #2: Two level of scale shown in this site. Level 3: low hazard incident record of levels up from the normal values between traverse no. 1 and traverse no.2, have impact on the environment, people and animals due to many soil cover collapse or subsidence sinkholes occurred, with fracturing in the house, roads, highways and pavements. Geophysical survey shown karst features extended in the subsurface with tenth of meter. Level 5: High hazard incident with wide-ranging consequences, between traverse no.4, no.5 and no.6, have impact on the people and environment and requiring the application of geological and geophysical field survey and measurements.

Finally, in construction site #3: Three level of incident shown in this site. Level 1: extremely low hazard in traverse no.1, no incident record as mentioned before. Level 2: very low hazard in traverse no.2 and no.3, some incident record serious up from the normal values in the area for people and animals due to many soil cover collapse and subsidence sinkholes occurred. The geophysical survey shown karst features extended in the subsurface. Level 4: medium hazard incident with local results, in traverse no.4, no. 5, and 6, is and have impact on the people and the environment. The geological survey show large karst features on the upper surface such as large collapse sinkhole or big depression. Geophysical survey shown large karst features extended in the subsurface such as buried sinkhole, cave or uneven rock bed topography containing pinnacles and cutters.

13. Through the comparison between the boring data by auger and geophysical data from (ERT) image section, found that there is small deference in the depth between the depth from the interpretation of (ERT) geophysical sections and the depth from the geological report of drilling by auger about 2.0m to maximum of 5.0m, if the ground surface is cover with sand and/or rock fragments. If the ground surface is covered with thick soil and /or with thick clay there is very small deference in depth cooperation and was found about 0.0m to maximum of 1.0m.

Several early engineering subsurface remediation techniques are available in repairing any construction site threatened by cover-collapse sinkholes, to transfer the load of the future building structure to recognizable bedrock. The best remediation technique of the sinkhole repair varies, depending on the size and stability of the hole.

An effective procedure can be rapidly used to fill the sinkhole by graded filter technique. The purpose of the graded filter is to allow water to seep into the ground while the soil is held back. In the case of great sinkholes the graded filter construction is essentially the same, but the final layers are fine gravel, coarse sand and fine sand. The uppermost layer is bentonite clay which blocks water seepage. Furthermore need of a new process of grouting method in the study areas as chemical grouting techniques. Additionally, need to control surface and subsurface water drainages must be put into operation in these relevant sites. Uses of bentonite drilling mud and the rock gutting from the drilling operation after the water and other liquids are removed to refill the depression and sinkholes in karst regions. Skin friction piles driven into the layers which contain non-stiff materials (soil, clay, silt and sand). Finally, due to the difference in the depths of marbleized limestone bed rock from one construction site to the other, the requirement to driven long end bearing piles down to the sound bedrock.

14. The survey of Phase I environmental site assessment, is generally considered as the first step in the process of environmental due wariness if the surface of these sites are considered to be contaminated with industrial pollution affected the site. This step include preparing the reports of environmental site assessment to construction site management. These reports very important which identifies that no potential or existing environmental contamination responsibilities in these construction sites.

15. To assess the air quality of these selected construction sites and to understand if it's there effected by any pollution. In this study practicable of (API) (Air Pollutant Index) or in Malay as (IPU) is a simple and generalized way to describe the air quality. It's calculated from several sets of air pollution data in Malaysia. This index shows that API reading of the study construction sites between 51-100 means and the Air Pollution Level (APL) is goods with no health implications.

XV. CONCLUSIONS

The current geo environmental case study focuses on the combination of geological, geophysical, aerial photographs, and satellite imaging techniques as identification techniques to assess the geo environment hazard of the subsurface geological carbonate karst features and its extends of the subsurface geological carbonate karst features including sinkholes, channel pipes, karstic voids or cavities, and the subsurface geological structures such as solution-widened joints, intensely fractured zones and faults. These techniques are coupled with engineering surface and subsurface remediation techniques and performed across three selected construction sites for housing complex projects located in north and south of Ipoh city (Kinta valley), Perak, Peninsular Malaysia.

Two-dimensional (2D) electrical resistivity tomography (ERT) surveys were carried out in this survey in order to image the subsurface and locate evidence for near surface karstic features such as voids or cavities including

sinkholes and to estimate the depth of the bedrock. Furthermore to estimate the reliability of (ERT) geophysical technique in recognizing such karst features or not. Resistivity's traverses were conducted along the survey area at each of the three construction sites. The orientation, extension and the degree of inclination of those traverses are shown in the location maps. The correct resistivity data was interpreted using res2dinv software. An assessment of the situation was surmised from the subsurface images. Subsequently an estimation of the possibility of a collapse occurring due to the presence of several cover collapse sinkholes and lenses packed with non-stiff moisturized clay were prepared.

This study also displayed that high resolution Electrical Resistivity Tomography (ERT) can be effectively realize to reflect the bedrocks. It's also completely suitable for differentiating surficial soil, clay, weathered rocks, compact or intact rocks and air-filled karstic voids or cavities and intensely fractured rocks. Interpretation of (ERT) inverse model sections can exposed to civil and geo environmental engineers the irregularity in subsurface karst topography of marbleized limestone bedrocks in Perak, the degrees of karst level which classified due to classification of karst ground conditions by (Waltham & Fookes, 2005) and the reason after the appearance of the karst features and the deference in the appearance of the karst features along these sites. Also, indicated that the depth of marbleized limestone bedrock topography was uneven, containing many pinnacles and cutters and identified the variance in the depth of bed rock from one site to the other.

Early planning is needed to mitigate or minimize the geo environment hazard of these features in these construction sites which lay over karstified carbonate bedrock environment. Initial consultation assumed of applying of reverse graded technique, driven long bearing piles to the sound bedrock due to difference in the depth of bed rock from one site to the other. Also need of new process of grouting method in the study areas as chemical grouting techniques and controlling of surface and subsurface water drainages must be put as primary suggestion in plans of operations these construction sites.

As a result of operating a Permanent Geo-Hazard Incident Scale (PGHIS), many levels of geo-hazard incident record up from the normal values shown in the area have impact on the environment and civilian people and animals. This scale have many levels which is determined on the basis of three factors and there is seven levels in this scale to assess the geohazard in any construction sitessituated over covercarbonate karst areas and effected by carbonate karst features .

The survey include Phase I environmental site assessment, is generally considered as the first step in the process of environmental due wariness if the surface of these sites are considered to be contaminated with industrial pollution affected the site. These reports show that no potential or existing environmental contamination responsibilities in these construction sites.

In this study practicable of (API) (Air Pollutant Index) or in Malay as (IPU) is a simple and generalized way to describe the air quality. To assess the air quality of these selected construction sites and to understand if it's there effected by any pollution.

XVLSUGGESTIONS FOR FUTURE SURVEY IN KINTA VALLEY

This geoenvironmentalcase study focuses onthe combination of geological, geophysical, environmental, aerial photographs, and satellite imaging techniques as identification techniques to assess the hazard of the surface and the subsurface due to the presence of various classes of carbonate karstenvironmentcontains solution features and it's extended. The geo environmental hazard of the sinkholes and other karst features such as, cavities and dissolution channel pipe can cause problems to the construction projects in the near future resulting from mismanagement during the initial phase of the projects, as the developers did not carry out prior geophysical technique in site characterization and geological studies. Moreover, the borings within these karsts regions is incapable of providing sufficient subsurface data for analysis.This might misrepresent the subsurface geological model, which might in turn lead to additional cost for corrective design or ad-hoc analysis. The results of applying the techniques were discussed and the suggestions are:

- I.** The respective states must implement and enforce a regulation that no construction project may begin in an area over carbonate karst environment, until the geological and geophysical survey is completed in order to avoid any future geo environment catastrophic problems.
- II.** The best plan in future site characterization is applying geophysical survey by (ERT) technique using a space interval not more than 10 m between two parallel lines, because of high lateral variation in the subsurface topography and lithology. Besides, this plan will give clear image to the subsurface.
- III.** If the future survey by applying (ERT) geophysical site characterization technique, must be developed to applying of 3D (ERT) geoelectrical investigation technique and 3D software to provide a clear image for the subsurface features and structures. Furthermore, to provide clear indications of their directions and extent under the subsurface.
- IV.** Using the borings method before applying any survey, at least drilling two testing boreholes to calibrate

and support the result of the (ERT) geophysical site characterization technique. After interpreted the image sections boring must be apply to inspect the positions which needs early planning to reduction the geo environment hazard of karst features of any construction sites over covered karstified carbonate bedrock. This must be done before starting any future construction projects.

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