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Environmental geology in urban development

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Abstract: Environmental geology, although well established in the geological fraternity, is still little understood by the rest of the community. This lack of appreciation on its usefulness in urban planning and land development has resulted, to some extent, in the sterilisation or non-optimal use of mineral resources in Malaysia, particularly with respect to non-metallic minerals. In addition, development over geologically hazardous areas, without proper mitigating measures, has contributed towards man-made disasters, thus adding to the cost of remedial and maintenance work. Another outcome, especially during periods of rapid development and without appropriate environmental geological inputs, has been increased erosion, landslides, flash floods, pollution of waters, rapid run-off and even lowering of the groundwater table. The long-term effect of this is an increase of water-stressed areas, especially during the dry season. Environmental geology can also be applied in many other areas of urban planning such as for the disposal of solid and toxic waste, determination of sources for water supply, infrastructure development (roads, dams, airports, seaports etc.), recreation and tourism, land reclamation, identification and clean-up of contaminated sites, as well as conservation, among others. Inspite of its wide variety of applications insufficient use of geology is made in urban planning. Environmental geology maps and reports (also known as engineering geology maps in Europe) can significantly assist the planner in planning of townships, preparation of structure and local plans or in drawing up of layout plans for specific projects. Even during the development stage advantage should be taken to update the geological database and consultants and developers should, with the help of geologists, translate it into potential environmental impacts and thus put in place appropriate mitigating measures. Although the applications of environmental geology are numerous yet it is insufficiently used. The reasons include insufficient or lack of cross professional interaction and lack of training in maximising the use of geology for urban planning and land development. This is compounded by the fact that reports written by geologists are too technical in nature and understood mainly by geological specialists. Furthermore the scale of maps is critical as, more often than not, they tend to be on a reconnaissance scale that are more appropriate for macro landuse planning. For site specific projects, maps on a detailed scale (1:1,500–1:5,000) will be more useful to enable the incorporation of elements of environmental geology in planning. There is certainly an urgent need to close this communication gap in Malaysia, in particular, and Southeast Asia, in general. In North America, Europe and Australia, progress has been made but more can be done. There is also an urgent need to produce simple thematic maps and reports, understandable to planners, architects, engineers, developers and even politicians, to ensure that maximum advantage is taken of geological inputs for urban planning and development. The thematic maps should cover geology, geochemistry of rocks, soils and waters, geotechnical properties of soils and rocks, mineral resources, especially construction materials, geotechnical classification of slopes, landslides, flood-prone areas, thickness of overburden (rock line), distribution and thickness of peat, groundwater flow pattern etc. However maps such as general foundation suitability, potential waste disposal sites, relative compressibility, sinkhole susceptibility, ripperbility potential, landslide susceptibility etc., derived from the raw data collected, will be easier to use and more useful to the planner or developer. The additional cost is very small when compared to the cost of the project or the potential benefits expected.

Since the early nineties and subsequently after the 1995 amendments to the Town and Country Planning Act (1976), geological inputs are now a requirement. For bigger projects such as the Kuala Lumpur International Airport at Sepang, the new administrative centre for Kuala Lumpur (Putrajaya), the information technology city named Cyberjaya and the International Commonwealth University of Malaysia, appropriate geological inputs were provided for layout plans. However this practice is not the norm and for the State level it is recommended that the Geological Survey Department be co-opted into

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committees dealing with regulation and control of development. The department will be able to help set up geological standards for land use and geohazard mitigation and formulate, jointly with Town and Country Planning Department, guidelines to assist in the provision of geological information to local authorities for preparing structure and local plans and to developers for preparing the Development Proposal Reports. It would not be out of place to introduce statutory requirements covering development within hazard areas, once geological standards and guidelines for development have been drawn up. Finally, with the use of environmental geology we hope to promote sustainable development by facilitating pre-disaster mitigation instead of post-disaster remedial action.

INTRODUCTION

Due to the rapid pace of development, parts of Malaysia, especially in the Klang Valley, have experienced unprecedented growth rates with growth areas expanding and encroaching on geologically hazard areas (geohazards). Due to the shortage of land, the urban centres have expanded over high-risk ground, such as hilly terrain, areas with karstic bedrock, ex-mining land, peat and soft sediment areas. The occurrences of geohazards such as landslides and sinkholes have affected the urban dwellers. Mishaps, resulting in loss of life and property, due to such geohazards have increased the awareness of planners, administrators and public on the importance of geological inputs in the planning and development of urban areas. Groundwater pollution and difficulties in finding suitable sites for disposal of toxic, solid and industrial wastes are the other problems facing the urban planners. However the general public is still in the dark with respect to the role of environmental geology in urban development. Although geological inputs are used by government and industry, it is far from being a norm. These inputs are also a necessity for optimal land-use if we want to avoid the sterilisation of mineral deposits or the non-optimal use of mineral resources. We need to save-guard and optimize the use of construction materials, such as sand, gravel, clay and aggregates, which one tends to take for granted. A lot more has to be done to make the various levels of Federal and State governments aware of the importance of environmental geology inputs in urban planning and development. Furthermore, through these inputs, appropriate mitigative measures can be taken at the planning and development stages which will eventually reduce remedial and maintenance costs. The paper highlights the use of geological inputs in urban planning and development, particularly the role of the Geological Survey Department (GSD) in providing relevant geological data for planning and development of new growth centres (Fateh Chand, 1997).

Table 1. A simplified chart of planning process in the Klang Valley and its weakness from the perspective of geology [Modified from Pereira & Ibrahim (1997)].

LEVEL	MECHANISM	PROCEDURE CONSIDERED	PARAMETERS	WEAKNESS
LANDUSE PLANNING	Preparation of structure plans, local plans, etc.	• Estimation of space requirement • Location suitability analysis	• Economic • Population • Existing landuse • Environment • Transportation • Utilities and • Communication, etc.	Only mining/minerals given consideration. No inputs on geohazards and their mitigation. No physical conservation of sites. Source of construction materials not included. No requirement for a construction suitability map to facilitate planning.
REGULATION AND CONTROL OF DEVELOPMENT	Application for landuse conversion	Evaluation provided by technical departments prior to approval by State Executive Council.	• Site gradient • Landuse zone • Access road • Road reserve • Flood prone area • Drainage requirement for low areas • Availability of adequate water supply	No inputs on the type and level of geological information required from GSD. No standards established with respect to geological hazards and their subsequent monitoring. No consideration for use of groundwater, no provision on supply of construction materials, and no provision for conservation of geological heritage.
	Application for planning permission	Standards imposed by various technical departments prior to approval of DPR and layout plan by Local Authorities		

CURRENT STATUS OF ENVIRONMENTAL GEOLOGY IN MALAYSIA

In Malaysia, planning for development comes under the ambit of the Town and Country Planning Act (1976). There are two levels of planning, namely:
(a) landuse planning;
(b) regulation and control of development.

Norasiah and Lok (1990) highlighted that the parameters used in the planning process are (1) economic (2) population (3) land-use (4) environment (5) transportation, utilities, and communication.

At both these levels, the role of geology is not spelt out and it is not mandatory to incorporate geological inputs in the planning process. Pereira and Ibrahim (1997) have ably summarised the salient features of the planning process (Table 1).

Departments responsible for public works, drainage and irrigation, telecommunications, electric supply, water supply etc., have established standards, which have to be observed during development. Accordingly, their inputs are vital. In the case of geology, no standards have been established or adopted. It is time that standards are formulated, adopted and used as guidelines for development. An example of such a standard is to ensure that no development is allowed within a distance of twice the height of a limestone cliff face. Studies by Shu *et al.* (1981), after reviewing historical records, have documented that the rock blocks/fragments fall within a distance of one and a half to three times the height of the cliff face, the median being about twice. Accordingly, no buildings or highways should be allowed within this hazard zone. If due to physical constraints a road has to be built within this zone then appropriate mitigative measures need to be taken such as using netting and rock anchors or constructing a ditch and bund to prevent rock blocks/fragments reaching the road during a rock fall. A further distance equivalent to the height of the hill is recommended to be incorporated as part of the green belt. Similarly, guidelines could be drawn up on the de-watering for construction of basements and recharging of groundwater in the surrounding areas during construction of subsurface structures. It is well known that de-watering of mines and excavations can result in subsidence of the ground, or the development of sinkholes in limestone areas (Chow, 1995). In addition, ground subsidence leads to the development of cracks in buildings. Examples of sinkhole development are in the Bau gold mining district in Sarawak and the tin mining district of Lahat near Ipoh. In the Perangin Mall area in Penang ground subsidence took place during excavation and de-watering of the basement.

It is generally felt by people in the geological fraternity that use of geological data is not being maximised. For instance, geology and mineral maps can be used for delineating mineral potential areas for land use planning, conservation of geological sites as geological heritage and for eco-tourism, as well as potential deposits of construction materials before they get sterilised by other forms of developments. Similarly geological maps can be used for mapping the type and distribution of soils to facilitate agricultural planning, in identifying sites for dams, residential areas, recreation places, waste disposal, land reclamation and alignment for highways. Detailed geological data can also be used for layout plans, in planning of site investigation (SI) work, including the type of equipment to use etc. For instance, in SI work for highways, geological inputs for selection of sites for detailed investigation would be more meaningful than an arbitrary selection, or one based on access. It is more important to characterise areas according to changes in geology and structure. Even within the same rock type or geological formation, many variations may be present which are not shown on 1:63,360 or 1:50,000 maps. Detailed mapping is required and accordingly greater attention should be focused in these areas. However, due to the several mishaps in the country, such as the collapse of a condominium, landslips, slope failures, sinkholes and debris flows, resulting in loss of lives and or damage to property, the Town and Country Planning Department (TCPD) took action in 1995 to modify their act whereby geological inputs are now mandatory in the planning process. This has partially addressed the weakness but what is still lacking is it does not specify who is qualified to provide these inputs. There is still no act to regulate those providing geological inputs. In Hong Kong and United Kingdom, the role of geologists is clearly spelt out. Chartered geologists, members of the Institute of Mining and Metallurgy and members of the Geological Society of United Kingdom are qualified to provide geological inputs. It is certainly time for the authorities in Malaysia to implement a similar system to ensure only qualified persons are allowed to provide geological inputs. As an interim measure, it is recommended that all geologists registered with the Institute of Geology Malaysia be accepted as geologists qualified to provide professional services. These names can be forwarded to the TCPD at the Federal, State and local council levels. Alternatively, they can be registered with GSD.

RECENT INITIATIVES

Notwithstanding the current set up, major government initiated projects, particularly at the Federal level, GSD, as a matter of routine, is called to provide geological inputs. The department now provides information from its integrated geoscience mapping programmes (IGMP). This has come about by a closer interaction between planners, engineers, geologists and other professionals.

Under the IGMP, the department collects and collates geological and mineral data, engineering geological, hydrogeological, geophysical, photogeological and geomorphological data as well as baseline environmental geochemistry information that can be used as inputs for proper planning and management. The outputs like those of IGMP are now becoming more user-friendly and digital thematic maps, which are more useful to engineers and planners for land-use and physical planning, are now being complied for urban development. The thematic maps produced are as follows:

- Surface and subsurface geology maps and cross-sections.
- Geohazards map (including sites of landslides, rockfalls and sinkholes).
- Geotechnical map (summary of site investigation data).
- Hydrogeological map.
- Geochemical map with baseline information.
- Geomorphological map (including land forms, ex-mining and flood prone areas).
- Construction materials map (including cut and fill earth materials).
- Construction suitability map.

In 1992, GSD initiated an integrated mapping programme in the Kuala Lumpur International Airport (KLIA) area, Sepang, to provide geological and geotechnical information for the preparation of a master plan of the new growth centre. Detailed geological, geotechnical and geophysical investigations were carried out (Zakaria Mohamad, 1995). Several sectorial reports and maps were produced and these have been used by planners and engineers in the preliminary layout planning and subsequent implementation of construction works of the area. The occurrences of peat and soft marine sediments and the potential impact of overpumping of groundwater were highlighted for the planners and engineers. Construction materials, including sand and granite resources, within a radius of 30 kilometers were also identified.

A similar integrated geoscience survey comprising geological, engineering geological, hydrogeological, geochemical and geophysical investigations was also carried out by GSD over more than 2,000 sq km in the Klang Valley and its surrounding areas. The survey commenced in 1994 and was completed in 1996. The data has been digitized and various thematic maps can be generated. GSD is currently undertaking similar projects covering the state of Penang, Cameron Highlands and Southeastern Johore.

Environmental geochemistry was introduced during the integrated surveys. The aim of the investigation is to provide baseline data and to assess the level of inorganic pollution for subsequent environmental monitoring and auditing. This is undertaken through the collection of stream sediment and stream water samples.

The federal administrative centre (Putrajaya, formerly called Perang Besar) and IT City (Cyberjaya) are other examples of the new approach in the use of integrated geoscience data in urban planning and development (Wan Mohammad Mukhtiar, 1997).

At the state level, the geological inputs are also provided by GSD but whether their usage is maximised in the planning process is uncertain. The geological information includes general geology, groundwater, construction materials, mineral resources, geohazards and classification according to landuse potential. Subsequent feedback received revealed that the data is too technical in nature and the format used in providing information is not user-friendly enough. It should be tailored to meet the needs of planners, engineers and other consultants. Furthermore no single format will be suitable for all the interested parties. This issue is now being addressed by GSD.

It is pertinent to point out that projects, such as the construction of dams, if funded by aid agencies like the World Bank, require inputs by geologists, as they are mandatory. In the case of projects undertaken by the private sector in Malaysia the amount of geological input is highly variable. It depends to a large extent on the project leader. What is more important is to make maximum use of geological data for planning, design and to provide for appropriate mitigative measures. This lack of appreciation of the importance of geology is probably due to the poor communication between the parties. If all the parties work as a team, the role of environmental geology will be more obvious and it can help in planning, design, development, mitigation and the monitoring process. This will eventually be a more cost-effective practice. Planners, architects, developers and project engineers should communicate their requirements and help in jointly developing with geologists the type of information required and the preferred format. This is crucial as one has to spell out the planning issues, the purpose of the information, whether for design or for policy/decision making, the presentation format, whether as raw data or processed data with thematic maps or even derived maps. Finally, the geologists need to know who the potential users are. Simplified thematic maps for multi-purpose use should be produced to cover geology, geotechnical properties of soils and rocks, mineral resources, construction materials, geotechnical classification of slopes, geohazard areas, thickness of overburden, isopach map of peat and/or soft sediments, and groundwater flow pattern. However maps depicting foundation suitability, potential waste disposal sites, relative compressibility, sinkhole susceptibility, rock ripperbility, landslide susceptibility etc., derived from raw data available or collected, will be easier to use and more useful to the planner or developer. The additional cost for site investigation is very small when compared to the cost of the project or the potential benefits expected. Costly oversights can be avoided and subsequent maintenance costs can be reduced.

For macro planning, using this approach, GSD prepares construction suitability maps which facilitate the drawing-up of layout plans. The construction suitability map is a simplified map showing the suitability of the area for development. The map contains information based on classes modified after the Hong Kong Geotechnical Engineering Office Classification. GSD uses four main classes based on an integration of important parameters. The classes are:

i) Class I

In areas classified as Class I, civil engineering works are not expected to encounter any foundation problems. Some cutting and filling of hill slopes may be required. These areas are generally flat or may have an undulating topography with low hillocks and composed of residual soils. The general gradient is less than 12 degrees and the risk for development is low. Beneath the soil may be a thick zone of weathered bedrock.

Prior to the development of Class I areas, a detailed SI should be carried out according to the layout plan to demarcate the thickness of the residual soil cover, its engineering properties and the type and depth of bedrock. This information is necessary for design purposes. However no surprises are expected.

ii) Class II

Class II can be divided into two sub-classes. **Class IIA** represents areas blanketed with alluvium. These areas generally have fewer problems compared to mined-out alluvial areas as in Class IIB. Beds of soft clayey material may be present.

Class IIB areas cover mined-out alluvial areas. Minor problems may be encountered in these areas, such as ground settlement as there may be lenses of slurry slime within the tailing sand.

Civil engineering works in these areas classified as Class II are not expected to encounter any major foundation problems. Prior to development in these areas, a detailed SI to study the subsurface lithology as well as their engineering properties should be carried out. This will help in identifying any problems associated with slime or any soft clayey beds.

iii) Class III

Class III areas are those areas that are underlain by limestone bedrock, hilly terrain with slopes 12 to 20 degrees and reclaimed coastal areas.

The limestone areas, which underlie former mining areas, may contain trapped slurry slime within the troughs of the karstic bedrock. The limestone bedrock has many pinnacles, deep troughs, cavities and caverns, which pose foundation problems. Prior to development over these areas, a detailed SI programme involving the study of subsurface lithology (including the depth, thickness and extent of the slime lenses), topography of the limestone bedrock and the extent of the cavities and caverns within the bedrock should be carried out. Information on the nature of the limestone can be obtained by undertaking a detailed microgravity geophysical survey or other appropriate geophysical technique to obtain the information which can help plan an effective SI investigation. Accordingly the information gathered will help in designing the foundation and to minimise cost over-run due to insufficient knowledge of the bedrock.

Hilly terrain of 12 to 20 degrees is classified as moderate risk. The engineering problems associated with the development of such areas are the stability of cut and fill slopes. Landslides and erosion may occur as a result of an increase in the pore-pressure due to periods of intense rainfall. However, slope stability problem can be addressed.

In the last few years, land reclamation along the coastal areas has been intensified. Coastal areas usually comprise mudflats with thick unconsolidated clayey or soft sediments. Reclamation of these areas with sand and slit can give rise to subsidence problems resulting from differential settlement of the ground materials.

Design for foundation of buildings in areas classified as Class III is expected to be a little more complicated and a detailed site investigation programme is required to geotechnically characterise these areas.

iv) Class IV

Class IV can be divided into three subclasses: **Class IVA** represents hilly areas with slope gradients more than 20 degrees. These areas are classified as high risk. Development of hilly terrain will expose barren land and cut slopes in which these may subject to soil erosion and landslides. Landslides usually occur in colluvium during periods of rainfall. Stringent measures will have to be taken to avoid soil erosion and landslides, if buildings are constructed on hill slopes. There is a need to minimize the cut and fill methodology commonly used in hillside development. Instead one should try to build in harmony with the topography. Cut slopes, if essential, should be well protected to avoid landslides and rockfalls. Detailed documentation of hilly terrain, such as the underlying lithology, geological structures, grade of weathering and type of soil i.e. whether it is alluvial, colluvial or residual is required for planning and design purposes. The drainage pattern and hydrology too should be documented. Areas with slopes greater than 30° are generally discouraged from being developed.

Class IVB are areas containing layers of peat and very soft sediments, and are unsuitable for civil engineering works or construction of buildings unless appropriate mitigative measures are undertaken. Any construction of civil works over such an area may require the removal and replacement of the peat and very soft sediments. Prior to development in the area, a detailed site investigation programme, based on the layout plan, will have to be carried out to determine the thickness and nature of the peat and very soft clay.

Also in this category are former municipal waste disposal sites, which tend to give rise to problems in connection with methane gas generation, fire, subsidence and groundwater contamination. Instead of rehabilitating such areas it is better to leave these as green open spaces.

Class IVC are areas covered by ex-mining ponds. Generally, the ponds, which are the remnants from the tin mining period, are of various sizes and many occur in the growth area. These ponds may contain soft slurry slime, and if they are to be developed, then reclamation will have to be carried out. However, prior to the reclamation, a detailed investigation will have to be carried out to characterise these ponds. The depth of the water in the ponds, the quality of the water and the thickness of the slurry slime, and the chemical, physical and engineering characteristics, will have to be studied. Only then can a suitable reclamation scheme be devised. However, it is generally recommended that the ponds be landscaped and retained as water bodies or theme parks in the overall development of the area.

DISCUSSION AND CONCLUSION

The geological information is of primary importance as inputs for the preliminary stages of project planning and design. Important structures may have to be resited to suit the geological conditions. The information, particularly that regarding the subsurface, is useful for planning and engineering requirements. A good example is the new Kuala Lumpur International Airport in Sepang where one of the proposed runways which was initially sited over peat and soft marine clay was relocated to the firmer residual soil of the Kenny Hill Formation.

Investigations carried out in the Klang Valley, its surrounding areas and elsewhere had highlighted the geological constraints, such as the occurrence of karstic bedrock, hilly areas, ex-mining land, peat and soft sediments, groundwater contamination problems and potential impacts of overpumping of groundwater on ground stability for construction purposes. Some of the information collected during the investigation, especially geochemical data, could also be used as baseline data to facilitate subsequent environmental monitoring and auditing.

Generally, the geological inputs provided by GSD have been integrated in land-use and urban planning and development. There is now a tendency for the government agencies to request for GSD's advice when a new urban project or growth centre is proposed. This shows that the planners and decision-makers are increasingly aware of the importance of geological inputs in land use planning and development. However in the private sector the use of geological inputs in design and construction of civil engineering structures is highly variable. It is strongly recommended that the use of geological inputs by qualified geological professionals be institutionalised in all civil works. These environmental geological inputs will facilitate mitigation against disasters and help reduce cost of maintenance and remedial work.

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