Development of GIS Based Landslide Hazard Assessment

by

Muhamad Hafiz bin Amiruzan

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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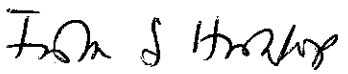
Approved by,



(Assoc. Prof. Dr. Indra S. Harahap)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MUHAMAD HAFIZ BIN AMIRUZAN

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ABSTRACT

The project was conducted to generate and integrate the development of spatial database landslides potential hazard mapping database in determining the level of safety and conscientious in earthwork analysis. Landslides constitute major geological hazard that occurs widespread, causing extensive damages and casualties all over the world. Expansion of urban and recreational development into unstable potential landslide area increases the number of residential and commercial properties threatened by the risk of landslides. Slope failure can cause fatality and property damage thus to avoid material loss and human casualty, potential unstable areas are determined during the early stage of project development planning. The study emphasized on mapping out the conceptual overview of potential landslide hazard with further evaluation on the factors relevant to the triggering sources of the hazard. Modules of study on specific zone such as geological parameters, environmental impact and growth of urban area were evaluated for the database research input prior to the real hazard mapping generated by Geographic Information System (GIS). These modules were further interpreted for possible identification and classification of potentially unstable site illustrated as hazard map.

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CHAPTER 1

INTRODUCTION

1.1 Background

Possibility of landslide occurrence is one of the major geotechnical concerns prior to development of certain area. Hence, predetermined assessment of these hazard was necessary to be perform in providing mutual access to identify and locate hazard potential zone prior to on-site development. Hazard assessments consist of certain primary elements: 1) hazards identification, interpretation and occurrence; 2) Identification of vulnerable urban development and populations; 3) Integration of both elements in the scope of geographic or spatial evaluation; 4) Analysis of relevant data to the susceptibility factor of the event.

The assessment of landslide instability and risk has become a topic of major interest for both geoscientists and engineering professionals as well as for the community and local administrations in many parts of world. In recent years, Geographic Information Systems (GIS), with its excellent spatial data processing ability [1], has attracted great attention in natural disasters assessment. The stability calculation of one particular location for landslide assessment can be performed within the GIS [1].

GIS technology is a tool of storing, processing, sharing and using geological information for the occasion. The general concept of conducting the assessment via integration of GIS program is to store effectively relevant data with related knowledge for the purpose to mitigate suitable planning strategy for making geological information easily readable and usable.

Development of GIS Based Landslide Hazard Assessment project was assigned for two (2) semesters, FYP (1) and FYP (2), in the year 2006 within allocated budget. The project involved full collaboration of a number of parties, especially in technical support and data retrieval process, in order to be successfully completed.

1.2 Problem Statement

Landslide is known as a significant natural hazard throughout the world which contributes to major economic losses and casualties. The event occurs at certain locations where the terrain was considered unstable and has the potential to fail, contributing to potential landslides event. There has been major concern in natural hazard assessment within the scientific community recently, as safety and precaution measures were taken into deep considerations. Identification of susceptibility aspects contributing to the event occurrence was considered necessary, moreover proper mitigation planning for future development is essential [2].

Proper hazard management system was initiated, rationally, due to the fact that people throughout the world enquire not only conditional life standard, but also safety concern of their homes. Concerning on the impact of development and environment, thorough efforts were also provoked in reducing the risk of experiencing all sort of potential disasters. Disastrous events occurred in many places around the world had enlightened the scientific community to take the matter seriously.

Properties and human safety were always at the most priority for conducting the evaluation. The urban planner should consider these criteria for evaluating the feasibility of developing certain area to cater for population expansion. Thus, proper studies performing the evaluation of spatial mapping of hazard zone classification within the area is required; by allocating all possible factors contribute to the hazard.

Constructing hazard mapping of certain location is relevant as a macro approach to obtain general idea of hazard classification before further micro research was pursued for specified point scale location. Integrating the GIS program to the assessment would generate database in managing proper arrangement and evaluation of data, hence provide ease of future data retrieval and updates.

1.3 Objectives

The following are the objectives of the project:

a) To determine and integrate the factors contributing to landslide occurrence.
b) To create a Hazard Map of the study area

1.4 Scope of Study

The assessments were purposely conducted to construct digital hazard mapping involving spatial evaluation of the study area, where hazard management was considered feasible to be applied to the site. Interpretations of geological and topological data in conjunction with human activities in a specific area were performed during the evaluations to enhance thorough understanding of the soil conditions.

The scope of study focuses on:

a) Literature studies and familiarization of the GIS program while gathering relevant data of the site.
b) Analyzing the study area for final spatial identification of significant factors contributing to landslide event.
c) Feasibility studies performing the Spatial Reasoning approach in evaluating the weight of on-site factors which contribute to the occurrence of landslides event.
d) Integrate all information into GIS program
e) Development of hazard mapping of the study area by overlapping all feasible hazard characteristics.

1.5 Project Planning

Overall project planning is summarized in FIGURE (1) and FIGURE (2).

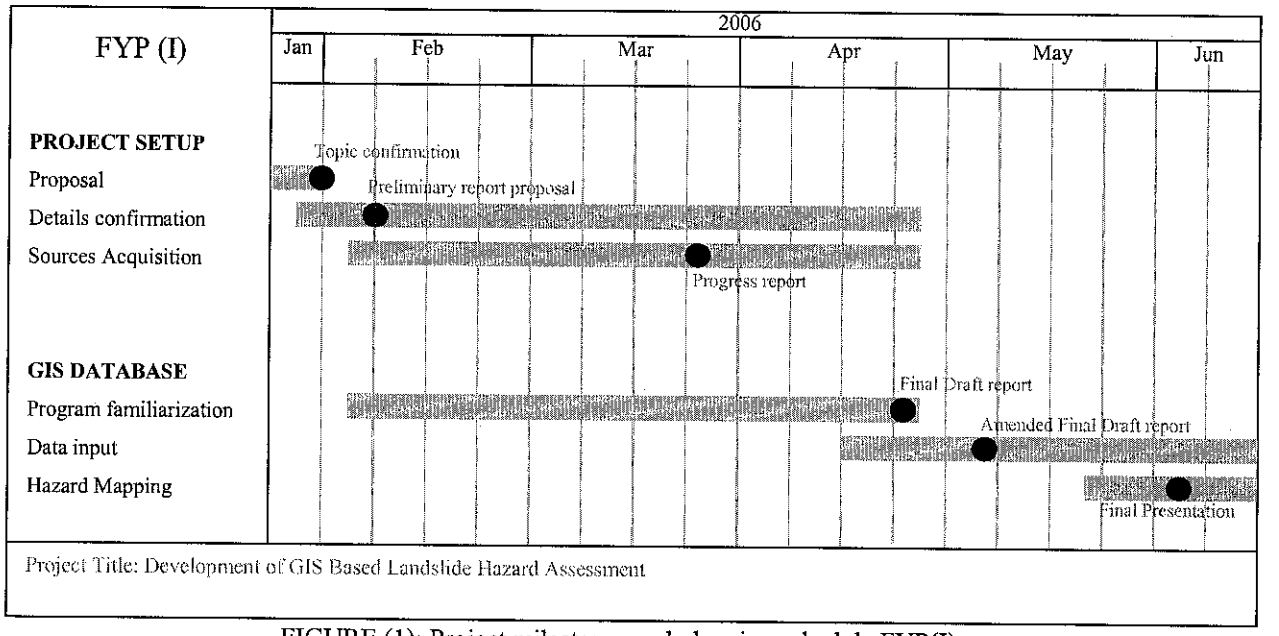

FIGURE (1): Project milestones and planning schedule FYP(I)

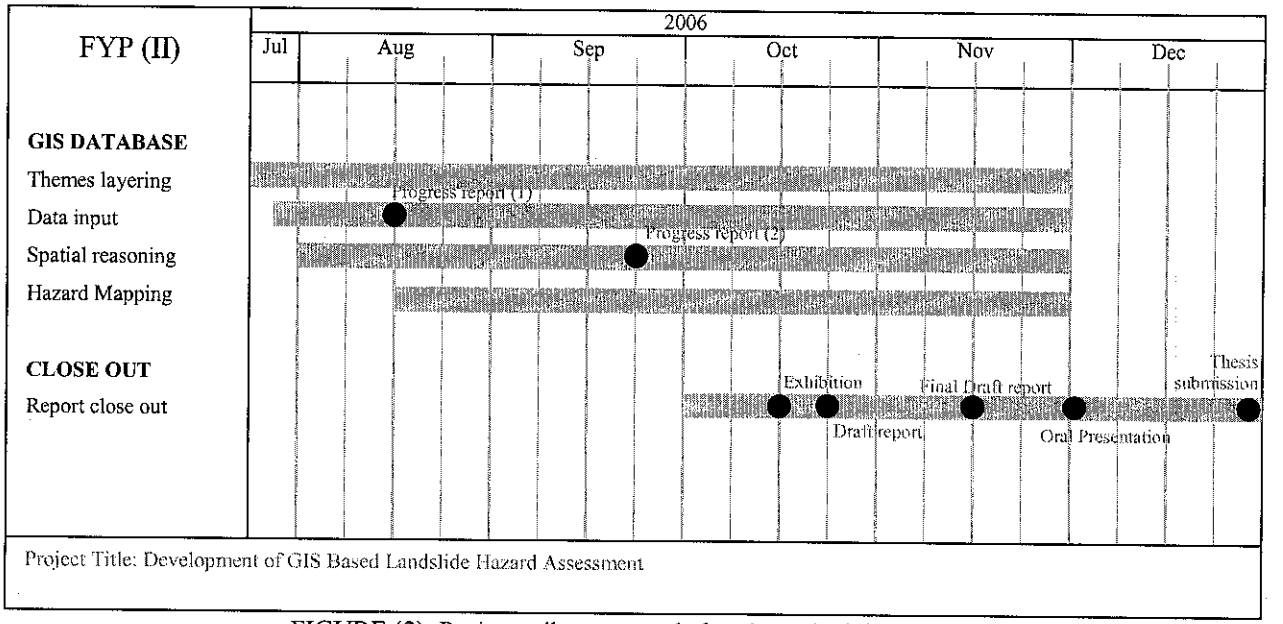

FIGURE (2): Project milestones and planning schedule FYP(II)

CHAPTER 2

LITERATURE REVIEW

2.1 Geographic Information System

A geographic information system (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, and edit data. Geographic information science is the science underlying the applications and systems, taught as a degree program by several universities.

Geographic information system technology can be used for scientific investigations, resource management, asset management, Environmental Impact Assessment, Urban planning, cartography, and route planning. For example, a GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, or a GIS might be used to find wetlands that need protection from pollution.

2.2 Definition: Landslide

Landslide is defined as the sliding or falling down of mass of earth, rock or debris from a mountain or cliff [3]. The event is caused by disturbance in the natural stability of a slope which may leads to massive destruction and casualties. Lose of life is the main threat associated with landslides that occurs at these particular sites [10]:

a) Area where vegetation destroyed caused by wildfires or human activities.
b) Steep slopes and areas at the bottom of these slopes.
c) Unstable area where landslides have been encountered previously.

d) Reengineered slopes characteristics due to development.

e) Channels along streams or river.

f) Areas directed to surface runoff.

Land slides are primarily associated with mountainous terrain but the event also might be possible to occur in the *low-relief* region. These areas can also be clarified as human caused region where activities such as mining, farming and deforesting could trigger landslides [10]. Erosions causing river bluff failures also contribute to the event, thus both natural and man made causes need to be mitigated.

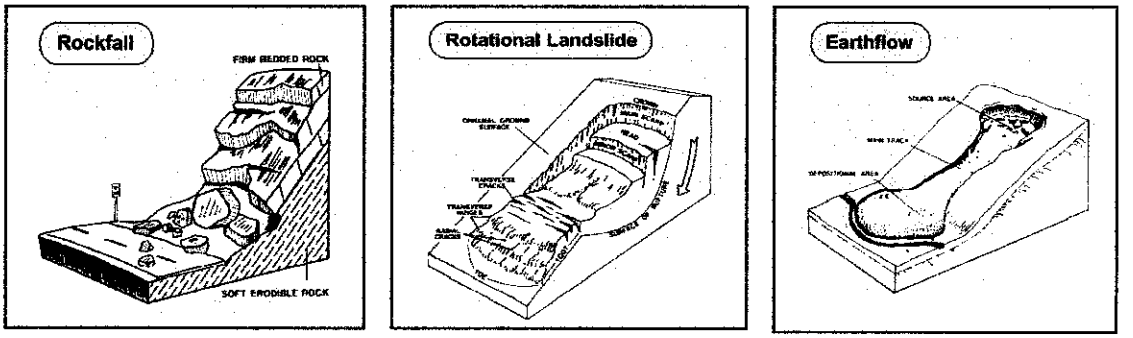

Figure (3): Types of landslides [2]

2.3 Digital Elevation Model (DEM)

DEM files are used to generate graphics such as isometric projections displaying slope, direction of slope, and terrain profiles between designated points. They may also be combined with other data types such as stream locations and weather data to plan forest fire control, or with remote sensing data to classify vegetation [3].

2.3.1 DEM derivatives: Slope

Slope is defined by a plane tangent to a topographic surface, as modeled by the DEM at a point. Slope is classified as a vector; as such it has a quantity (gradient) and a direction (aspect). Slope gradient is defined as the maximum rate of change in altitude (tan θ), while slope aspect (ψ) was described as the compass direction of this maximum rate of change (FIGURE 4). Analytically, slope gradient at a point is the first derivative of elevation (Z) with respect of the slope (S), where S is in the aspect direction (ψ). At the same time the first derivative of a function at a point can be defined as the slope (angular coefficient or trigonometric tangent) of the tangent to the function on that particular point, hence [3]:

$$\tan\theta = \text{rise/run} = \partial Z/\partial S$$

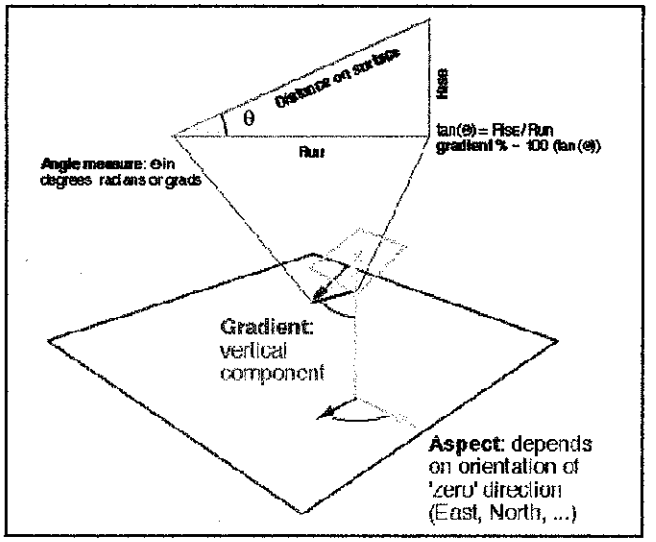

FIGURE (4): Slope components [3]

The technique or algorithm adopted to calculate slope gradient and aspect varies according to the type of DEM selected to model the topography. Models for structuring elevation database can be square-grid, TIN (triangular irregular network), and contour-based ones [2].

2.4 Factors Contributing to Landslide Potential

Factors which contribute to landslide potential of an area may be divided into natural factors and human factors [2]. Natural factors most often cited in the literature are material type and thickness, geomorphology, precipitation, and undercutting of slopes. Human factors include modification of slopes, overloading slope tops, modification of drainage, and removal of vegetation

2.4.1 Natural Factors

a) Material type and thickness

Landslides and mass movements of all types tend to occur in geological materials that are poorly consolidated (loosely packed) and fine grained in texture. Investigations of earth flows show that they occur in a variety of grain sizes: sand, silt, and clay [2]. Silt and clay predominated, as these materials tend to be of lower strength and more easily deformable than coarser materials. Sediment thickness or overburden thickness is a significant factor in determining slide potential. Increasing thickness of the unit or overlying units will contribute in increasing load. Failure occurs when this load exceeds the internal strength of the material.

b) Geomorphology

Slides occur where there is a steep slope on an unconfined face in material of low strength. Where there is a more gradual slope, more weight at the base of the slope helps to confine the pressure at depth. In the case of the Rockland slides, failure at the base of a relatively steep slope where pressure was not constrained by weight of slope material. However, some of the more fluid types of slides can be initiated on remarkably gentle slopes of 7% [3]. Larger rotational slides typically require at least a 12% slope for initiation. More typically, slides require slopes of at least 15% to 25% for initiation of movement.

c) Precipitation

Almost universal in the literature is the recognition that precipitation can play a significant role in initiation of landslides. Heavy winter precipitation, severe late winter and early spring rains, and rapid spring thaws resulting in loss of soil strength and additional water in the system all present landslide problems. Additional water in the system affects the stability in two ways. First, the weight of the water is an additional load on the materials in the system: second, the pore pressure increases with the additional water and reduces the strength of the material. Once strength is reduced, gravitational forces exceed the friction force thus slope failure begins.

2.4.2 Human Factors

a) Modification of slopes.

Oversteepening and undercutting of slopes are common in road and facilities engineering, or landscaping construction. Undercutting of slopes commonly occurs to provide more flat space for buildings or roadways. This practice removes lateral support and undermines the slope, leading to landslides in many areas [2]. Oversteepening of slopes can occur as fill is used to extend flat areas near tops of slopes.

b) Overloading slope tops

The weight of fill and structures on top of a slope places additional load on the materials below. If this additional load causes the total load to exceed the strength of the material, then slide may occur.

c) Modification of drainage

Factors include leaking water and sewer lines, poorly drained roads, septic systems, landscape watering, seepage from reservoirs are some of the examples of drain modifications. These modifications can result in additional load from water weight and reduction in material strength through increased pore pressure.

d) Removal of vegetation.

Plant roots stabilize slopes by binding soil particles. Vegetation and roots also slow runoff, thereby reducing gullying and the removal of soil. Evapotranspiration by vegetation can also reduce pore pressure at some times of year by removing ground water. Thus, removal of vegetation can promote slope instability. However, it is only the upper part of the section of soil that is stabilized by vegetation. Moreover, in the case of large trees, there is both reinforcement of the slope by tree roots and extra loading on the slope by the force of wind on the branches. The net effect suggests that shrubs are superior to trees for slope stabilization, or that removing large trees will actually increase slope stability somewhat.

2.5 Integrating GIS-based Landslide Hazard Assessment

Expansion of urban and recreational development into unstable potential landslide area increases the number of residential and commercial properties threatened by the risk of landslides. Preliminary detection of potentially unstable area was initiated during the early stage of project development planning. Application of Geographic Information System (GIS) in initiating early assessment of landslide prone area could save valuable time, cost and effort, considering also enhance technology that have been develop for the purpose of data capture were available to replace conventional qualitative method. GIS-based assessment is a quantitative method that simplified the task of data collection, representation, storage, retrieval and update, for the purpose to judge disaster mitigation and preparation [1].

2.5.1 Preparation of inventory and parameter

Several spatial data layers or landslide conditioning parameters are necessary for evaluation, together with the landslide inventory. GIS techniques provide a powerful tool for processing and integrating such amount of spatial data when combining or performing analysis on these layers. Certain factors have been evaluated for the assessment where these factors are believed to have potential for landslide occurrence.

Four (4) known factors have been identified and integrated for the database [2]:

a) Slope angle

Measurements of changes in elevation over a measured distance proceed with calculating the percentage of slope. Data was extracted from the topographical map.

b) Slope aspect

Determination of slope direction with respect to the bearing orientation. Data was derived from the topographical map.

c) Geological characteristic

Indication of subsurface rock formation. Data was captured from the geological raster map of the site.

d) Normalized difference vegetation index

Gradient of vegetation density covering the area. Data was extracted from satellite image.

2.5.2 Risk Weight allocation

Level of hazard was assigned for respective factors since these data would vary on the degree of landslide hazard influence to the site [7]. Weight applied to the risk factors varied base on how much influence these factors responded to the scenario. Integrating and overlapping these factors would evaluate cumulative risk assessment for particular point covering the whole area, hence producing the allocation of hazard risk. Analytical Hierarchy Process (AHP) method that complies with logical reasoning was applied to solve the matter [8].

2.5.2.1 Pairwise comparison

Justifications of priorities are simplified by incorporating less precise way of expressing judgments, such as words instead of numbers. Words are used instead of numbers in order to indicate or express judgments, since words are easier to justify than numbers.

The Analytical Hierarchy Process (AHP) is based on criteria that are measured on a ratio scale. In AHP the decision maker has to make a comparison for every pair of criteria: first qualitative and then quantitative on a scale from (1) to (9) to make the method operational.

This scale is presented here in FIGURE (5) for a binary relation:

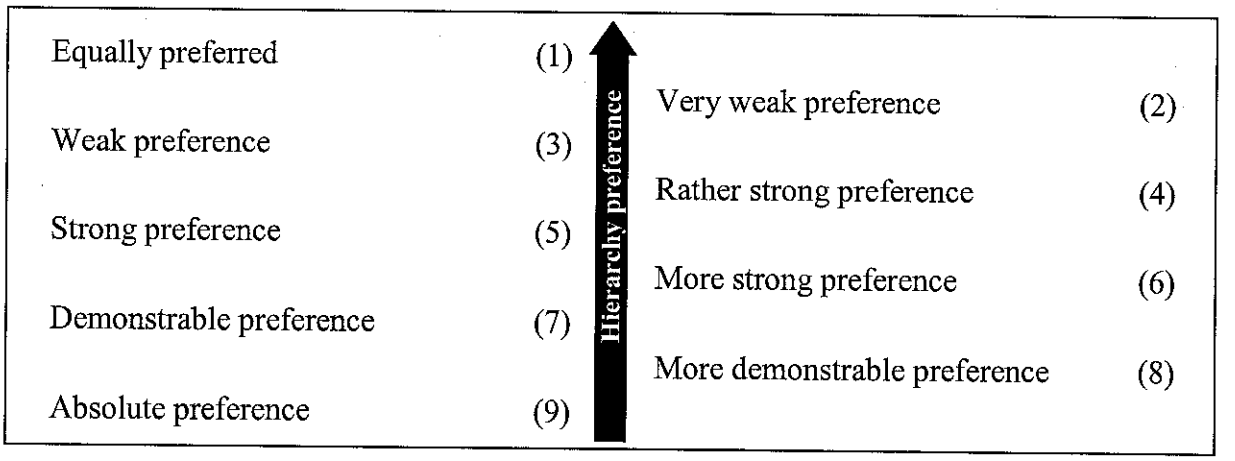

FIGURE (5): Hierarchy preference scale indication [9]

The method then creates a matrix containing the pairwise comparison judgments for the criteria, from which a priority vector is derived of relative weights for these elements. Moreover, due to the fact that a lot of information is retrieved from the decision maker, the method can deliver an inconsistency measure. This measure can be used to verify in what measure the judgments supplied are consistent. The decision maker is totally consistent if for all sets of criteria, the relationship among them holds. AHP is especially designed to assess weights within a hierarchical structure of the criteria. However, due to the fast-growing number of pairwise comparisons it is not sensible to use the method for a large set of criteria.

2.5.2.2 Spatial Reasoning approach

Spatial reasoning is one of the methods to evaluate such assessment, which concerned on cognitive, computational and formal aspects of making logical inferences about a spatial environment. Integrating spatial data with GIS program require the user to express their knowledge in such a way that the program can interpret effectively. Since our knowledge of spatial geographic environment is considered imperfect, thus the program should also able to operate under uncertainty. Computational spatial reasoning concerned with integrating and applying the approach into the computational devices [7].

- **Fundamentals**

Relevant data was gathered prior to perform analysis hence spatial cognition is considered an important research topic, which focuses on cognitive aspects of spatial reasoning relevant to the study. The idea of implementing the reasoning technique was to develop significant, reliable and logic expression of data qualitative assessment [7]. Potential approaches are derived as follow:

Syllogism

- A form of reasoning in which a conclusion is drawn from two given or assumed propositions (premises); a common or middle term is present in the two premises but not in the conclusion, which may be invalid.
- Example:

	Low vegetation contribute to landslide
+	High runoff water contribute to landslide
	Both factors contribute to landslide

FIGURE (6): Particular deduction technique

Syntactic analysis

- Focus on terms used in the data statement; consist of proper noun (subject), verb, and spatial preposition. Denotional view of the meaning of statement (semantics) is determined by referring to the domain entity. Hence, relevant data input must have been denoted first before emphasizing on the complex preposition of the data structure.

Evaluations of available premises (facts and rules) are subjected to the knowledge of the user, whereby the theory associated to the knowledge is refer to the conclusions extracted from its premises, using the rules of deduction. Thus, by introducing more premises for the analysis enhances more reliable conclusions.

Both provable preposition (theory) and facts have to be related in satisfying the concept of reliable knowledge base reasoning approach; Soundness and Completeness.

- **Application in GIS**

Integrating the means of the knowledge base on logical reasoning will contribute to the logical assessment of data acquired. The methodology is simplified in the illustration represented via FIGURE (7):

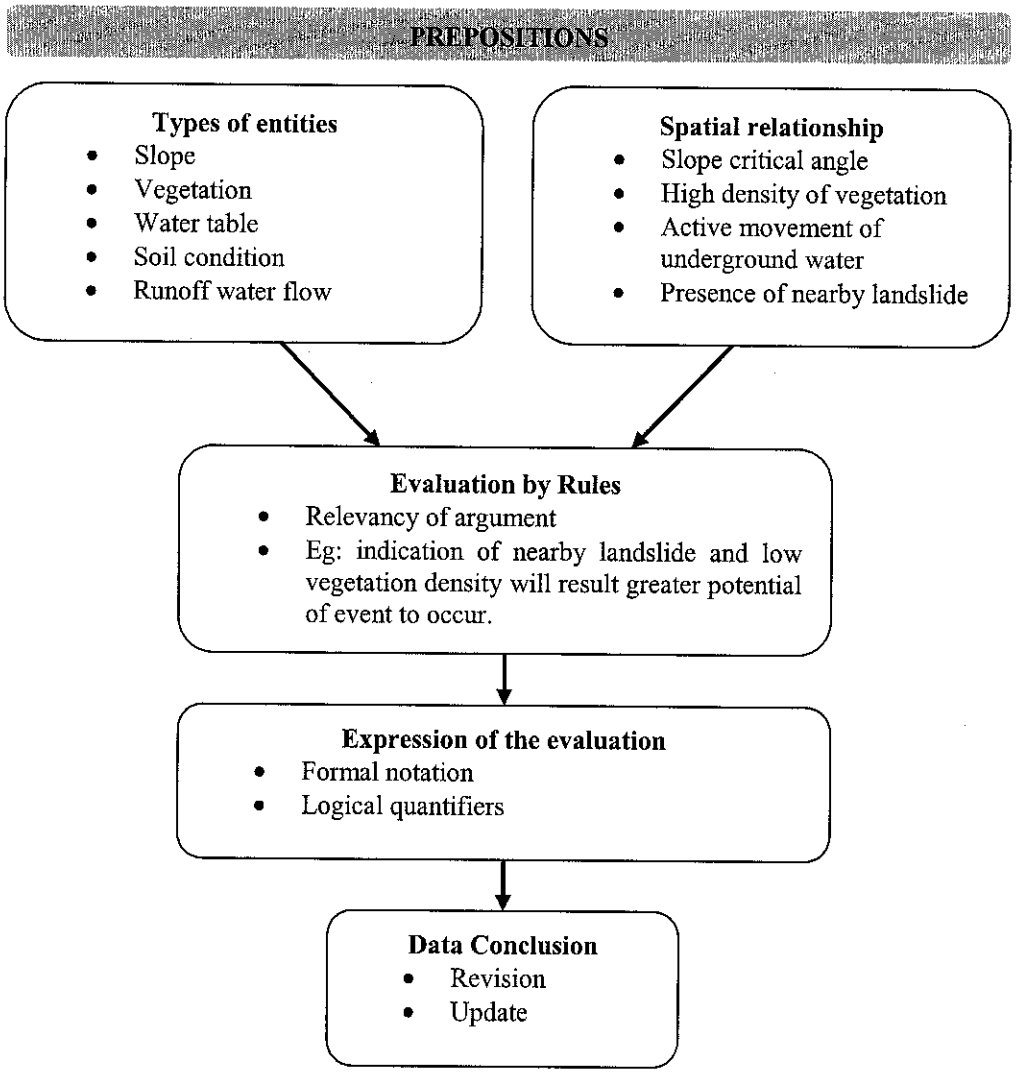

FIGURE (7): Spatial reasoning approach [7]

2.6 Georeferencing

Georeference defines the relation between rows and columns in a raster map and XY-coordinates. The location of pixels in a raster map is thus defined by a georeference. It is advised that raster maps of the same area use the same georeference. A georeference uses a coordinate system which may contain projection information. Georeference is a service object, usually for several raster maps.

There are five (5) main types of georeference [1]:

a) Georeference corners

A North-oriented georeference to be used during rasterization of vector data or as the North-oriented georeference to which you want to resample maps.

b) Georeference tiepoints

A non-North-oriented georeference to add coordinates to a satellite image or to a scanned photograph, a scanned map, etc. without using a DTM.

c) Georeference direct linear

Adding coordinates to a scanned photograph while using a DTM.

d) Georeference orthophoto

Adding coordinates to a scanned aerial photograph while using a DTM and camera parameters.

e) Georeference 3D

Generating a three dimensional view of maps.

CHAPTER 3

METHODOLOGY

The project required geological and topological data of an area thus determining ideal specific location to meet the purpose was necessary. Data was acquired from relevant parties before further deciphered into the GIS database. These data involves interpretation of satellite images, topological map and in-situ geological characteristics.

Selection of the parameters mostly depends on certain factors of concern, such as availability of the data, quality of the data and scale of the work scope. Preparing the susceptibility map for the site can be concluded in FIGURE (8) below:

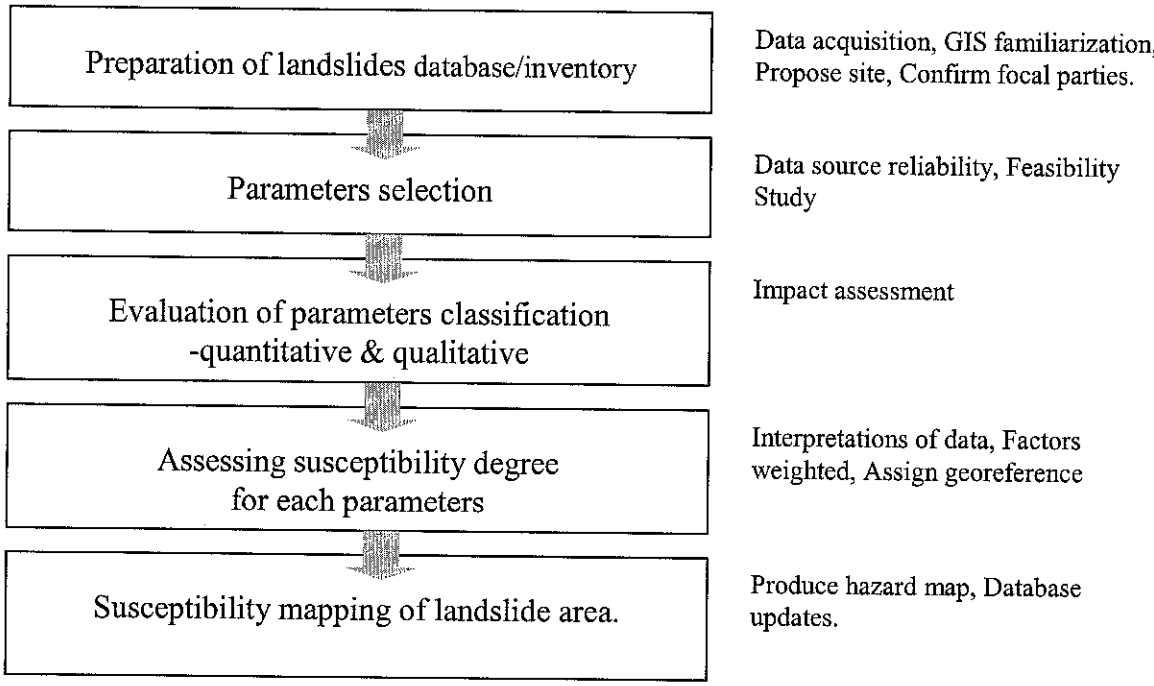

FIGURE (8): Brief methodology for project execution

3.1 Development process

Hazard assessment considered both physical and social vulnerability of potential loss of properties or life, from natural or technological hazard. Utilizing Geographic Information System (GIS) enables people to perform analysis in achieving multi-hazard information to improve mitigation planning. Hence, collection of appropriate and relevant data was performed for the specific location or study area.

3.1.1 Data Collection

Determining the characteristics of the areas exposed to landslides can provide useful information for identifying future landslide occurrences. Several spatial data layers, or potential landslide conditioning parameters, are essential for further evaluation, together with the landslide inventory. Since such amount of spatial data required, GIS techniques provide powerful tool for processing and integrating large amounts of spatial data when combining series of analyses on these layers.

Landslide inventory mapping and database was prepared to be as detailed as possible and data included should be reliable, which include whenever necessary, extensive field work, visual observations and recording and satellite image interpretations of the site. Considering macro analysis of site, moderate precision of evaluation based on available data interpretation are to be considered.

Potential factors of evaluating some value to the potential risks of landslide event are selected and analyzed. Raw data such as topographical map and satellite images were then analyzed and interpreted, applying the knowledge of spatial reasoning to distinguish the landslide prone area. Factors contributing to landslide occurrence that have been considered in the study are summarized in FIGURE (9).

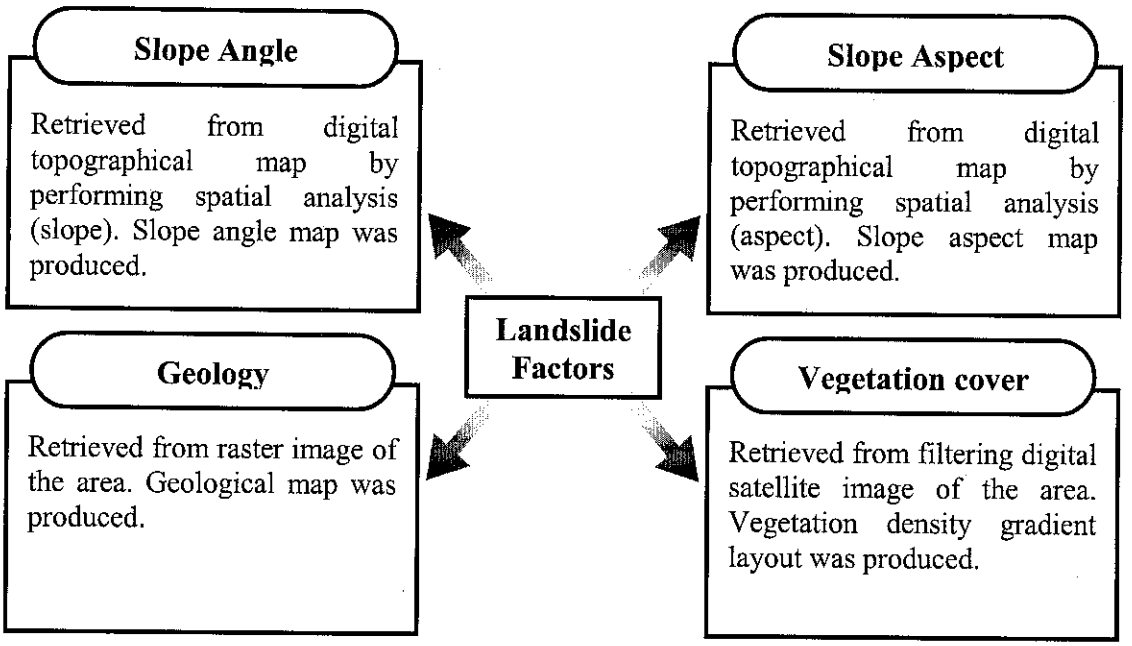

FIGURE (9): Identified parameter contributing to landslide occurrence

3.1.2 Data Analysis

Three (3) main inputs were identified as raw sources to be analyzed in order to generate the required parameter of the study. These are the topographical map, the satellite image and the geological attributes of the site. Analyzing the input enable four (4) themes developed through specific analysis is summarized in FIGURE (10).

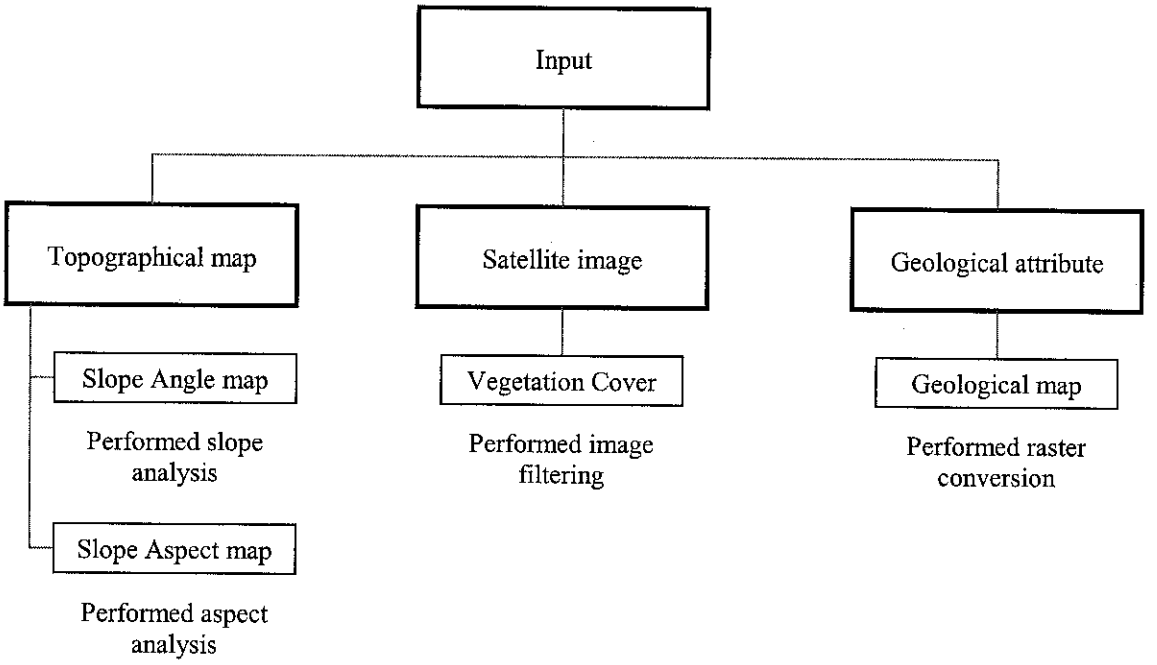

FIGURE (10): Input and output parameter of the analysis

Detail step by step procedures handling the program in order to execute the analysis are attached in Appendix (1).

3.1.3 Data Overlaying

GIS utilized layers, known as themes, to overlay different types of information, much as some static maps use arbitrary formation overlays to add tiers of information to a geographic background. Each theme represents a category of information, such as roads or vegetation cover. As with the conventional Mylar (arbitrary formation) maps, the layers which are underneath remain visible while additional themes are placed above. Thus, by applying GIS software, respective data were plotted on the themes and these themes were overlapped to generate the landslide susceptibility map. The concept of data overlaying is illustrated in FIGURE (11).

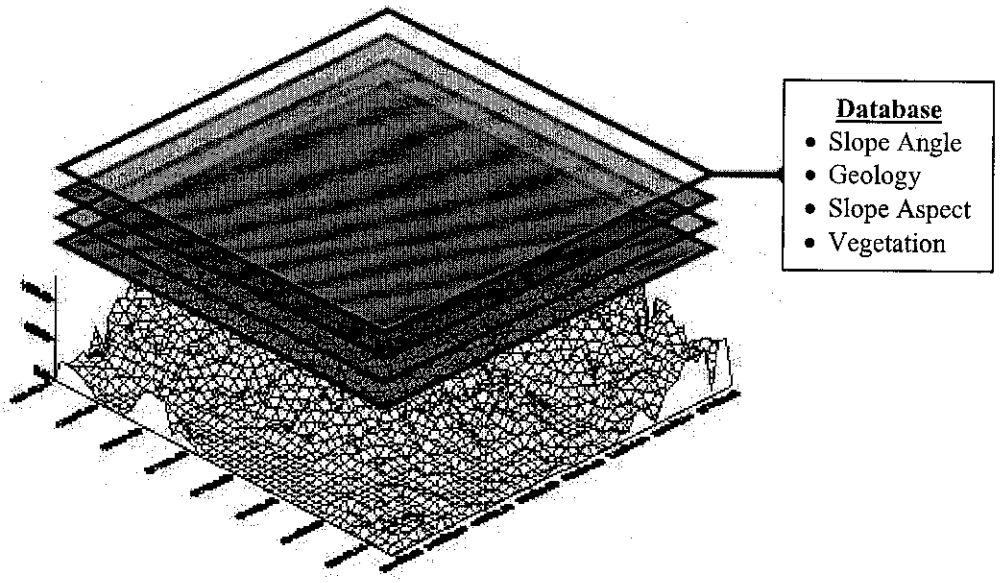

FIGURE (11): Data overlapping and integration

Georeferencing for each layer was assigned in order to overlap these themes accordingly, utilizing the Georeference tiepoints, which is applicable to add coordinate reference to a satellite image or to a scanned photograph without using a Digital Terrain Model.

Detailed step by step procedures of handling the program in order to execute the analysis are attached in Appendix (2).

3.1.4 Hazard Map representation

Themes were layered or stacked using GIS software, thus generating gradient base susceptibility map. Digital database enable users to perform efficient data retrieval and necessary updates with reasonable cost, high reliability and sustainability. These planned procedures are summarized in FIGURE (12).

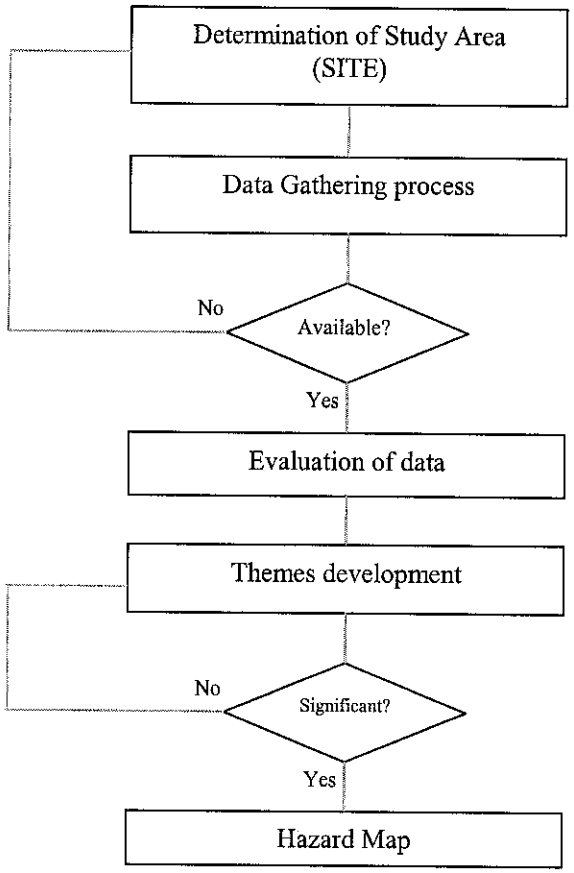

FIGURE (12): Process flow chart diagram

3.2 Tools and Equipment

Tools and equipments used in order to complete the project are as follows:

a) Window© base PC

b) Raw data

   i. Topographic map retrieved from JUPEM digital map (block no. 3661a)

   ii. Satellite image retrieved from PETRONAS PIRI GIS database

   iii. Geological map retrieved from MACGDI GIS database

c) Data conversion program

   i. DEM conversion program

      - Dxf2xyz 2.0©; available freeware retrieved form the internet

   ii. Surfer 6.0; illustrated 3-D model of the site

d) Spatial analysis and database program

   i. ArcView 8.0©; extracts the DEM thus further generates the Slope Angle and Slope Aspect themes.

   ii. ILWIS 3.3 Academic©; as the platform to store the database.

   ILWIS for Windows© is a Windows-based, integrated GIS and Remote Sensing application consisting of:

   a) Display of raster and multiple vector maps in map windows

   b) Display of tables in table windows

   c) Interactive retrieval of attribute information

   d) Image processing facilities

   e) Manipulation of maps in a Map Calculator

   f) Manipulation of tables in a Table Calculator

   g) GIS analysis tools

3.3 Budget Allocation

In order to complete the project, RM 250 per semester was provided, with a total overall budget of RM500 for the project. Proposed budget allocation has covered the following:

1. Data/Information relevancy.
    - Required data need to be bought from agencies/providers.

2. Transportation
    - Requires traveling for site survey.

CHAPTER 4

RESULTS AND DISCUSSION

Scope of findings and discussion were entitled to; (1) Study Area, (2) Themes Development and (3) Database interpretation.

4.1 Study Area

As per evaluation, the propose location for the site was selected at Gua Tempurung hillside area, district of Perak Tengah, Perak, Malaysia. The site is potential to be developed further and was chosen due to previous historical background where a landslide event had occurred in October, 2004. In considering these criteria, the particular area was selected for the project. The location of the site is illustrated in FIGURE (13).

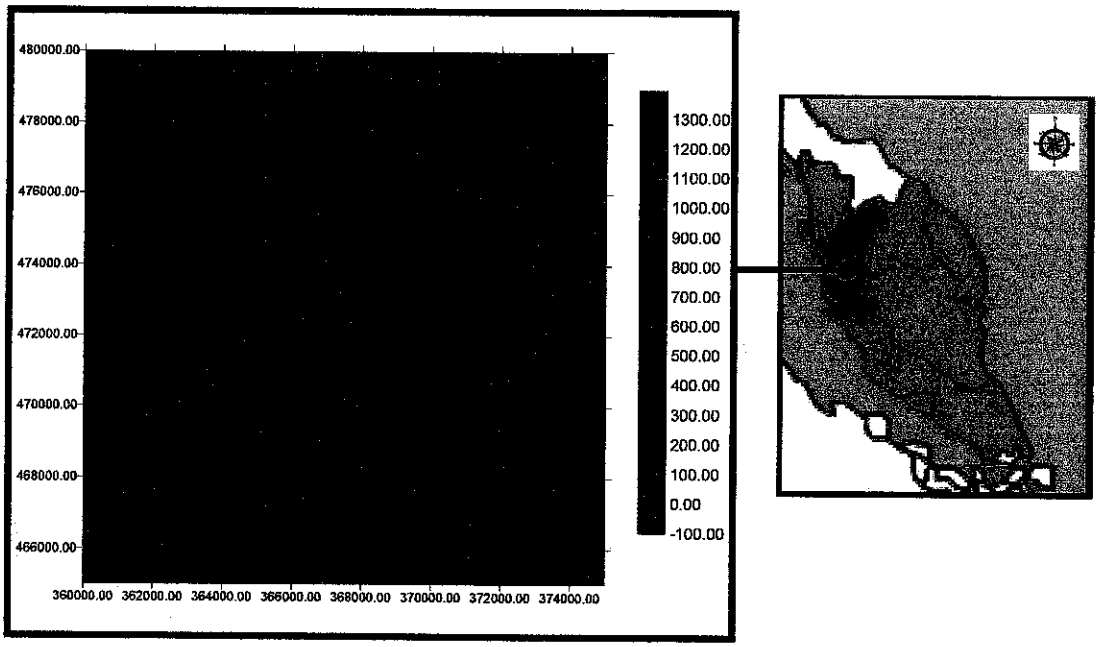

FIGURE (13): Location of SITE topographic map
(Modified from 3661a.dxf/JUPEM 2003 Topographic data)

Digital elevation and positioning data extracted and photograph taken at the site are illustrated in Appendix (3).

4.2 Themes Development

Four (4) themes were successfully developed for the GIS platform prior to landslide hazard assessments. Slope angle, Slope aspects, Geological map and Vegetation cover layer have been successfully generated.

a) Slope Angle map

Slope identifies the steepest downhill slope for a location on a surface. Applying the Slope Analysis command in ArcMap© enabled an input surface raster and calculates an output raster containing the slope at each grid. The lower the slope value, the flatter the terrain and vice versa, the higher the slope value thus indicate steeper unstable terrain. The output slope raster can be calculated as percent slope or degree of slope. Slope map of the area is illustrated in FIGURE (14).

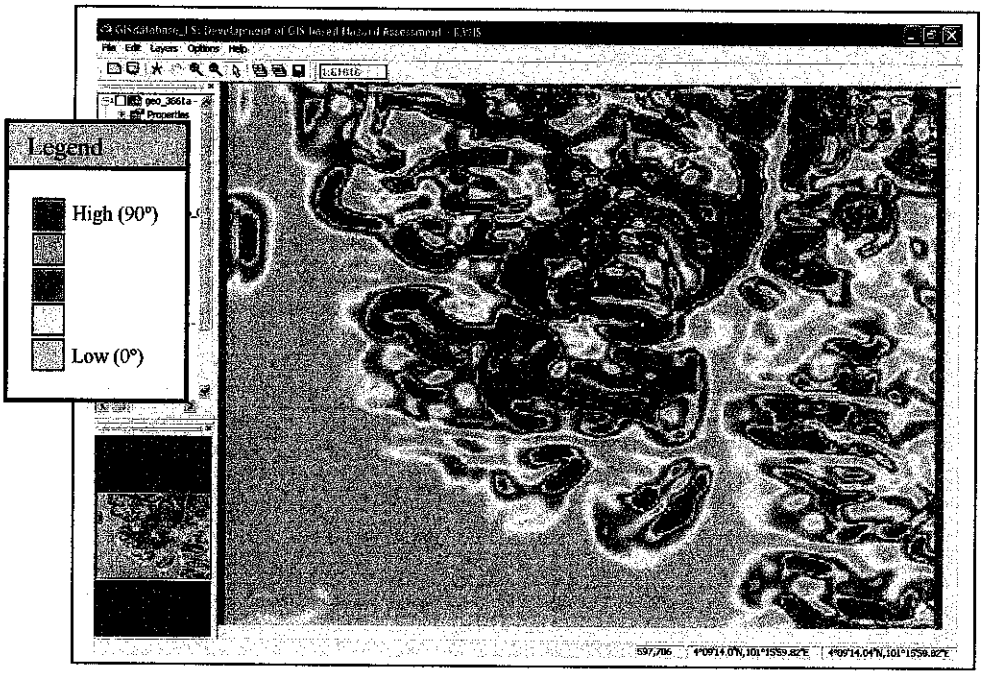

FIGURE (14): Generated slope map of the SITE

b) Geological map

The structure and strength of foundation also contribute to the susceptible hazard triggering the landslide. Hence, incorporating the factor into the database would likely support the theory that the strength of soil structure was strongly influenced by the mineralogy and physical characteristic of the grain particles. For instance, limestone foundation would be considered unstable due to the fact that it reacts with acid and have the probability to generate sinkhole. Interaction of slippery soil to different adjacent soil, for example clay to intrusive rock, would cause instability to the adhesive contact of both geological properties. Geological map of the area is illustrated in FIGURE (15).

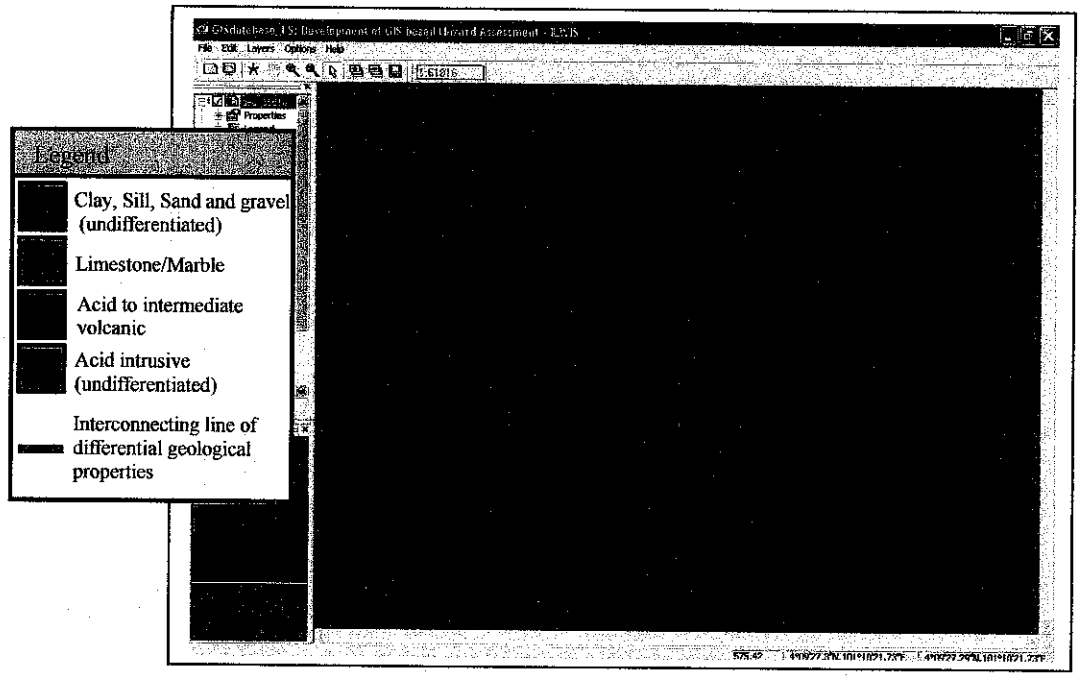

FIGURE (15): Geological map of the SITE

c) Vegetation Cover map

Presence of vegetation in particular location reduces the risk of landslide occurrence due to the fact that trees provide external support to the soil and protection against direct impact of weathering agent, thus reducing the frequency of weathering process. Vegetation cover are presented in FIGURE (16).

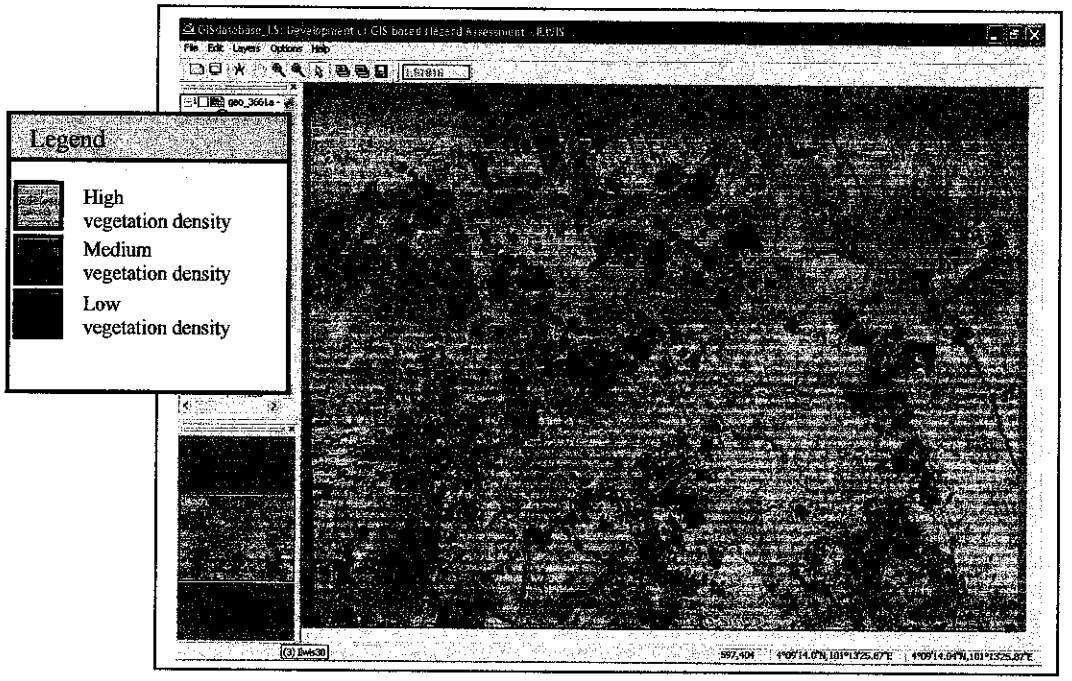

FIGURE (16): Vegetation cover of the SITE

d) Slope Aspect map

Direction of the slope affected the flow of runoff and groundwater on particular location. Exposures of the plane to surrounding (nature) also contribute as susceptibility factor to the hazard. Slope Aspect map is presented in FIGURE (17).

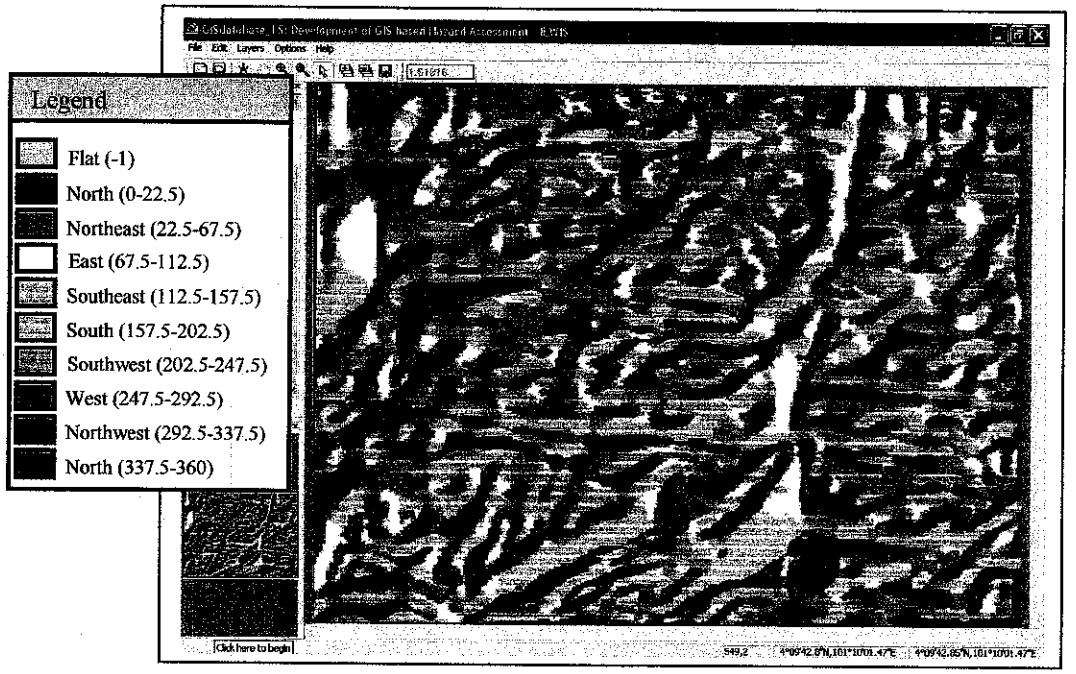

FIGURE (17): Generated slope aspect map of the SITE

4.3 Database Interpretation

Themes were then overlaid and assigned weight prior to their contribution to hazard susceptibility. Summation of weight maps was then performed in order to generate the landslide hazard assessment layout. Through knowledge and consultation performing the reasoning approach to these contributing parameters, themes are weighted and prioritized by means of hierarchy preference. Results are tabulated in TABLE (1).

TABLE (1): Factor contribution weight allocation to potential landslide through AHP method.

Factor	Angle	Geology	Vegetation	Aspect	Mean
Angle	1.000	2.000	6.000	7.000	3.750
Geology	0.500	1.000	4.000	8.000	3.375
Vegetation	0.200	0.250	1.000	3.000	1.113
Aspect	0.143	0.125	0.333	1.000	0.400
Sum	1.843	3.375	10.333	19.000	8.638

Factor	Angle	Geology	Vegetation	Aspect	**Weight**
Angle	0.543	0.593	0.484	0.368	**0.497**
Geology	0.271	0.296	0.387	0.421	**0.344**
Vegetation	0.109	0.074	0.097	0.158	**0.109**
Aspect	0.078	0.037	0.032	0.053	**0.050**
Sum	1.000	1.000	1.000	1.000	1.000

Through the reasoning and analysis, it is concluded that Slope Angle contributed the most hazard influenced (49.7%) followed by Geology (34.4%), Vegetation (10.9%) and Aspect (5%). Since both Angle and Geology contributed much to the landslide influence, these themes are considered as major contributing factor, and further concluded that both Vegetation and Aspect are the minor factor.

Overlapping both critical Angle and Geology in the database would definitely indicate the location of severe (high) landslide prone area.

Slope Angle and Geological map of the site are overlaid to indicate the prone landslide potential hazard location illustrated in FIGURE (18).

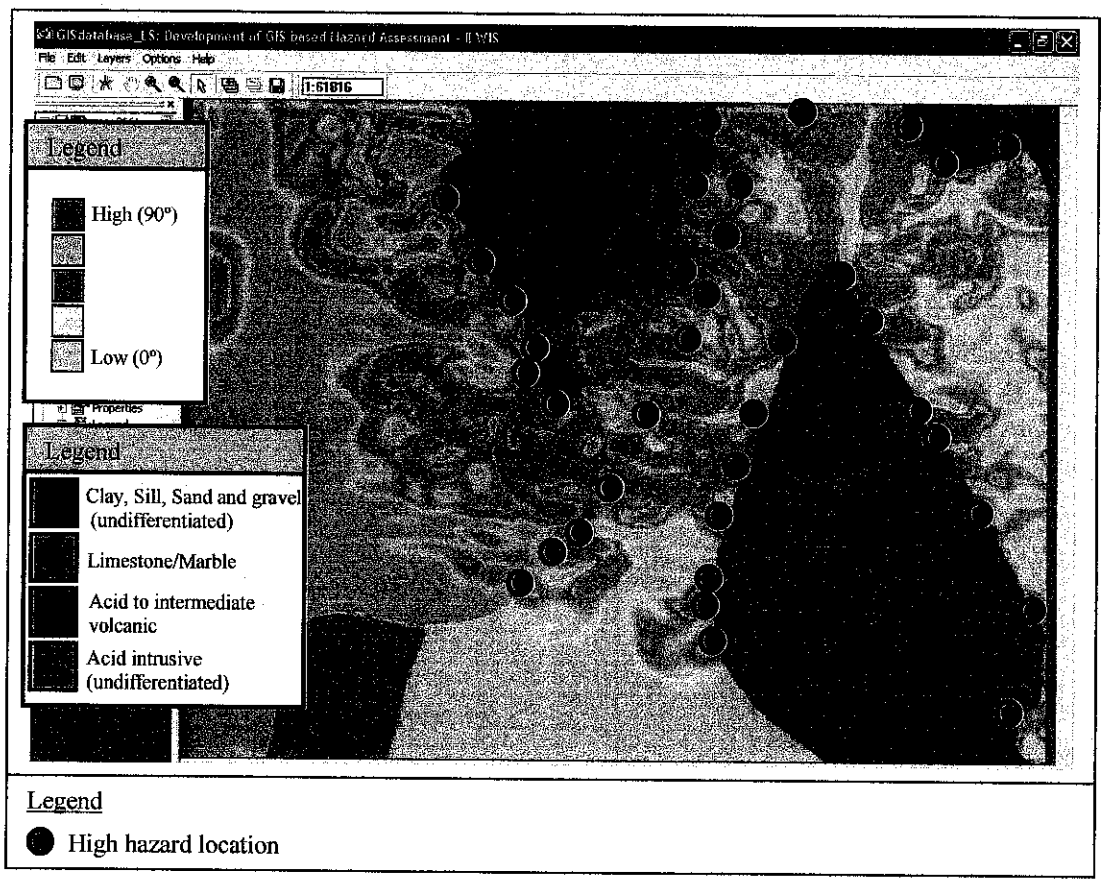

FIGURE (18): Potential hazard representation of the SITE through data overlaying; overlapping Slope Angle and Geological factor.

Further rectification and verification of the landslide hazard need to be conducted in these particular coordinate listed in TABLE (2).

TABLE (2): Landslide hazard potential point coordinate of the SITE.

Coordinates	
Latitude	Longitude
4° 14'48.50"N	101° 14'44.03"E
4° 14'34.30"N	101° 14'30.78"E
4° 14'32.1"N	101° 14'30.15"E
4° 14'21.7"N	101° 14'26.98"E
4° 14'08.9"N	101° 14'22.59"E
4° 13'55.90"N	101° 14'19.72"E
4° 13'41.90"N	101° 14'14.47"E
4° 13'25.00"N	101° 14'09.68"E
4° 13'01.95"N	101° 14'01.12"E
4° 12'54.50"N	101° 13'57.95"E
4° 12'24.36"N	101° 13'44.09"E
4° 12'05.60"N	101° 13'36.05"E
4° 11'58.30"N	101° 13'32.03"E
4° 11'45.14"N	101° 13'25.66"E
4° 11'15.67"N	101° 13'09.47"E
4° 11'03.43"N	101° 12'57.56"E
4° 10'49.75"N	101° 12'44.30"E
4° 10'44.27"N	101° 12'39.08"E
4° 10'14.77"N	101° 14'12.95"E
4° 10'27.04"N	101° 14'10.17"E
4° 12'56.62"N	101° 14'43.51"E
4° 14'24.55"N	101° 11'57.66"E

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The Hazard map allocate potential landslide risk point in the study area thus reducing the scope of conducting thorough soil investigation in-situ, by pin-pointing certain particular location or area of interest. Each phase of project developments requires a lot of effort, time and efficient planning. Besides due to the tele–working condition of data gathering from respective resources, the complexity of the project is defined at moderate to high level whereby certain area need to be clarify and justify. Top processes of the project need to be clear especially in the definitions of requirements and knowledge on feasibility studies on data captured. Execution of the project would be appreciated if the concept can be digested in the real-time hazard management studies. In addition, to be able to cooperate along with lecturers, relevant parties and seniors would provide handful experience of throughout the project progress. Conclusively, to have the project finished within timeframe, effective results and gaining experiences are goals to achieve at the end of the project working horizon.

5.2 Recommendation

Further evaluation and verification of the generated Hazard map need to be clarified due to the fact that the database serve as a guide positioning platform in order to indicate potential landslide prone area. Onsite testing such as resistivity testing, surveying and soil investigation can be further conducted in order to rectify the fundamental theory and assumption prior to mitigation planning

Prior to site development, the database needs to be updated in order to produce feasible landslide hazard indication of the study area. More potential themes related to landslide prediction could be assessed in order to generate a more reliable hazard map.

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APPENDIX

APPENDIX (1) : Step by step illustration performing the analysis

- Slope Angle and Slope Aspect

APPENDIX (2) : Adding layers (themes) in GIS programming

APPENDIX (3) : Relevant details on study area (SITE)

- Photographs taken at site
- XYZ positioning of 3661a (SITE)

  -Extracted from JUPEM digital topographic map

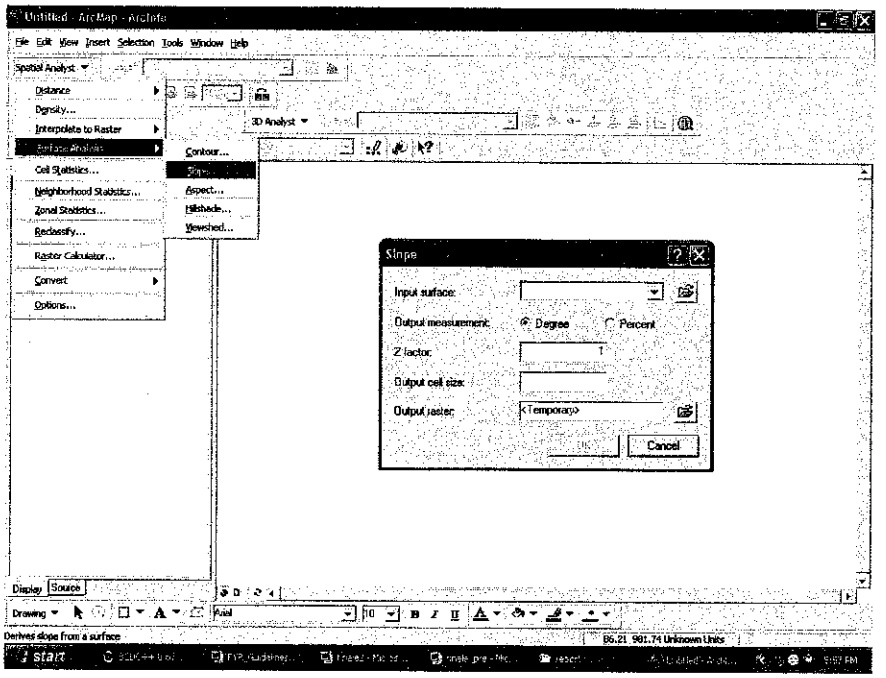
Appendix (1)

1) Slope Angle analysis

The *Slope* function enables the user to create a slope raster for an entire area, enabling the interpreter to get an impression of the steepness of the terrain and to use the output for further analysis.

Procedures:

1. Click the Spatial Analyst dropdown arrow, point to Surface Analysis, and click '*Slope*'.
2. Click the Input surface dropdown arrow and click the surface intended to be measured.
3. Choose the Output measurement units.
4. Optionally, type a value for the Z factor.
5. Optionally, change the default Output cell size.
6. Specify a name for the output or leave the default to create a temporary dataset in your working directory.
7. Click "*OK*".



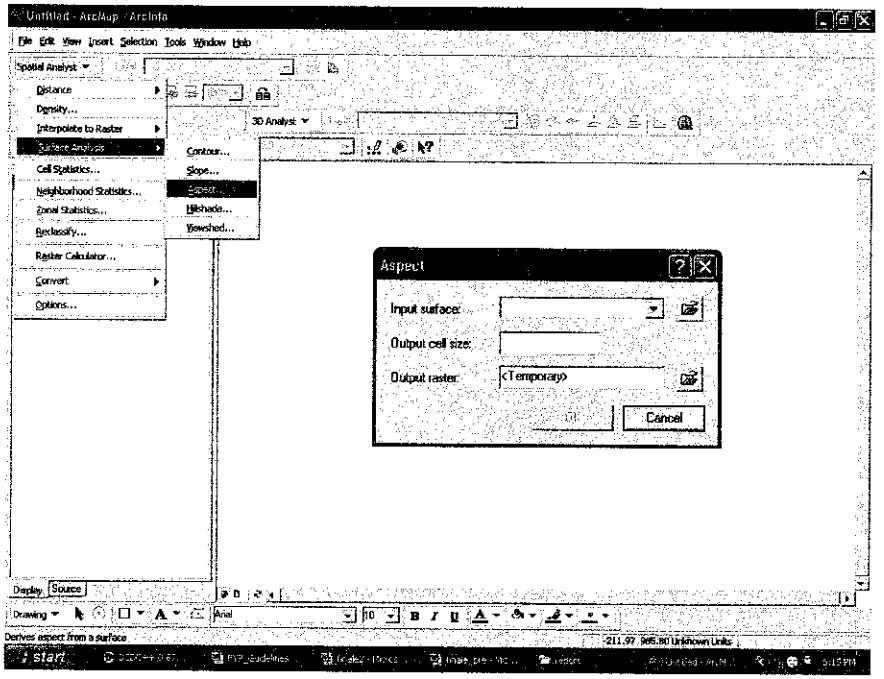
ArcMap© 8.1: Generating Slope Angle analysis method Illustration:

2) Slope Aspect analysis

The *Aspect* function enables you to create a map displaying the steepest downslope direction from each cell to its neighbors for an entire region. It is most commonly used with an elevation raster to identify the direction of slope.

Procedures:

1. Click the Spatial Analyst dropdown arrow, point to Surface Analysis, and click '*Aspect*'.
2. Click the Input surface dropdown arrow and click the surface for which the user want to calculate aspect.
3. Optionally, change the default Output cell size.
4. Specify a name for the output or leave the default to create a temporary dataset in your working directory.
5. Click '*OK*'



ArcMap© 8.1: Generating Slope Aspect analysis method Illustration:

Appendix (2)

1) To add extra layers to a map window:

   i. From the Layers menu, choose '*Add Layer*'

   ii. In the white space of the '*Layer Management*' pane of a map window, click the right mouse button, and choose '*Add Layer*', '*Add Grid Lines*', or '*Add Graticule*' from the context-sensitive menu,

   iii. Click the '*Add Layer'* button in the toolbar of the map window,

   iv. Press the '*Insert*' key on the keyboard when a map window is active,

   v. Drag one or more point, segment, or polygon maps, a raster map, a map list, or annotation text objects from a Catalog or from Windows Explorer to an existing map window.

2) To remove layers from a map window:

   In the '*Layer Management'* pane in a map window:

   i. Select a layer to be removed, and click the '*Remove Layer'* button in the toolbar of the map window, or

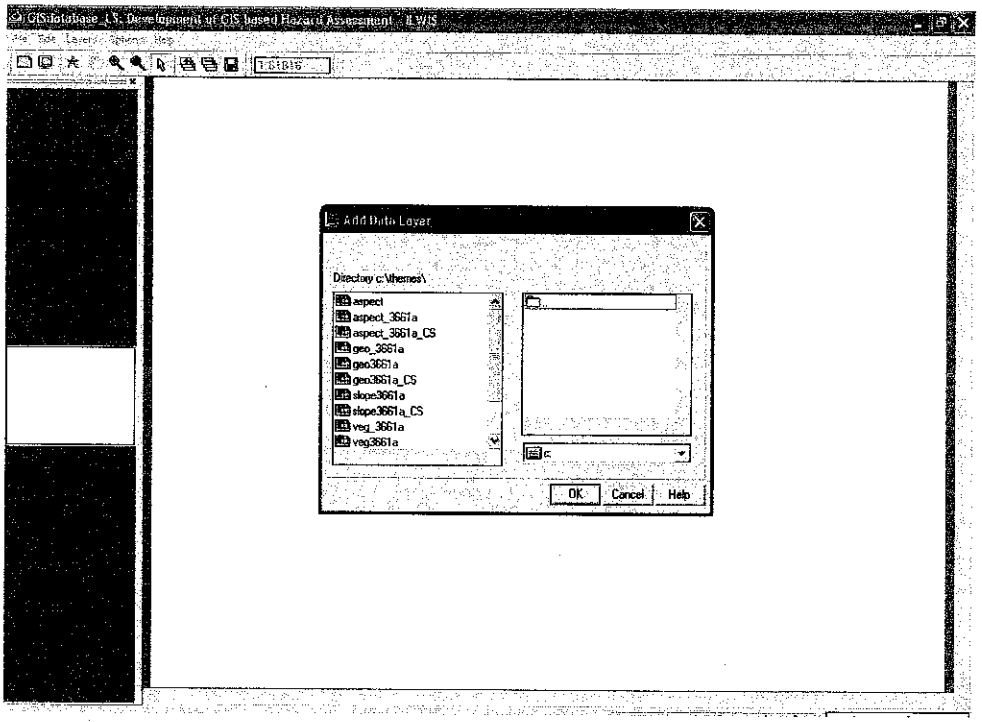
   ii. Click the layer to be removed with the right mouse button, and choose '*Remove Layer*' from the context-sensitive menu.

3) To hide or show a layer in a map window:

   In the '*Layer Management'* pane in a map window:

   i. Click the check box to hide a layer, or

   ii. Click the check box to show a layer.



ILWIS 3.3©: GIS development: Add layer (themes) illustration

Appendix (3)

SITE photographs:

Figure (a): Peak of the contour at SITE

Figure (b): Steep slope approximately 45° angle at SITE

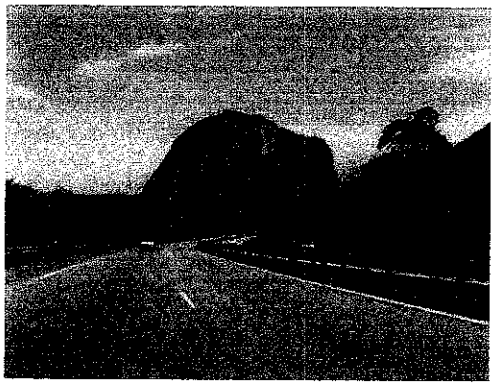


Figure (c): Limestone hill at location

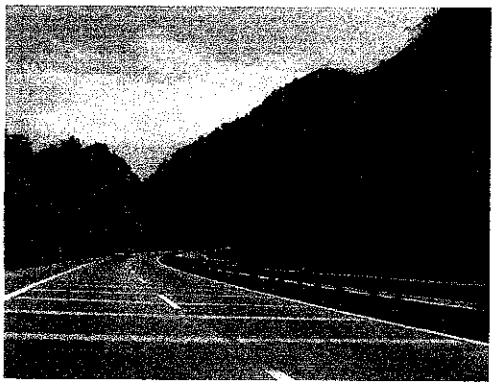


Figure (d): Modification of hill slope

Figure (e): Modification of hill slope

Figure (f): High slope (approximately 70°) sighted at location

SITE control points (X,Y,Z):

374979.7	480000	0
375000	480000	0
375000	479982.3	0
374869	480000	0
374979.7	480000	0
360000	466200	0
360000	466386	0
360000	466127	0
360000	466200	0
365400	465000	0
365313.8	465000	0
366665.9	465000	0
365400	465000	0
365243	465000	0
364312.1	465000	0
365282.4	465000	0
365243	465000	0
371302	480000	0
371338.1	480000	0
370963	480000	0
371302	480000	0
360000	470397	0
360000	470498	0
360000	470314.5	0
360000	470397	0
360000	470498	0
360000	470788	0
371338.1	480000	0
371359.2	480000	0
360000	473422	0
360000	473468.5	0
360000	473391	0
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360000	473632	0
360000	473816	0
360000	473468.5	0
360000	473632	0
360000	473242.5	0
360000	473391	0
360000	471740.5	0
360000	473242.5	0
360000	471515	0
360000	471740.5	0
360000	471385.7	0
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360000	469977	0
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363717.5	475131.9	0
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363697.3	474951.1	0
363696.8	474844.1	0
363693.1	474789.6	0
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364506.1	475508.5	0
364490.2	475415.9	0
364460.8	475299	0
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364269.8	474884.3	0
364209.8	474795.1	0
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366274	472500	0
366294.4	472520.7	0
366425.2	472609.4	0
366603.6	472738.8	0
366713.3	472807	0
366964.1	472945.8	0
367073.2	473492.4	0
366873.2	473760.2	0
366791.3	473894.3	0
366721.1	474121.6	0
366710.9	474300.3	0
366748.2	474439.2	0
366823.7	474657.7	0
366930.9	474840.3	0
366992.6	474919.9	0
367105	475091.4	0
367178.9	475234.3	0
367189.6	475335.2	0
367171.2	475396.3	0
367043.2	475473.6	0
366904.7	475559.6	0

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366525.9	475878.6	0	367524.1	470317.3	0
366350.7	476040.9	0	367500	470315.9	0
366300.2	476053.9	0	370212.7	465000	0
366200.1	475999.3	0	370223.9	465125.1	0
366098.7	475931	0	370480.4	465089.1	0
365991.4	475836	0	370523.3	465311.8	0
365871.8	475796.9	0	370529.2	465618.2	0
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365452.3	475782.8	0	370646.4	466302	0
365356.9	475714.4	0	370659.4	466478.8	0
365241.8	475714.5	0	370694.9	466762.5	0
365161.7	475717.5	0	370716.7	466986.3	0
365002.9	475737.1	0	370723.6	467168.3	0
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364817.2	475732.5	0	370788.8	467255.8	0
364739.7	475738.3	0	370941.3	467232.7	0
364681.9	475735.1	0	371074.9	467213.1	0
364598.5	475719	0	371157.1	467210.8	0
364561.5	475701.3	0	371200.1	467241	0
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369856.5	470247.1	0	371199.3	467618.7	0
369835.7	470363.4	0	371191.2	467745	0
369812.5	470463	0	371181.2	467865.8	0
369782.6	470518.7	0	371130	468069.9	0
369715.2	470558.9	0	370997.3	468280.3	0
369633.1	470521.1	0	370949	468356.8	0
369535.8	470449.2	0	370902.1	468444.2	0
369420.4	470423.4	0	370858.3	468521.4	0
369289.1	470410.7	0	370807.6	468596.5	0
369092.1	470397.8	0	370757.6	468632.5	0
368983	470385.7	0	370701.5	468589.8	0
368845.5	470380.9	0	370662.9	468482	0
368694.3	470379	0	370641.1	468448.2	0
368541.8	470366.3	0	370596.8	468369.2	0
368414.3	470365.8	0	370565.4	468330.1	0
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367741	470395.3	0	370406.3	468791.8	0
367677.8	470364.6	0	370413.9	468811.3	0

370442.7	468865.4	0	368344.4	467362.7	0
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368145.3	467544.7	0	368201.2	467485.3	0
368336.4	467620.5	0	368159.4	467535.7	0
368254.8	467779.6	0	366281.3	472500	0
368400.4	467859.5	0	366260.3	472474.7	0
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369487.3	467535.2	0	365266.4	472477.8	0
369466	467473.3	0	365177.1	472492.1	0
369463.8	467407.2	0	365164.5	472500	0
369496.4	467350.3	0	363451.5	471238	0
369491	467314.5	0	363368.7	471284.4	0
369472.1	467268.4	0	363364.5	471367.4	0
369410.9	467262.9	0	363344.1	471388.7	0
369333.2	467277.7	0	363234.2	471420.8	0
369248.3	467310.5	0	363177.5	471481.1	0
369190.1	467325	0	363151	471572	0
369168.4	467314.1	0	363160.9	471623.8	0
369177.1	467250.2	0	363225.8	471654.6	0
369220.5	467167.2	0	363302.2	471705.2	0
369224.7	467124.1	0	363320	471751.7	0
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369101	466974.3	0	363239.9	471975.1	0
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369099.2	466858.9	0	363160	472116	0
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368152	468289.8	240	369523.4	469448.7	260
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367841.5	475256.8	780	367535	475155.6	920
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367804.8	475699.5	920	367527.8	476008	960
367723.5	475648.4	920	367528	475979.3	960
367704.4	475623.8	920	367538	475946	960
367703.4	475526.1	920	367565.2	475915.8	960
367679	475478.3	920	367579	475872	960
367628	475435.5	920	367590	475847	960
367595.7	475408	920	367622.8	475812.1	960
367595.8	475383.7	920	367649.8	475754.4	960
367596.1	475336.1	920	367705	475727.6	960
367570.2	475298.1	920	367703.2	475708.4	960

367674.5	475669.2	960	367678.6	474778.3	820
367628.4	475617.5	960	367625.5	474752.7	820
367629.4	475573	960	367589.2	474746.4	820
367630.9	475531.8	960	367571.5	474743.7	820
367611.4	475497	960	367503.2	474752.8	820
367542.8	475424.4	960	367496.7	474751.7	820
367533.1	475388.1	960	368097.5	474827.2	840
367522	475361.8	960	368072.2	474818.8	840
367500	475343.4	960	368002.6	474816	840
367505	475986.5	980	367931.9	474808.7	840
367505	475986.1	980	367917.8	474812.3	840
367510.6	475937.7	980	367846.6	474802	840
367533.5	475904.8	980	367773.2	474813.4	840
367550.1	475878.1	980	367715.8	474844.7	840
367563.3	475819.6	980	367689.4	474843.1	840
367605.4	475759	980	367649.7	474809.1	840
367648.7	475710.7	980	367604.2	474788.2	840
367646	475676.3	980	367585.3	474789	840
367623.2	475652.3	980	367549	474796.2	840
367605.4	475627.4	980	367500	474798.8	840
367593.2	475590.8	980	367695.9	476039	860
367587.9	475526.7	980	367713.5	476016.8	860
367559.5	475486.8	980	367713.7	476016.6	860
367508.4	475436.9	980	367767.8	475967.3	860
367500.2	475405	980	367825.7	475926.9	860
367500	475403.6	980	367829.7	475872	860
367492.6	475887.1	1020	367862.5	475842.5	860
367520.4	475785.2	1020	367928.8	475810.5	860
367539.8	475753.2	1020	367957.3	475793.8	860
367551.8	475726.3	1020	367988.9	475778.4	860
367567.1	475699.9	1020	368015	475767.7	860
367568	475673.1	1020	368041.5	475726.8	860
367549.4	475584.4	1020	368068.9	475663.3	860
367540.2	475534.8	1020	368100.4	475639.4	860
367517	475509.8	1020	368192.3	475613.5	860
367500	475494.9	1020	368232.7	475593.8	860
367481.1	475781	1040	368251.9	475567.8	860
367515.1	475719.2	1040	368249.6	475555.8	860
367534.7	475690.3	1040	368234.3	475548.3	860
367533.7	475671.8	1040	368190.1	475552.3	860
367526.4	475616.1	1040	368147.4	475589.2	860
367518.2	475568.7	1040	368069.6	475612.2	860
367516	475543.3	1040	368031.6	475637.1	860
367511	475533.6	1040	367993.2	475636.6	860
367914.5	474771.1	820	367906.8	475624.9	860
367841.3	474755	820	367852.3	475626.1	860
367752.8	474760.5	820	367819.4	475611.1	860
367703.3	474781.3	820	367816.9	475591.1	860

367831	475564.7	860	367761	475593.8	880
367842.3	475540.5	860	367771.4	475556.8	880
367835.9	475519.4	860	367779	475528.3	880
367810.7	475477.1	860	367777.6	475509.5	880
367796	475436.1	860	367772.7	475489.7	880
367759.5	475414.5	860	367767.2	475465.3	880
367709.4	475391.4	860	367743.3	475445.3	880
367684.3	475355.9	860	367663.4	475397.7	880
367692.1	475293.6	860	367655.2	475301.1	880
367678.7	475267.4	860	367630.8	475273.1	880
367658.2	475233.5	860	367597.7	475242.7	880
367668.4	475178.5	860	367600.8	475214.9	880
367707.9	475111.8	860	367628.5	475172.4	880
367746.5	475070.3	860	367650	475139.8	880
367803.6	475031.1	860	367663.8	475098	880
367818.8	474993.4	860	367725.2	475042.6	880
367893.8	474928.7	860	367770.4	474990.1	880
367928.1	474916.6	860	367770.4	474970.8	880
367979.6	474908.9	860	367755.6	474956	880
367995.2	474891.8	860	367704.8	474944.6	880
367994.7	474867.1	860	367661.3	474933.2	880
367985.6	474861.4	860	367648.1	474904.6	880
367946.7	474860.3	860	367627.2	474894.5	880
367879.3	474832.2	860	367593.8	474892.5	880
367853.6	474840.6	860	367547.1	474903.1	880
367793.7	474838.4	860	367532.4	474896.3	880
367774.2	474901.8	860	367515.6	474874.6	880
367734.6	474904	860	367500	474855.8	880
367680.5	474893.5	860	368167.4	474407.3	620
367658.4	474845.4	860	368120.6	474360.6	620
367642.3	474836.3	860	368097.7	474356.8	620
367591.8	474835.4	860	368039.2	474361	620
367573	474840	860	368026.2	474375.6	620
367534.2	474834.7	860	368011.8	474389.4	620
367500	474824.4	860	367988.2	474398.7	620
367665.1	476040.5	880	367965.3	474390.5	620
367680.8	475983.8	880	367943.1	474350.3	620
367752.1	475940.5	880	367892.5	474306.8	620
367760.4	475908.2	880	367873.7	474246.9	620
367771.9	475836.8	880	367854.7	474234.3	620
367813.1	475817.8	880	367831.9	474242.6	620
367877	475807.8	880	367791.2	474254.6	620
367919.1	475772.5	880	367735.6	474259.1	620
367955.4	475727.6	880	367712.5	474279.6	620
367955.4	475697.5	880	367669.8	474304.6	620
367883.9	475654.8	880	367607.7	474330.7	620
367787.4	475638.8	880	367591	474334.4	620
367771	475624.7	880	367577.5	474329.9	620

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367550.5	474243.9	620
367536	474224.8	620
367516.4	474223.3	620
367512	474223.2	620
367503.9	474223.9	620
367934.1	474384.3	640
367898.5	474354.1	640
367840.6	474294.7	640
367804.8	474301.8	640
367751.1	474303.3	640
367710.4	474348.4	640
367673.1	474368.7	640
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367504.6	474344.9	640
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367655.3	474480.2	680
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367994	473884.6	520
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368147.6	473861.6	520
368178	473841.2	520
368201	473827.3	520
368238.6	473788.1	520
368293.8	473761.1	520
368330.8	473748	520
368377.3	473705.8	520
368395	473665.8	520
368455.4	473640.2	520
368500.2	473622.9	520
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368545.8	473537.3	520
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368656	473403.7	520
368693.2	473323.1	520
368691.2	473299.8	520
368689	473275	520
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368351.3	473201.7	520
368289.7	473204.7	520
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368221.4	473231.7	520
368204.4	473223.2	520
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367880.3	472814.2	520
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368162.3	472663	520
368174.6	472629.5	520
368144.8	472606.4	520
368122.5	472596.2	520
368113.5	472593.3	520
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367741.8	473848.2	580
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367903.1	473771	580
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368373.9	473541.8	580
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368475	473458.3	580
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368296.5	473281.2	580
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368209.3	473301	580
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