CHAPTER III

SYSTEMIZATION OF GILM

In constructing of geological information for land management to serve maximum beneficial uses, the concepts of working must meet the solutions as being described in last topics of chapter 2. They are as follows :-

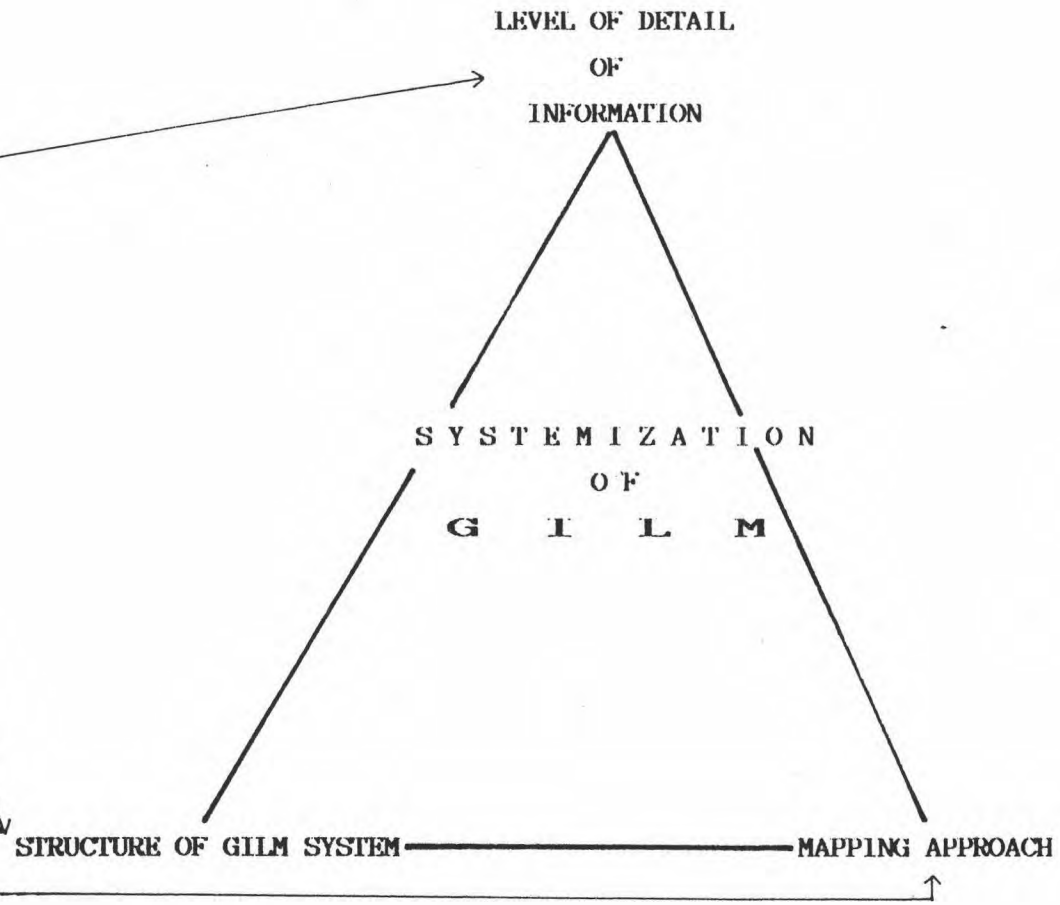
1) GILM system should be prepared to demonstrate information in different level of details according to level of treatments (regional and local). Details of information demonstrated on map should be designed to facilitate in generating more details of information or in simplifying the information to meet the needs the application.

2) GILM should cover all topics of geological information being needed. Lists of all map topics should be prepared and identified to facilitate a systematically arrangement in serving maps making and map uses.

3) GILM should be systemized into stages of information in order to facilitate users having different status of geological knowledge. Maps demonstrating information of lower stage concerns to person having more knowledge in geology. The information can be developed to higher stages of information, through the process of evaluating and analyzing, to serve planner not being trained in geology.

Figure 3.1 to illustrate relationship of framework concept and 3 subjects of GILM systemization

Solution
GILM should be prepared to demonstrate information in different level of details according to level of treatment (regional and local).
GILM should cover all map topics of geological information needed, and this must be simlified the illustration to be the simplest and thematic detail.
GILM should be systemized into stage of information in order to facilitate user of different status.
GILM should be designed according stage of information, starting from date in lower stage of information, and develop to theme in higher stage of information. Thus facilitate in updating and in preparation of information for variation of objectives.



4) GILM system should be designed in order to facilitate in updating of information, without disturbing the whole system. This is necessary when new data are found, or existing data is needed to be changed or being added, to serve new objectives.

In formulation of GILM system, there are subjects to be identified and discussed. They are the main element of systemization of GILM, which are consist of Level of Detail of Information, Structure of GILM System, and Mapping Approach in Formulating of GILM System.

3.1 Level of Details of Information

Observation on GILM being prepared for various objectives, it can be noted that the level of details is varied depending on objectives and size of the area to be studied. The area may be bounded by administrative boundary, geographical boundary or geological boundary. More than that, in one sets of information maps being prepared for a particular work, although they are prepared on map of the same scale but level of details are different and can not be matched with the map demonstrating other information. Thus causes different result in the derived map of later stage being synthesized those information, and leads to inefficient result in land management.

In Preparation of GILM to serve land management the level of details of information should be considered to match with the level of treatment which is depending on the purposes of treatments.

In formulating of GILM system concerns to level of details of information, catégories is considered. The following categories and referred previous works are listed as the following:

1) Classification of maps according to scale refers to the work of UNESCO (1976), International Geographic Union - IGU (refer from Zuidam, 1985); and suggestions made by Marsh (1978).

2) Level of treatments, which are directly related to level of information needed for treatment, refers to the works of Marker and McCall (1989); Doornkamp (1989); Luttig (1989); Dent and Young (1981); and works of FAO (1969).

3) Demonstrating of details of information, method of study and data source, which vary to topics of GILM refers to I.T.C.'s terrain mapping system (Zuidam, 1989); the terrain hierarchy compiled by Mitchell (1973); structural feature mapping proposed by Gold (1980); and the level of detail in hazard mapping by Doornkamp (1989).

4) Application of information according to various works in land management refers to the suggestion of Valdiya (1987); and Grant (1986);

Based on these previous works level of information are demonstrated on level of map scale, level of treatment, level of detail and data acquisition are demonstrated on table 3.1.

Table 3.1 To correlate level of information from selected previous concepts in level of scale, level of treatment, level of detail &data acquisition, and some of applications.

Sources	1:2,000	1:5,000	1:10,000	1:25,000	1:50,000	1:100,000	1:250,000	
UNESCO	site plan	detail map		large scale map	medium scale map		synoptic map	Level of Scale
IGU		plan		basic map	large scale synoptic		medium scale synoptic / small scale synoptic	
	<----------(detail map)---------->				<----------(synoptic map)---------->			
Marsh,	large scale						small scale	
Doornkamp,	site investigation such as engineering project				local planning		regional planning	Level of Treatment
Marker & McCall	site			area			regional	
Luttig.	community planning				regional landuse planning		province plan.	
Dent & Young	special purpose survey			project planning	regional landuse planning		regional or national landuse planning	
FAO,	special purpose survey			field level or urban development	district landuse planning		broad region or national landuse plan	
Mitchell	land element	land subfacet		land facet and land clump		land catena	land system	Level of Detail and Data Acquisition
	large scale aerial photo			medium scale aerial photo occasionally SPOT and LANDSAT		LANDSAT, SPOT, ERS., and small scale aerial photo		
ITC,	terrain component geomorphological detail			terrain unit geomorphological unit		terrain system (pattern) main geomorphologic unit	terrain/geom province	
GOLD	joint trace (cm.-ten of meters)		fracture trace (100 m. - 1.6 km.)				linearment trace (> 1.6 km.)	
	Outcrop field mapping large scale air-photo		air-photo			air-photo sattelite, mosaic of air-photo, mosaic of sattelite		
Doornkamp	specific hazard form/-material characteristics			detail of larger hazard area	hazard site		boundary of area contain hazard	
	aerial photo field mapp.,	aerial photo ,airborn., field mapp., photogram., process - monitoring.		aerial photo , field - mapping	satellite image, air-photo mosaic		satellite image, photographically reduce air-photo mosaic	

Grant	Terrain componet (1:10,000 or larger) Trafficability of natural surface Liability to flood Road and airfield pavements Suitability of natural as subgrade Source of borrow for pavement materials (gravel, crushed rock, screenings, etc.) and estimates of quantities Source of borrow for concreting materials (sand, aggregate, etc.) and estimates of quantities Building foundations Susceptibility to volume change with moisture change Susceptibily to settement under load Earth tands Topographic suitability Material suitability	Terrain Province Terrain Pattern (1:250,000 or large) Deep underground rock examination General statement only for factors specific at lower levels in the classification Formation for rad or railway construction Earthworks - quantity - equipment Bridging frequency Culverting frequency Airstrip construction - topographic suitability Dam sites - topographic suitability Underground excavations affected by surface features General statement for factors specific at terrain unit or terrain component level of classification Terrain Units (1:50,000 or large) Formation for road or railway construction : Location/Prferred location of grade line Suitability of natural material as base course Source of borrow for embankment Proportion of rock excavation Airstrip construction : Location, Suitability of natural material as a base course, Proportion of rock excavation Dam sites : Location, Source of borrow for embankment Building construction : Location General statement for factors specific at terrain component level of the classification
Valdiya	Rural landuse management (local) + Recognition and demacration of land primality (apable of supporting forest, pasture, and agriculture + land for watershed conservation Urban landuse management (local) + Stability of ground for the foundation of structure, freedom from natural hazard + ability of water of requisite quality in sufficient quanity + Development of site for recreation road, water supply etc.	Regional landuse management + land for agriculture, courbanization and industrial + area for water resource development (dam, reservoir, canal) + transport network (road, railway) + exploitation of natural resource + zone of bigger natural hazard + Defence requirment

Example of Level of Application in Engineering Works and Landuse Management

Basing on previous works, level of details of information proposed in GILM system in this study are discussed as the following:-

1) Level of details of information should be prepared in two levels. They are the Regional level (regional scale), and the Local level (local scale). The regional level demonstrates information of less details than those appeared in the local level. Those which demonstrate information being more detail than demonstrated in local level should be classified as information for site planning, and should be recorded separately from GILM. The details of information prepared for the Regional level (regional scale) should satisfy working in land management in broad area. To classify details of information should not be specific only to a particular area but to be applied for the whole region of the area studied, having intention to select a suitable area for further detail studied. Information prepared for the Local level (local scale), the information should serve in decision making to select the area or site for that particular use, basing on one specific characters which is depend on objective of application.

2) Classification of information in 2 levels of details, the regional level and local level, are suitable with existing topographic map used in Thailand following the international standard. They are the scale of 1:50,000 and 1:250,000. Details of information in GILM system should be prepared according to these standard scale.

3) Practically, GILM prepared on both scales are sufficient to serve planner in information selection to meet their requirements in any administrative boundaries; Tambol, Amphoe, Changwat. Preparation of 2 level of detail, is still necessary. According to information technology available in recent day, GIS technology and remote sensing technology, facilitate in converting scale and details of information. It seems that preparation of GILM of one scale should be sufficient. However, to prepare GILM of larger scale need more temporal and monetary requirement. Economically, preparation of GILM at appropriate scale to meet the objectives in land management should be decided.

4) To facilitate converting of scale, information appears on each levels of detail, should be designed in such a way that, the information on both levels should have its relationship. One map unit of information on regional scale can be reclassified to more different units of related subject of information on local scale. Besides, several units of related subjects demonstrated on local scale can be combined into one unit maps in regional scale.

Table 3.2 illustrates relationship of level of scale, level of detail, level of treatment, and map topics which are correlated from table 3.1.

3.2 Structure of GILM System

This subject is derived from the framework concepts. Structure of GILM system is the main point in systemization. There are subjects to be identified and discussed as **Map**

Table 3.2 To sumary relationship of level of scale, level of detail, level of treatment and map topics which were observed and summaried from table 3.1.

Scale	Large scale 1:25,000	Medium scale 1:50,000	Small scale 1:250,000
Level of tretment	Local level		Regional level
Level of Detail	terrain unit - terrain component	terrain system - terrain unit	terrain province - terrain system terrain unit
Area Coverage	To treat level of small area such as part of county, some specific, area as community, project area (~10 km^2)	To treat for level of medium area such as level of county area, district, urban etc. (<1,000 km^2)	To treat for level of large area such as level of Region, Province, Large county area, etc. (>1,000 km^2)
Map Topics	Specific topics which be required of detail fieldworks and laboratory study	General topics which should be designed to facilitated converting of scale from reginal to local and/or local to regional	

Topics and Group Map Topics, Stage of Information, and PIU System. There are as the following :-

3.2.1 Map Topics and Group of Map Topics

Information used in land management are presented in map form. So, the map topics are the first to be discussed in structure of information.

Map topics of 67 previous works are carried out and listed all of them in Appendix B. They consist approximate in 600 topics. All of them were systemized to get out for the same names of map topics.

Group of map topics is very important in systemization. From diagnosis of previous works, they can be observed into 2 grouping. The first is grouped by subjects of information, another one is grouped by degree of inference.

For systemization, group of map topics appeared in previous works were considered and applied. All of them are listed in Appendix C. They are considered and summarized into 9 groups of map topics. They are ; Landform and Process, Geological Material, Geological Structure, Geohydrology, Geological Hazard and deterioration, Geological resource, Geotechnical properties, and Suitability of landuse suitability.

The basic concept of grouping is to be done by subjected, but this should be related to degree of inference.

This is important in formulating stage of information in following topics.

All of map topics were summarized the names that has equivalent detail of information into new appropriate names. The rename of map topics is done by 2 principals.

1) The names of map topics must be intended to detail of its informations and intend to degree of inference. (low, medium, and high degree)

2) Each of map topics must be simple to facilitate systematically arrangement in serving maps making and map uses.

In systemization, map topics from previous works are arranged by those principals and fix each of topics into those groups of map topics. These are illustrated in table 3.3.

3.2.2 Stages of Information

GILM works prepared by previous works which has been already discussed in Chapter II. There are one common character showing their effort in managing of information to facilitate users. Information or themes of maps are grouped according to its nature of application, and be arranged from basic information in geology to more "degree of application," or in other words "degree of inference". Accordingly, the example of GILM of previous work which be selected to be classified and being demonstrated in table 3.4. They can be explained as the following.

Table 3.3 List of map topics, which are collected and simplified from Appendix B, and to be appended of possible map topics in land management interests.

LANDFORM AND PROCESS	GEOLOGICAL MATERIAL	GEOLOGICAL STRUCTURE	GEOHYDROLOGY
Surface processes map Physiographic units (types) map Landform units (types) map Landscape features map Terrain hierarchy (unit) map * land zone/land division/ land province /land region/land-system/land catena/land facet/land clump/land subfacet/land element (Mitchell,1991) Drainage system map Drainage pattern map Coastal cell system map Area/site/location or boundary of specific terrain feature map * kast feature/volcanoes/ glacier trace/coastal feature-type/ eolian dune/lake-standing water area/marsh/swamp/ wetland/landslide trace/ alluvial fan/point bar/ placer/ancient-shoreline/ former tidal flat/delta/ etc.) Area/site/location or boundary of specific process influence * total deposition/erosion * total degradation/ aggradation * specific process such as flood area/flood type/ tidal innudate mass movement type/karst process/eolian/wave and current/coastal erosion/ deposition/coastal system (cell)/ etc. Hypsometric map levelling heigh map altitude above mean sea level map Ground elevation map Slope map	Geological material (Earth-material) map Rockmass/outcrop (bedrock) material map Lithological (solid/solid and drift/drift only) map Superficial (surface) material map Location (area/site) of particular geomat. deposite/ distribution map * mineral deposite (arsenic/ tin/copper/lead/zince/ gold/silver/wolfram/ iron/sapphire/china clay/silica sand/ etc.) * fossil fuel (coal/oil shale/petroleum/coke) * industrial rock (marble/ granite/slate/travertine / etc.) * construction materials (aggregate/road stone/ earthfill/construction sand/laterite/ etc.) * special properties material (quikclay/ expansive soil/loose-sand/landslide dep./salt bearing soil/sheared rocks/ etc.) * other geomat. (lava flow/ quartz veins-dikes/ hydrothermal-veins/ granite intrusion/bay mud/loess/hard pan duricrusts/beach rock/ organic soil/peat/ placer deposite/ diseminated-toxic element/ etc.) Related themes : Depth of bedrock map/Top soil thickness map/ etc.)	Regional geological structures map Detail geological structure map Linear structure map * Major fault/fracture map * Detail (minor) fracture map Circular (feature) geological structure map Stratigraphic map (litho-/bio-/ chrono-) Active fault zone/locations map Earthquake (seismicity) location map Tectonic movement map (global/ continent/region/local) Other relate themes * Basic geologic map * Metamorphism zoning map * etc.	Aquifer map Water supply strata map Groundwater rechart area (strata) map Groundwater quality/quanity map Groundwater chemical properties map Groundwater flowing rate map Groundwater level and yield map Groundwater flowing direction map Subterrainial stream map Quality of water and precipitation Valley and stream map Surface water flowing map Surface drainage runoff rate map

(Table 3.3, cont.)

GEOLOGICAL HAZARD	GEOLOGICAL RESOURCE	GEOTECHNICAL PROPERTIES	LANDUSE SUITABILITY	MISCELLANEOUS
Risk of hazard map * flooding * landslide * seismic/earthquake * volcanic * landslide/earthflow * subsidence * flood of hericane * Tsunami destruction area * submerged area from sea level risk Susceptibility zone/area of hazard/deterioration map * land erosion * coastal erosion * rivermouth siltation problem * toxic mineral/element disseminated * active fault zone hazard Mine refuse potential map Land pollution susceptibility map etc.	Geological resource potential map * mineral * industial rock * fossil fuel * construction material * earthfill * groundwater (shallow/depth) * surfacewater Mineral resource quality map Geoheritage site value map Potential of water supply area map etc.	Geotechnical properties (solid, solid and drift, drift) map * permeability map * corrosion potential * shrink-swell potential * strength of material * ease of excavation/ compaction/drilling / etc. * expansive condition * seismic response condition * susceptibility to frost of soil * susceptibility to liquifaction Land/slope stability map (natural/cut slope/ trench wall) Subsidence susceptibility map Watertable rise condition Flow aquifer rate Foundation condition map Required condition for intense rock blasting Capacity to accept liquid waste area/ site map Capacity to accept solid waste area/site map Cost for reclaimation Cost for treatment of mine fire Cost of engineering works * topsoil removal * cleaning and gubbing * cut and fill * embankment * drainage treatment * excavation * etc. etc.	Suitability zone/area/ site for geological resources developement * mineral resource (surface/underground mining) * industrial rock * construction material resource * coal mining * groundwater Suitability zone/area/ site for land development/build up area * industrial (heavy/ light) park * commercial settlement * newtowe/urban area Suitability zone/area/ site for agricultural development/conservation Suitability zone/area/ site for (active/ passive) recreation Suitability zone/area/ site for other specific requirment * natural conservation * watershed conservation * land supporting forest/ecosystem * national park * tourism (active/ passive) * geological heritage study area Selected specific civil engineering works coridors map * road * transport network * railway * canal dradging * irrigation system Suitability zone/area/ site for specific project Constraint/environmental effected area from development etc.	Geoscience heritage site map * kast/cave/doline fossil location/ ancient shoreline/ sea notch/sea stack/ sea cave/table land/ typical geological formation/water fall/rapid/mushroom rock/wetland/hot spring/geiser/water gap/wind gap/ etc. Location/Area distinctive man-made feature relat * mine * underground mine fire area * madeground * earthfill * irrigation canal * dam & resevoir & pond * coastal protection structure * ancient settlement Landuse and land cover map

1) Geologic data in general, do not have characters demonstrating the value relating to the area. The information of this nature belong to a group of information having non low degree of inference.

2) Geologic information belongs to a group of engineering geology for example. They are usually indicated with comparative value of technical properties of the area. These properties can be synthesized information indicating the risk of hazard, and potential or capability in land development. These nature of geological information can be grouped in low to medium degree of inference.

3) Group of information are indicated with comparative value being added by compiler through evaluation and analysis of geologic information of lower degree of inference. The information of this nature can be classified to a group having degree of inference of medium to high.

4) Group of information are indicated with suitability of the area for particular activity, for example in agriculture, land development and etc.. These information have its nature be ready used for planner. Such information is considered to have a highest degree of inference.

In systemization of GILM according to this study, information should be prepared in topics and grouped of topics according to its nature of subject in geology. These topics and groups of topics are arranged in orders to serve users who has different background in geology. At the same time, information of each orders can be processed based on

Table 3.4 To compare degree of inference of themes in groups of map topics of selected previous GILM works.

Groups of Map Topics	Degree of Inference		
	Low	Medium	High
Cargo and Mollory, 1977			
Topography	<----->		
Hazard		<----->	
Evaluation maps			<----->
Engineering geology		<--->	
Earth materials	<----->		
Floyd, et al., 1982			
Element maps	<----->		
Derived maps		<----->	
Potential maps			<-->
Gostelow and Browne, 1986			
Element maps	<----->		
Derived maps		<--->	
Potential map			<--->
Marker and McCall, 1988			
Basic geological map	<->		
Applied geological map		<----->	
Environmental geology map			<--->
Nikorn Mungkung, 1992			
Basic maps	<---->		
Derivative map		<----->	
Thematic map			<----->
Final Integrate map			<->
Sunya Sarapirom, 1992			
Terrain map	<------->		
Cost surfaces		<-->	
Intergrated Terrain-cost model			<->
Final			<--->

Group of Map Topics	Degree of Inference		
	Low	Medium	High
McHarg, 1969			
Major data	<------->		
Value Map		<--->	
Suitable areas maps			<---->
Composite map			<----->
Mckenzies and Utgend, 1975			
Basic Data Map	<----->		
Resource Capability Map		<-->	
Resource Suitability Map			<----->
Montgomery, 1969			
Map of basic data	<-->		
Interpreted basic data	<------->		
Map used in planning		<--->	
Nickless et al., 1982			
Element maps	<----->		
Derived maps		<----->	
Potential maps			<----->
US Geological Survey and Department of Housing and Urban development 1971			
Basic data	<----->		
Interpretative studies		<-------->	
Valdiya, 1987			
Regional Landuse Management			<----->
Rural landuse management			<----->
Urban landuse management			<----->

(List of Map topics in each groups of map topics are illustrated at table 2-12 (p.48)

evaluation and analysis to synthesize information of higher order. Accordingly, information prepare for GILM system in this study are organized and be called a "Stages of Information". They are "Primary Geological Information" (PGI), "Intermediate Geological Information" (IGI), and "Ultimate Geological Information" (UGI). Map topics and grouped of map topics belongs to each stages are demonstrated in table 3.5. They are described as the following.

Stage 1 : Primary Geological Information - PGI

PGI is an information having its nature of basic geology, which are derived in the first stage in preparation of GILM. They must be prepared by person who has knowledge in geology by surveying of data either directly in the field or by other methods. Commonly, remote sensing are used as an important tool in mapping.

Elements of all fields in geology are recorded, and are separately mapped according to subjects. And on each maps shall be simplified as much as possible not to contains several topics. Information being prepared by this way, it can facilitate user in selecting of information to fit their purpose. It can also facilitate compilers, the geologist, in updating of information when necessary. The topics or themes prepared on each maps can be identified and be grouped to subjects which can be commonly understood by both users and compilers. They are for example, geomorphology and process, geological materials, geological structure, geohydrology and etc..

This nature of information is not normally changed and can be continuously compiled for all areas for ready uses.

Stage 2 : Intermediate Geologic Information - IGI

IGI is an information demonstrating a relative potential or capability value in geological characters of that particular area. The information is derived in the second stage being prepared from data or information of the first stage. In some topics, depending on its nature, they can be prepared directly by surveying or measuring in the field, for example those engineering properties. Information of IGI stage has its nature being oftenly changed according to the objectives of application. The topics of GILM belongs to 2nd stages (IGI) can be grouped as potential resources, risk and susceptibility of geologic hazards, and information demonstrate geotechnical properties. List of map topics are demonstrated in table 3.5.

Information of the second stage (IGI) are prepared from evaluation and analysis from the 1st stage information (PGI). It can be prepared from one a several topics of PGI. The example in evaluation of PGI to IGI are demonstrated in case study being discussed in Chapter IV.

Stage 3 : Ultimate Geologic Information - UGI

UGI is an information demonstrating suitability of the area to be applied in a particular activity according to its geological properties. Information of this stage is derived from evaluation and analysis of the 1st and 2nd stages of

information, PGI and IGI. The result are synthesized to compile information of UGI. In fact, UGI is prepared in the most simple form being ready used for planner who has limited background in geology. Practically, the information of UGI stages are demonstrated variously according to objectives. So that, they are not prepared for all possible applications, but they can be prepared whenever necessary from information of PGI and IGI stages. The topics of UGI stages can be grouped according to applications, they are for example, suitability area for geological resources development; suitability area for land development etc. List of maps' topic are demonstrated in table 3.5.

3.2.3 PIU System

The name PIU system is firstly developed in this study to call the structure of information being designed for GILM system. The structure of information is constructed and managed according to 3 stages of information, PGI-Primary Geological Information, IGI-Intermediate Geological Information, and UGI-Ultimate Geological Information. The first alphabet of each stage's name are used to called PIU system.

According to the stages of information already discussed, it can be concluded that the GILM should be constructed or managed through the stages of information, PGI, IGI, and UGI. The PGI are derived at the first stage from collecting data from various sources, mainly they can be available from integrated surveys of field study, existing data and remote sensing interpretation of aerial photographs and satellite

Table 3.5 To illustrate the possible topics of GILM maps which be classified into stages of information, PGI: IGI: UGI (PIU SYSTEM)

PGI Groups of Map Topics/ Description/ Sample of Map Topics
(1) Landform and Process: Geomorphic features of land such as elevation, slope, geometry, landform, surface process, etc :- Surface processes map/ Physiographic map/ Landform units (types) map/ Drainage system map/ Coastline features map/ coastal cell system map/ Area/site/location or boundary of specific terrain feature map/ Area or boundary of specific process influence map/ Hypsometric map/ Slope map/ etc. (2) Geological Material: Distribution of various lithologic rock and superficial deposits, including mineral deposite site or other specific geomaterials , etc.:- Geological material map/ Location (area/site) of particular geomat. deposite/distribution map/ Related themes such as : Depth of bedrock map/Top soil thickness map/ etc.) (3) Geological structure: General structure such as fold, fault, bedding and stratigraphy, include foliation of metamorphism, etc.:- Regional/Detail geological structures map/ Linear structure map/ Circular (feature) geological structure map/ Stratigraphic map (litho-/bio-/chrono-)/ Active fault zone/locations map/ Earthquake location map/ Tectonic movement map / Other relate themes as Basic geologic map, Metamorphism zoning map, etc. (4) Hydrogeology: Hydrogeological condition of study area, such as aquifer, static level of groundwater, flow direction, etc:- Geohydrological map/ Aquifer map/ Groundwater rechart area (strata) map/ Groundwater quality/quanity map/ Groundwater chemical properties map/ Groundwater flowing rate map/ Groundwater level and yield map/ Groundwater flowing direction map/ Subterrainial stream map/ Surface drainage runoff rate map/ etc. (5) Miscellaneous: Some characteristics which closed relate with geology but cannot grouped into other topics.:- Geoscience heritage site map/ Location/Area man-made feature relate geology map/ Landuse and land cover map/ etc.
IGI Groups of Map Topics/ Description/ Sample of Map Topics
(6) Risk of Hazard and Deterioration: Analysis of the PGI for hazard danger risk area and present in form of relative risk area such as High, Moderate, Slight, or Non (danger area).:- Risk of hazard map such as flooding, landslide, seismic/earthquake, volcanic, Susceptibility area of hazard or deterioration map such as land erosion, coastal erosion, rivermouth siltation problem, toxic mineral/element disseminated, active fault zone hazard/ Mine refuse potential map/ etc. (7) Geological Resource Potential: Analysis of PGI for potential of resource development area in form of relative potential area such as High, Moderate, Low or Non (potential development):- Geological resource potential map such as mineral, industial rock, fossil fuel, construction material, earthfill, groundwater/ Mineral resource quality map/ Geoheritage site value map/ Potential of water supply area map (8) Geotechnical properties: Relative geotechnical properties which especially use in engineering works.:- Engineering geological map/ Geotechnical properties map such as permeability map, corrosion potential, shrink-swell potential, strength of material, seismic response condition,etc./ slope stability map (natural/cut slope/trench wall)/ Subsidence susceptibility map/ Required condition for intense rock blasting map/ Capacity to accept waste area/site map/ Cost for reclaimation/ Cost of engineering works/etc.
Description for UGI Map Topics/ Sample of Map Topics
(9) Zone or area of relative suitability particular land for included land developmet by evaluated the IGI. Maps present in form of the relative suitable area such as 1st Most suitability, 2nd, 3rd, 4th, or Least suitability.:- Suitability zone/area/site for geological resources developement such as mineral resource, industrial rock, construction material resources, coal mining, groundwater/ Suitability zone/area/site for land development/build up area such as industrial park, commercial settlement, newtowe/urban area/ Suitability zone/area/site for agricultural development/conservation/ Suitability zone/area/site for (active/passive) recreation/ Suitability zone/area/site for other specific requirment such as natural conservation, watershed conservation, land supporting forest/ecosystem, national park, tourism/ geological heritage study area, Selected specific civil engineering works coridors map/ Suitability zone/area/site for specific project/ Constraint/environmental effected area from development/etc.

* List of all map topics separated by groups of map topic are illustrated at table 3.3)

images. The information are collected and demonstrated separately according to subject in geology which will be used as "element" information in generating new information of the same stage of information or be analyzed evaluated to synthesize information of the higher stage of information IGI and UGI. In practice, each separated information should be designed for each map topics to be demonstrated in thematic form of map. This is to facilitate in managing of information, collection, recording, analysis and retrieving of data basing on GIS.

Theoretically, in systemization of geological information for land management basing on PIU system shall benefits as the following :-

1) Map topics can be designed to cover the information needed form analysis in serving objectives in land management. All of map topics in geology relating to land management in serving various objectives can be pre-listed and pre-designed systematically. This will serve and facilitate the system design in managing GILm with the aid of GIS.

2) The information being managed under PIU system are systematically organized and show its situation being factual data or analyzed data.

3) In the view of GILM compilers, or mappers, in preparation of GILM under PIU system, geologists of all disciplines and having different level of geological knowledges can participate in preparation of GILM according to their initial experiences.

4) For users, GILM being prepared under PIU system will facilitate planners to select information according to their information according to their experience in using geological information.

5) In updating of information when it is needed, some topics or part of information can be selected for updating without disturbing the whole system.

6) GILM being organized under PIU system are easily managed with the aid of GIS and are easily selected for analysis together with other non geological information.

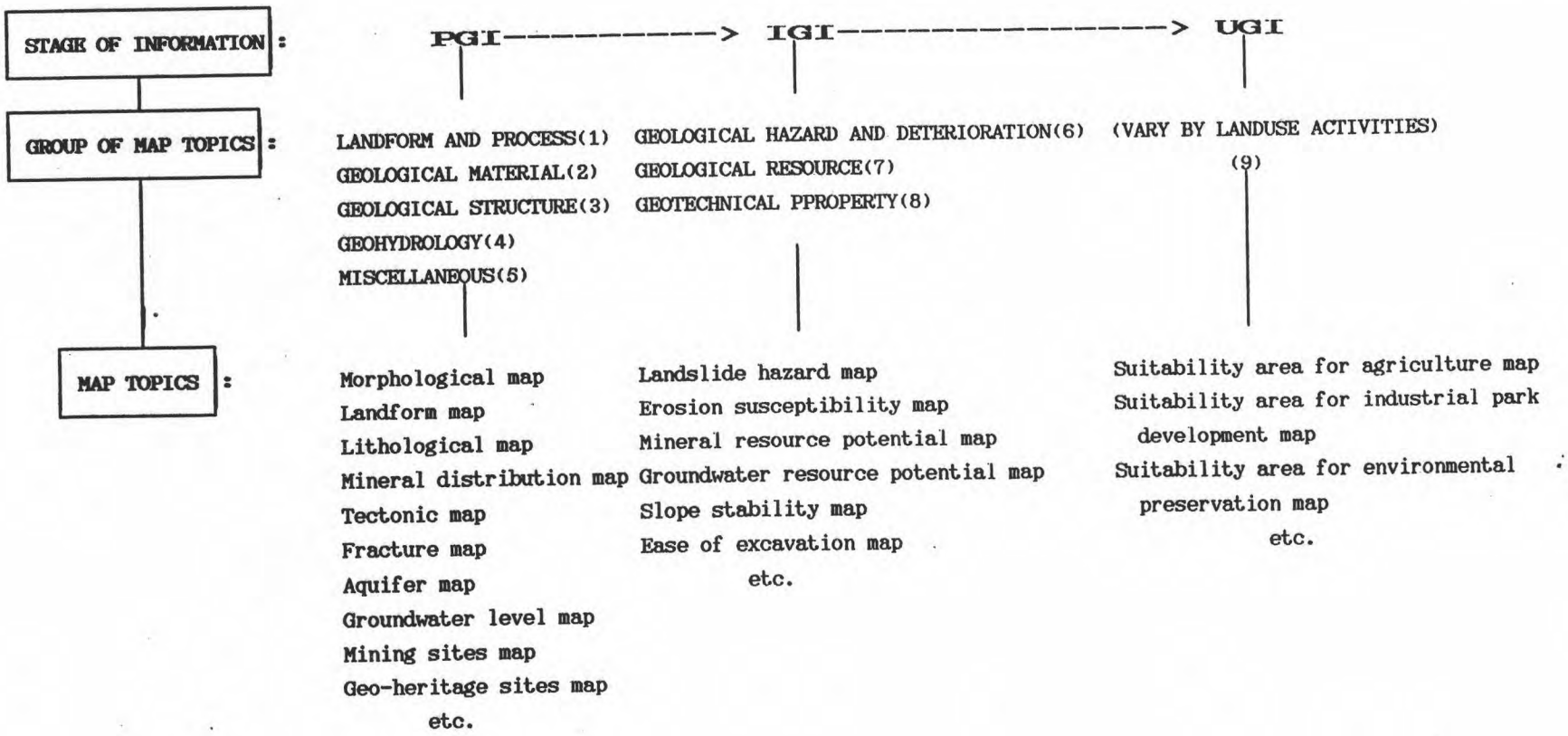
7) Theoretically, PIU system could be applied not only for geological information but also for the other earth science information.

Figure 3.2 illustrate the structure of PIU system.

3.3 Mapping Approach in Formulating of GILM System

Formulating of GILM in according to stages of information, the information are compiled and demonstrated on map. Each map indicates one nature of information. Maps of the same nature shall be grouped and be arranged in orders of stages of information, PGI, IGI, and UGI. Information belongs to lower stages of information PGI can be evaluated and analyzed to form information of higher stage of information IGI and be synthesized information of highest stage of information UGI being ready used for planner. To facilitate

Figure 3.2 To illustrate structure of PIU System



preparation of GILM map topics and groups of map topics are listed and be discussed in this section.

3.3.1 Preparation of map in thematic form

Demonstrating of information found in previous works some are separately demonstrated with simple subject being thematic. While the others are demonstrated with complex information composed of several subjects being now thematic. In formulating of GILM system to be followed by this study, the information needs to be classified into topics as smallest as possible, or being synthesized into topics of higher order of stages of information. All of them are demonstrated on maps having thematic in nature. Accordingly, the maps demonstrating geologic information of non-thematic form must be transferred to maps demonstrating geologic information of thematic form. Titles of maps are designed on being introduced for the particular maps relating to its subject. For the best result, map code should be designed for that particular maps, the example shall be shown in the case study in the next chapter. Table 3.6 shows the examples of conventional maps demonstrating geologic information in non-thematic form, and maps created for GILM system demonstrating in thematic form.

3.3.2 Relationship of information PGI, IGI and UGI

Maps' topics and groups of map's topics and sorted in order of stages PGI, IGI and UGI. The basic or primary stage of information PGI, which is derived from surveying, there are synthesized to create information belongs to higher stages of

Table 3.6 To illustrate the examples of conventional maps demonstrating geological information in non-thematic form, and map created for GILM system demonstrate in the thematic form..

Conventional map	Simplified to thematic map
Basic geologic map (1) Geomorphologic map (2) Soil map (3)* Geohydrologic map (4) Environmental geologic map (5) Engineering geologic map (6) Topographic map (7)	Geological material map (1,2,3) Stratigraphic map (1) Fault/fracture map (1) Morphometic map Morphographic map Morphochronological map Morphogenetic/diamic map Physiogrphic map (2,3,7) Slope map (2,3,7) Landform unit map (2,3,7) Drainage map (2,4,7) Surface process map (2,3,4,7) Aquifer map (4) Groundwater flowing map (4) Surface water flowing map (2,4,7) Geological resource maps (5,6) Geological hazard maps (5,6) Geotechnical properties of geomat. Maps (6) * Strength map * Permeability map * Stability map * Wast capacity map etc.

information, IGI and UGI. They are processed through, mapping techniques, map overlay and weighting score for example. Recent technique in handling information with an aid of computer, GIS is generally applied and be and efficient tool in information's processing. Table 3.7 is constructed for map topics check-list for design series of informations.

3.3.3 Remote sensing in preparation of GILM

Remote sensing including aerial photographs and satellite imageries, being presented in the forms of image or digital, are efficient tools in aids of formulating GILM. They are generally used in collecting and evaluating of information in both conventional way using manual method and by modern technique using GIS ; based on digital in collecting of data, analyzing and evaluating of data, and retrieving of data.

Remote sensing are sources of geologic information and non-geologic information appearing on the same geographic base. This will facilitate in presentation of informations to be prepared in thematic forms. Remote sensing can be used in surveying of data and in evaluating of information in compiling both of geologic and non-geologic information to be used in land management. Not only that, also remote sensing of multidates will allows information collected and updated. And due to its resolution and techniques in detecting of data being developed in these days, allows remote sensing to be enhanced in order to demonstrate various data, and also to be enlarged and reduced to various scale of information. Its capability as mentioned, hence, remote sensing becomes a necessary tool in formation of GILM. For case study in

Table 3.7.1 Check-list for designing series of map topics used in preparation of GILM : Relationship of PGI and IGI

	PGI	Landform and Process																				Geological Material													Geological Structure												Geohydrology														Miscellaneous			
	IGI	Surface processes map	Physiographic units (types) map	Landform units (types) map	Landscape features map	Terrain hierarchy (unit) map	Drainage system map	Drainage pattern map	Coastal cell system map	Area/site/location or boundary of specific terrain feature map	Area/site/location or boundary of specific process influence	• total deposition/erosion	• total degradation/aggradation	• other specific process	• etc.	Hypsometric map	Levelling heigh map	Altitude above mean sea level map	Ground elevation map	Slope map	etc.	Geological material (Earthmaterial) map	Rockmass/outcrop (bedrock) material map	Lithological (solid/drift only) map	Superficial (surface) material map	Location (area/site) of particular geomaterials deposite/distribution map	• mineral deposite	• fossil fuel	• industrial rock	• construction materials	• special properties material	• other geomaterial	Depth of bedrock map/top soil thickness map	etc.	Regional geological structures map	Detail geological structure map	Linear structure map	• Major fault/fracture map	• Detail (minor) fracture map	Circular (feature) geological structure map	Stratigraphic map (litho-/bio-/chrono-)	Active fault zone/locations map	Earthquake (seismicity) location map	Tectonic movement map (global/continent/region/local)	Metamorphism zoning map	etc.	Aquifer map	Water supply strata map	Groundwater rechart area (strata) map	Groundwater quality/quanity map	Groundwater chemical properties map	Groundwater flowing rate map	Groundwater level and yield map	Groundwater flowing direction map	Subterrainial stream map	Quality of water and precipitation	Valley and stream map	Surface water flowing map	Surface drainage runoff rate map	etc.	Geoscience heritage site map	Location/Area distinctive man-made feature relate geology map	Landuse and land cover map	etc.
Geological Hazard and Deterioration	Risk of hazard map																																																															
	• flooding																																																															
	• landslide																																																															
	• seismic/earthquake																																																															
	• volcanic																																																															
	• landslide/earthflow																																																															
	• subsidence																																																															
	• flood of hericane																																																															
	• Tsunami destruction area																																																															
	• submerged area from sea level risk																																																															
	• etc.																																																															
	Susceptibility zone/area of hazard/deterioration																																																															
	• land erosion																																																															
	• coastal erosion																																																															
	• rivermouth siltation problem																																																															
	• toxic mineral/element disseminated																																																															
	• active fault zone hazard																																																															
	• etc.																																																															
	Mine refuse potential map																																																															
	Land pollution susceptibility map																																																															
	etc.																																																															
Geological Resource	Geological resource potential map																																																															
	• mineral																																																															
	• industial rock																																																															
	• fossil fuel																																																															
	• construction material																																																															
	• earthfill																																																															
	• groundwater (shallow/depth)																																																															
	• surfacewater																																																															
	• composite of water resource																																																															
	• etc.																																																															
	Mineral resource quality map																																																															
	Geoheritage site value map																																																															
	Potential of water supply area map																																																															
	etc.																																																															
Geotechnical Property	Geotechnical properties (solid and/or drift) map																																																															
	• permeability map																																																															
	• corrosion potential																																																															
	• shrink-swell potential																																																															
	• strength of material																																																															
	• ease of excavation/compaction/drilling/etc																																																															
	• expansive condition																																																															
	• seismic response condition																																																															
	• susceptibility to frost of soil																																																															
	• susceptibility to liquifaction																																																															
	• etc.																																																															
	Land/slope stability map (natural/cut slope/trench wall)																																																															
	Subsidence susceptibility map																																																															
	Watertable rise condition																																																															
	Flow aquifer rate																																																															
	Required condition for intense rock blasting map																																																															
	Capacity to accept liquid waste area/site map																																																															
	Capacity to accept solid waste area/site map																																																															
	Cost for reclaimation																																																															
	Cost for treatement of mine fire																																																															
	Cost of engineering works																																																														
	• topsoil removal																																																														
	• cleaning and gubbing																																																															
	• cut and fill																																																															
	• embankment																																																															
	• drainage treatment																																																															
	• excavation																																																															
	• etc.																																																															
	etc.																																																															

Table 3.7.2 Check-list for designing series of map topics used in preparation of GILM : Relationship of IGI and UGI

IGI \ UGI	Suitability zone/area/site for geological resources developement	* mineral resource (surface/underground mining)	* industrial rock	* construction material resource	* coal mining	* groundwater	* etc.	Suitability zone/area/site for land developent/ build up area	* industrial (heavy/light) park	* commercial settlement	* newtowe/urban area	* etc.	Suitability zone/area/site for agricultural developent./conservation	Suitability zone/area/site for (active/passive) recreation	Suitability zone/area/site for other specific requirments	* natural conservation	* watershed conservation	* land supporting forest/ecosystem	* national park	* tourism (active/passive)	* geological heritage study area	* etc.	Selected specific civil engineering works corridors map	* road	* transport network	* railway	* canal dredging	* irrigation system	* etc.	Suitability zone/area/site for specific project Constraint/environmental effected area from developent	etc.	
Geological Hazard and Deterioration																																
Risk of hazard map																																
* flooding																																
* landslide																																
* seismic/earthquake																																
* volcanic																																
* landslide/earthflow																																
* subsidence																																
* flood of hericane																																
* Tsunami destruction area																																
* submerged area from sea level risk																																
* etc.																																
Susceptibility zone/area of hazard/deterioration																																
* land erosion																																
* coastal erosion																																
* riversouth siltation problem																																
* toxic mineral/element disseminated																																
* active fault zone hazard																																
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* embankment																																
* drainage treatment																																
* excavation																																
* etc.																																
etc.																																

compilation of GILM of Changwat Prachuap Khiri Khan remote sensing are used, and be demonstrated in the following Chapter 4.