Action Plan for the Establishment of a National Geographic Information System for Natural Resources Management

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Thailand Development Research Institute Foundation

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Chapter 1
Introduction

In the last few years there has been a literally unparalleled growth in the use of GIS technology within the Kingdom. From no sites as little as five years ago, there are now over thirty sites applying this technology. This increase reflects a worldwide phenomena which has made GIS technology the fastest growing segment of the computer industry—it is expected to reach over $10 billion US a year by 1994.[1]

Why has GIS shown such rapid growth? Basically because GIS is a technology that **works** coming at a time when it is **needed.** Concern for our environment and resource base is reaching all levels of the world's societies. Since most of the information needed to properly manage our earth's environment is spatial in nature it is only natural that people have turned to this technology seeking solutions to these types of problems. If we are going to change our world in a conscious way, we must first have a conscious understanding of what our world is really like.

The maturity of any technology is basically a function of the success it enjoys when it is applied. Probably the most severe test GIS has undergone to date has been its use in the recent conflict in Kuwait, both during the *Desert Shield* and *Desert Storm* operations.[2] This was a literal *life and death* trial—the lives of Allied forces and civilians depended to a great deal on the successful application of GIS technology. The results should speak for themselves.

While the potential benefits of GIS technology have been recognized by many nations, there is now also recognition of some of the obstacles to the full and rational use of this technology. For example, three national GIS research centers have been established in Canada (IGISE, Institute for GIS in Education) , the United States

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[1] Hughes, J. 1990, *GIS Job Opportunities Abound*, GIS World Vol. 3, #6, pp.63-68.
[2] Porter, E. 1991 *GIS: Washington*, GIS World Vol. 4, #2, pp.30-32.

(NCGIA, National Center for Geographic Information and Analysis), and in the United Kingdom (RRL, Regional Research Labratories) to promote this technology (more will be said about these centers later).

The explosive growth of GIS technology in Thailand, while promising and certainly of benefit to the continued development of the Kingdom, still needs some assistance to realize its full suite of advantages for the Kingdom. The GIS industry within Thailand is still in a relatively embryonic state. As such it is still somewhat amenable to **constructive** changes to its future directions. The time is therefore ripe for the development of a plan to outline the future paths that this technology will take within Thailand. The proposed form of this plan to promote GIS in Thailand takes shape within a National GIS (NGIS) Center, the five year action plan for which is the subject of this report.

In designing a plan for any organization, it is important to consider the possible forms the agency will **finally** assume. While one may **attempt** to absolutely designate this final form, it will only rarely resemble the actual organizational structure of the agency. For instance, outside influences from global economic factors will have an influence on the organization—will a nation's economy support the designated activity at the required levels of spending? Political questions arising as governments and their policies change—previously agreed upon policies can be reversed literally overnight. It is therefore important to build some measure of flexibility into any plan that involves an organization. This measure of flexibility may take the form of a set of **major functions** that the agency should undertake to achieve its main role, along with some broad strategies to help it fully develop these functions. It is as equally important to build in some flexibility for an organization to **improvise**. While planning is significant, in the end an organization's ability to improvise in the face of an ever changing world will, to a large extent, determine its success.

One logical form for a technology promoting agency is a **center**. All research and implementation activities, budgeting, coordination, etc., would be centralized. These activities would be **controlled** entirely from within the center. There are several advantages to such an omnipotent agency, there is however one **fatal drawback**—its creation involves the turning over of certain *powers*[3] by the various agencies nominally under its control, something usually repugnant to any organization.

Another form for this agency, one that is perhaps more amenable in the Thai context where **compromise** and **consensus building** are important, is as part of a network of *equals*. The agency's role would then be one of coordination rather than domination. It would serve the user community in a positive and above board manner—its activities being **transparent** to the user community. This theme will be further developed in the following sections.

As for the **main** institutional location for either of these two models, it logically belongs within the government ministry assigned the task of **technology promotion**—the Ministry of Science, Technology and Energy (MOSTE). MOSTE has a clearly defined and well accepted role for these types of activities and is thus the most appropriate *home* for this technology promoting agency.

The following section provides an introduction to spatial information, who has it, and what good is it. It is provided as a background for the National GIS Center's Action Plan.

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[3] In this case information, which in a sense is power.

Chapter 2

An Introduction to Spatial Information

The Information Age

The *Information Age* is upon us, and to such an extent that information has recently been called the *currency of the future.*[1] We are swimming in a sea of data from the morning newspaper to the nightly television news, from minute-by-minute stock prices to the latest figures on deforestation, information floods our senses and at times threatens to overwhelm us. The human race seems obsessed with information: we are constantly developing new information sources (surveys, maps, satellite images), as well as novel ways of gathering and organizing it (computers, satellites, laser disks). We have even begun calling those dealing with it *information workers* rather than the more pedestrian *clerical workers*. Why is this so? Why do we gather such immense quantities of data?

Information gathering seems to be a fundamental human activity that stems from two basically human traits—our ability to make decisions and our innate curiosity. Placed in a strange environment, we will immediately start to explore it; this is readily apparent to anyone who has ever watched a small child. Perhaps more importantly, humans make decisions—from mundane choices such as *what shall I wear today*? or *what shall I have for lunch*? to the more profound *where should I locate my new factory*?; *what should I do about deforestation*?; *what might happen if the sea level really does rise*?; *what is an acceptable industrial pollution load that does not compromise the quality of life or deflate a booming economy*? This need to make decisions has helped fuel this enormous collection and dissemination of data. Paralleling this, perhaps even leading it, has been a technological revolution allowing us to harness the power of

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[1] 28th Annual URISA Conference Theme, Edmonton Alberta, Canada, August 1991.

computers to process and to help gather our information.[2] Computing power once restricted to major government agencies and large corporations is now being delivered to our desktops. Real computer power can now be had at a modest price, making it affordable to an increasingly wider audience.

The Need for Information

All fields of human endeavor require information. Real estate agents must know the state of a piece of property as well as the current market conditions in order to turn a profit. A civil engineer laying out a road needs to know the slopes, soil and geological conditions over the proposed route; other required information might include the location of sites with suitable building materials close to the proposed route. A governor allocating budget might need to know which of the villages in his province are short of water in order to establish how much of his limited budget is necessary for building weirs and irrigation canals. In arriving at a policy to protect a country's remaining forest a government minister responsible for natural resources would need to know the status quo of the forest as well as the historical rate of its encroachment—is it *slowing down or accelerating*? This type of political decision might be further complicated by the involvement of landless farmers—*how many and how poor are they*? Each of these various activities and the decisions associated with them requires information in order to be successfully carried out.

Natural resources management is a field where information is crucial, and where information has been acknowledged as the first requirement to successful management of natural resources and the environment.[3] Recognition of changes in the status of the earth's environment or resource base is underlaid with a thorough grasp of the facts about that change—the past, the status quo and the potential futures. Monitoring threats to biodiversity, reckoning real environmental costs in national accounts, and creating viable pollution control policies all need accurate and timely information. But what kind of information? And where do we get it?

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[2] One may argue the chicken or the egg here—which came first, the information explosion, which drove the need for computer or computer themselves, which created the information explosion by virtue of making it easier to collect and store data.

Characteristic of natural resources and environmental concerns are questions regarding *where*—what is the quality of water **here**? Is there any forest left **there**? Can bananas be profitably grown **here**? **Questions of geography are involved**. In fact, geography and the data describing it are a part of our everyday world.[4] Almost every decision taken by humans is constrained, influenced or motivated by geography. For example, fire trucks are sent to fires by the fastest route; local governments receive their budget share on the basis of population; and diseases are investigated by identifying areas of prevalence and rate of spread. Some of today's most pressing problems intrinsically involve geography—tropical deforestation, acid rain, rampant urbanization, overpopulation, global climate change, even hunger.

Geographic Information Systems

Thus, a real need for geographic information has paralleled the computer revolution and the coming of the Information Age. This need and the opportunity afforded by increasingly cheaper computing power have together resulted in the creation of a computer-based technology specifically designed to handle geographic data—**Geographic Information Systems**. A Geographic Information System (GIS) is, in its broadest sense, a collection of computer-based procedures used to store and manipulate geographic data. Geographic data are inherently a form of **spatial information**. What is spatial information, and what role does it in play in the management of natural resources? What is a GIS, and how can using a GIS help in the decision-making process? The following sections will attempt to answer these questions.

What Is Spatial Information?

From earliest times, people have been making maps of the earth's surface and of the environment around them. Some cave drawings indicated routes to hunting areas, others showed where water might be found. Land surveying and map making played an integral role in the Roman Empire. Military strategists have long made and used maps—

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[3] Clark, W.C., 1990, *Managing Planet Earth*, Scientific American Special Issue: Managing Planet Earth. Vol: 261 #3, pp 18-28.

The Art of War, published during China's period of the Warring States (476-221 BC), emphasized the creation and use of maps as one of its five principles of warfare. The first recorded evidence of maps in Thailand was a military map compiled in 1350 AD, during the reign of King Rama I.[5]

Fundamental Components of Spatial Information

Traditionally, geographic data have been shown to users in the form of maps. Paper maps and the accompanying documentation have been what customarily constitutes a geographic database. Geographic data are commonly characterized as having three fundamental components:[6]

- **the phenomena being reported** (physical dimensions such as size or some type of class)
- **the spatial location of this phenomena**
- **the time when this phenomena were active**

Spatial information describes phenomena existing at a certain location, at a specific point in time. It is information relating to a discrete place on the earth's surface or **georeferenced** data.

Physical dimensions might include population, width of a road, depth of a lake, or the elevation of a mountain peak. The class of a phenomena might be the type of rock, a soil, a category of forest, or even the name of a city. The location—pointing out exactly where something can be found—is usually specified with reference to some kind of coordinate system, such as latitude and longitude, or UTM[7] meters, which are commonly found on base maps here in Thailand or even street addresses.

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[4] ESRI, *Understanding GIS*, 1991.

[5] Tongsawang, T. et al, 1987, *Map and Photo Reading* (in Thai), Sang Chan Publishing, Bangkok.

[6] Aronoff, S., 1990, *Geographic Information System: A Management Perspective.* WDL Publications, Ottawa, Canada.

[7] The UTM or Universal Transverse Mercator method of projecting the earth's surface onto a grid was developed by the United States Army in 1947. Its main advantage over other type of map projection is that it uses rectangular coordinates and can be used the world over. For a more detailed description see John Synder, 1982, *Map Projection Used by the United States Geological Survey*, Geological Survey Bulletin 1532.

While usually not stated explicitly, the element of time is often a critical component of spatial information. Some types of spatial data, such as soils and mountains, are fairly static, in theory changing little over time.[8] On the other hand, some spatial information, such as land use, is exceptionally dynamic. If an area is undergoing rapid change, information can go out-of-date quickly, making it unsuitable for decision making requiring the most current data. However, if one were interested in historical trends as input into predictive models, this type of *dated* information becomes an extremely valuable asset.

Aspects of Spatial Data

In using spatial information, we must always keep in mind that this data is only an *abstraction of reality*, because in collecting spatial data, it is not feasible to assemble every bit of information available over an area. It is not wanted nor is it needed—we want only data we think would be useful. The most important aspects of spatial data to consider are accuracy, precision, time, currency and completeness. **Accuracy** measures how often, by how much, and how predictably the data will be right. **Precision** measures the fineness of the scale used to describe the data and at which it was collected. Scaling is an important concept that is very often misunderstood by those not familiar with cartographic principles. The scale at which data are collected will determine future usage. A soil map sampled at a scale of 1:50,000 will **never** have the precision or accuracy of a 1:10,000 scale map regardless of the scale to which the map graphic is enlarged.

Very often, people will try to mix drastically different map scales—resulting in the creation of unscientific garbage. Thus, a map may have an apparent precision that does not match its true precision—a situation that will lead to incorrect decisions based on an *apparently* accurate map. A general rule-of-thumb in combining map scales is to always progress towards coarser map scales (for example combining 1:50,000 and 1:25,000 scale maps the resulting product would normally be used at 1:50,000). **Time** indicates at what point or over what period of time were the data collected. **Currency** designates how recently the data were collected. **Completeness** refers to how much of the area of interest is covered by the available data.

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[8] This is commonly called the shelf life of data.

Guidelines for Collecting Spatial Information

There are several principles or guidelines generally applied to the collection and use of spatial information:[9]

- **You can't use data that you don't have.** The pieces of information that are collected will have an impact on the type and the level of analysis that can be accomplished. Who holds spatial information and what policies govern its availability also play an important role.
- **The most cost-effective data collection method is to collect only data that you really need.** It is costly to collect, store and analyze data. Excess data can hinder analysis by making access to the really needed data that much harder.
- **The ideal data quality is only as good as you need it** (the minimum level that will get the job done).
- **It costs more and more to get less and less data quality.** The law of diminishing returns also applies to spatial data collection. Each gain in data quality usually costs more effort (money, time, etc.) to acquire.
- **Data is of no value unless it is the right data, in the right place at the right time.** The way that we organize spatial data plays a major role in its successful use. Geographical databases are usually so large that when computerized the form and organization will have a major impact on the productiveness of the system.
- **The best data model is the simplest one that does the most with the least data.** Modelling always involves costs. These costs may be budget, time or wrong answers. The more complex the model, the more costly it is to use.
- **A too high or too low performance level is expensive.** A level of data collection or modelling above that which is required can sometimes be costly because it produces results that do not contribute much to success; while under performing will add costs by producing incorrect results, by being late, or by losing opportunities due to better solutions.

Points, Arcs, and Polygons

Spatial information itself is usually represented on maps as one of three types of spatial primitive: point, arc, or polygon feature (see ***Figure 2.1***). Points are used to represent the location of geographic phenomena at a point or when a line or area feature

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[9] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

is too small to represent at the map scale. Examples of point data include groundwater wells, point pollution sources, mountain peaks, or cities (on a small scale map). An arc is an ordered set or string of points. Arcs are used to represent features that are too small to be shown as a polygon (such as roads or streams) or which have no real width (such as political boundaries or contour lines on a topographic map). A polygon feature is an area or region enclosed by arcs. Forests, soils, or a lake are examples of polygon features.

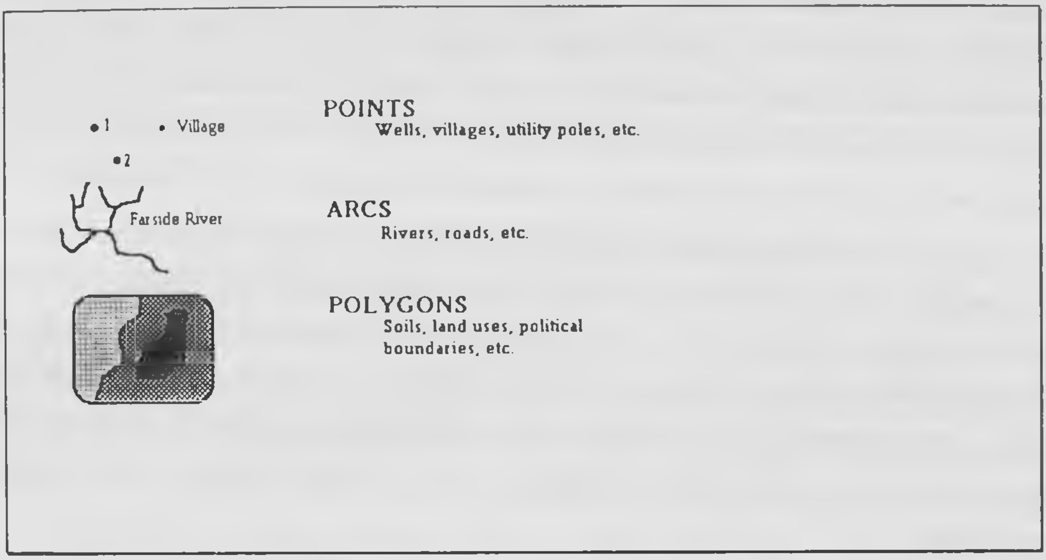

Figure 2.1: Spatial Information Primitives

Discrete and Continuous Data

Some geographic information can be decomposed into one of the three spatial primitives mentioned above—these types of information can be thought of as **discrete** spatial data. Another type of spatial data that does not readily fall into such neat categories is called **continuous** data. Continuous features are not spatially discrete; there are no well-defined breaks between possible data values.

Elevation data (which in reality is a surface) is an example of continuous data.[10] An elevation surface can be thought of as having an infinite number of points. As mentioned above, it is not practical or possible to record every point on the surface—we

[10] Elevation refers to an absolute height above some datum plane, usually sea level.

can only hope to gather the most significant points. Normally, samples are taken across the surface at regularly spaced points such as in a grid or as a series of contour intervals.

The triangulated irregular network or TIN is another method, that is being widely adopted for storing and manipulating continuous data, especially elevation data. The surface in question is approximated by a series of irregularly spaced points in space, each having high information content.[11] These points should approximate features found on the earth's surface such as ridges, stream channels, mountain peaks, valleys, passes or even man-made features such as dams or roads. Thus, it is not necessary to sample areas of little or no change in elevation (and therefore of little interest) such as flat river plains, instead, efforts can be concentrated on areas of high relief such as mountains, valleys, and so on. The points are developed into a series of connected triangles, where each of the triangle's nodes corresponds to one of the irregularly spaced points on the surface. Besides the raw elevation data, two other important pieces of information are derived from elevation surfaces—slope and aspect. **Slope** is a measure of the rate of elevation change, while **aspect** is the direction that a surface faces. Slope is often an extremely crucial piece of spatial information to many natural resource and engineering applications.

Who Has Spatial Information?

In Thailand, various branches of the Royal Thai Government (RTG) hold a monopoly on spatial information. While some private companies or universities may occasionally carry out ad hoc surveys, all systematic spatial data collection is carried out under the auspices of one RTG agency or another. *Table 2.1* provides a brief overview of the various spatial data collection tasks and inventories of the RTG.[12] As with any

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[11] ESRI, 1987, *TIN Users' Guide*. For further information concerning TIN, also see T.K. Puecker et al, 1976, *Digital Representation of Triangulated Irregular Network (TIN)*, Office of Naval Research, Geography Program, Tech. Report #10, H. Akima, 1978, *A Method of Bivariate Interpolation and Smooth Surface Fitting for Irregularly Distributed Data Point*, ACM Transactions on Mathematical Software, 4(2), or M.J. McCullagh and C.G. Ross, 1980, *Delauney Triangulation of a Random Data Set for Isarthmic Mapping*, Cartographic Journal, #17(2). The pioneering work on TIN was done at the Department of Geography, University of Zurich by Martin Heller and colleague.

[12] For a more detailed description of the various spatial information gatherers see TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*

other type of information, there are two groups concerned with spatial data—those who create it and those who consume it.

Royal Thai Survey Department

By far, the military is the largest source of spatial information in the Kingdom. This is not surprising given the interest the military has traditionally shown in maps and geographic data throughout history. This is also due to Thailand's recent history of communist insurgency and the existence of sometimes unfriendly neighbors on two of its four international borders.

The Royal Thai Survey Department (RTSD) is the section of the Royal Thai Army (RTA) charged with creating base maps of the Kingdom, and thus is a producer of spatial information. RTSD functions include ground and air survey for map production, staff education, geodesy, and geophysical research. It will also carry out ad hoc mapping projects at the request of other RTG agencies. Since its products are ordinarily used within the military, data security is a main concern of the RTSD, especially in border areas. Consequently, its map products are not widely distributed. In terms of data updating, RTSD will normally update about 50 base maps a year, with emphasis given to sensitive areas or special projects. While it is striving to accelerate this process with the aid of computerized mapping systems (CAM) and satellite imagery (especially SPOT), it is hampered by a lack of recognition for the importance of its work. This has resulted in a relatively limited budget compared to the size of its task. While exact budget figures for mapping and map updating are unavailable, it was reported several years ago that the RTSD's normal mapping budget amounted to only 3 million *baht*.[13] (*Table 2.2* provides some of the available budgetary details for those RTG agencies concerned with spatial information).

The Base Map

RTSD's main product is a map used as a basis for other maps—a base map. It depicts essential geographic features such as elevation, infrastructure, major political

[13] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*

boundaries, and surface water features like rivers and lakes. It is used as a foundation for other maps that are devoted to a single theme such as soil or land use maps.[14]

An accurate base map is essential to our ability to make use of spatial data. It provides the basic coordinate system or geo-coding for these thematic maps.[15] Thus, all thematic maps constructed from the same base map will have a common coordinate system. A common and accurate coordinate system is a critical factor to consider in geographic data analysis. For example, if we are overlaying two maps, it is essential that the features which should overlap do indeed overlap—for instance, if the coordinate systems differed by an offset of 100 meters, the road features on one map may well fall into the ocean on another map, making a hash of any analysis attempted with this data.

Thailand is extremely fortunate to have the entire Kingdom covered by base maps at a scale of 1:50,000.[16] The cities, villages, mountains, beaches, plains, rivers, canals, and infrastructure are mapped over the whole country. Thus, a solid foundation exists upon which other thematic data, such as soils, land use or geology, can build. Because of the RTSD base map scale, the majority of natural resource and environmental information, is therefore most widely available at a scale of 1:50,000 or 1:100,000.[17]

Department of Land Development

The next largest holders of spatial information in the RTG are those agencies charged with managing the Kingdom's natural resources—its soil, water, minerals and forests. In terms of data volume, the largest is the Department of Land Development (DLD) within the Ministry of Agriculture and Cooperatives (MAAC). By law, DLD is responsible for mapping soils, present land use, and geomorphology,[18] as well as formulating agricultural land use plans for the entire Kingdom. Another primary

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[14] Maps devoted to a single subject or theme are commonly referred to as **thematic** maps.

[15] Geo-coding is the process of aligning referenced X,Y coordinate locations to geographic features.

[16] A scale of 1:50,000 means that for every one distance unit, say centimeter, on the map there exist 50,000 in the real world. Thus, one centimeter on a map represents 500 meters on the earth's surface. The larger the scale (that is the smaller the scale number) the more accurate the data.

[17] Data reproduced at a scale of 1:100,000 are usually a reduction of data at 1:50,000. While it may be done for purposes of data accuracy, data is most often printed at this scale simply to save production costs. It takes fewer 1:100,000 scale maps to cover a given area than 1:50,000 scale maps.

responsibility includes soil and water conservation. DLD also produces geomorphology maps at scales ranging from 1:100,000 to 1:1,000,000, on an ad hoc basis.

DLD has completed an inventory of soil over the whole of the Kingdom at a scale of 1:50,000. It also has a large, comprehensive database with detailed information concerning the physical and chemical characteristics for each of the soils found in Thailand. Although land use maps for much of the country also exist, they are usually not current, due to the exceptionally dynamic nature of this data. On average, land use maps are about five to seven years old; however, as indicated previously, they are excellent information sources concerning past conditions and can thus be vital in understanding and predicting land use changes.

The DLD is both an information consumer (RTSD base maps) and an information producer (soil and land use maps). It is perhaps its own best customer, in that the soil maps it produces are fundamental to the formulation of provincial land use plans. Several other RTG agencies, including Royal Irrigation Department, Department of Mineral Resources, Office of Agricultural Economics, Office of Agricultural Extension, Agricultural Land Reform Office, Office of Accelerated Rural Development, also use its soil maps and land use data.

Overall, the DLD's information policy is more liberal than that of most RTG agencies. It sells provincial soil maps and reports at a nominal cost,[19] and it will sometimes provide its land use maps and plans upon official request. It is also willing to provide physical and chemical soil information in a digital form, although no policy has been established concerning costs, distribution restrictions, or liabilities. The DLD is presently improving its information by automating its soil map database and introducing image analysis facilities to accelerate its land use mapping.

The DLD's allotment for geographic data gathering purposes amounted to about 21 million *baht* for the budget year 1991, a significant decrease over 1990's budget of 27

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[18] Briefly, geomorphology is the science dealing with the form of the earth's surface. It seek to quantify the shape and origin of the earth's mountains, foothills, river valleys and plains.

[19] For example, DLD will sell a provincial soil map for as little as 250 *baht*. For a province like Samut Prakan with an area of almost 600,000 *rai*, it costs approximately 900,000 *baht* to gather the soil data (using 1.5 *baht* per *rai* mapping cost). DLD would have to sell 3,600 sets of maps to recover its data gathering cost.

million *baht*. The proportion of total budget expended for spatial data gathering also declined, from 3% to 1%, while its budget as a whole grew by some 24%. This may be attributed to the declining importance of agriculture to the Kingdom's economy as well as to the fact that the country's soils are now almost 100% mapped. This decline is worrisome since land use data will play an increasingly important role in allocating the Kingdom's diminishing land resources which are severely threatened by the current rapid urban expansion. Moreover soil information—particularly engineering characteristics—will continue to play a meaningful role in construction, especially during the present construction boom. Soil information also assists rural poor in improving their crop production and resulting income.

Over the last two years, the DLD has allocated an average of about 2% of its total budget for the gathering of spatial information. This represents merely 0.08 *baht* per *rai* when the whole Kingdom is considered. The budget that the DLD expends on assembling spatial information is insignificant when compared to the value of what is being mapped. For instance, soil erosion alone accounts for around 3 billion *baht* per year, while the value of agricultural land has been estimated at 5 billion *baht* per year.[20]

Department of Mineral Resources

The next largest spatial information holder within the natural resources group is the Department of Mineral Resources (DMR) in the Ministry of Industry. The DMR is charged with mapping and evaluating all of Thailand's mineral resources—the groundwater, tin, lignite, antimony, construction materials, etc. It acts as a geoscience technical center, on a national and regional basis, to disseminate the information it has compiled to the public.

DMR's 1:50,000 scale series of geologic maps covers about 50% of the country with the remainder being mapped at a rapidly accelerating pace. The whole Kingdom is covered by 1:250,000 scale maps. Hydrogeologic (groundwater) maps cover a portion of the country, usually where groundwater usage is critical or where groundwater resources are plentiful. Major groundwater areas that are mapped include the BMR, Chiang Mai, and Hat Yai areas. Groundwater well data, however, covers most of the wells under the

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[20] Theodore Panayotou, personal communication, 1990, Harvard Institute for International Development (HIID).

DMR's permit obligation. This information has been developed into a comprehensive database made available to the general public. The DMR has recently completed a nationwide magnetic survey with the aid of the Canadian government, this is being made available at a scale of 1:50,000 as an aid to mineral exploration and evaluation.

Table 2.1 Main Spatial Information Producers

Ministry/ Agency	Main Product
Royal Thai Army	
RTSD	Topographic maps (1:50,000, 1:250,000)
Ministry of Agriculture and Cooperatives	
DLD	Soil, land use (1:50,000)
RFD	Forest, forest reserve (1:50,000, 1:250,000)
RID	Irrigation infrastructure, climatic, hydrology, statistics
Ministry of Interior	
DOL	Cadastre (1:1,000, 1:5,000, 1:10,000)
DTCP	City plans (1:8,000, 1:16,000, 1:20,000)
DCD	NRD2C database
Ministry of Industry	
DMR	Geology (1:50,000, 1:250,000) Hydrogeology (1:50,000) Groundwater wells
Ministry of Science, Technology and Energy	
NRCT	Satellite imagery (various scales)
Office of the Prime Minister	
NSO	Political boundary (1:50,000, & 1:5,000)

Table 2.2 Spatial Information Producers Budget Allocations

Ministry Agency	1990 Mapping	1990 Total	1991 Mapping	1991 Total
Ministry of Agriculture and Cooperatives				
DLD	27 (3%)	1,023	21 (1%)	1,268
RFD	77 (3%)	2,791	101 (3%)	3,692
RID	355 (2%)	14,732	420 (2%)	16,818
Ministry of Interior				
DOL	91 (8%)	1,096	135 (9%)	1,456
DCD	14 (1%)	947		
DTCP	14 (7%)	188	20 (5%)	410
Ministry of Industry				
DMR	27 (3%)	916	26 (2%)	1,093
Ministry of Science, Technology and Energy				
NRCT	83 (55%)	150	127 (57%)	221

Notes: Figures in millions of *baht*. NRD2 Survey is biannual, thus no budget requests until 1992.

Source: Budget Bureau

In general, the DMR's information policy regarding its geological maps is fairly restricted. It normally limits distribution of its geological maps to other RTG agencies but will occasionally furnish maps to mineral exploration or mining companies cooperating with it. The DMR supplies its spatial information to the Office of National Energy Authority, the Royal Irrigation Department, the Royal Forestry Department, and the Department of Land Development, among others. On the positive side, the DMR is in the process of establishing its own integrated information system. This is unique among RTG agencies, since the DMR has had a clear policy regarding information for several years and has carried out its own feasibility study for this information system.[21] DMR's total 1991 budget was 1.093 billion *baht* of which some 2% was earmarked for

[21] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

mapping purposes. This is a decrease compared to its 1990 budget of 916 million *baht*, which allocated about 3% for mapping. Again, the expenditures on spatial data gathering pale in comparison to the value of the theme being mapped. Mineral exploitation accounts for about 20 billion *baht* per year, while groundwater extraction amounts to about 10 billion *baht* per year.

Royal Forestry Department

The Royal Forest Department (RFD), MAAC, is responsible for information concerning the country's forests, forest reserves,[22] and national parks. Since the implementation of the logging ban, its main task has been the management of the Kingdom's forests. It accomplishes this task through ground survey and satellite image interpretation and is perhaps the foremost institute in the country in terms of production remote sensing work. RFD's forest reserve maps are an important information source for land ownership, at least as far as public versus private land is concerned. For example, the Agriculture Land Reform Office relies heavily on these maps in determining potential land reform areas.[23] While these are normally stored as log books[24] or in the form of 1:250,000 maps, they can be transferred to the more widely available scale of 1:50,000.[25] The RFD will usually provide maps of forest reserve and forested land on official request.

The RFD's geographical data gathering budget for 1991 is 3% of its total budget of 3.69 billion *baht*. This represents virtually no change from 1990's budget share of 3% against a total budget of 2.79 billion *baht*. Forested land has been estimated to be worth

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[22] The term forest reserve is misleading, as it may or may not have anything to do with forested land. Technically it refers to land not forest, that is nominally under the jurisdiction of the RFD. It may have had forest cover at one time in the past, but this may not be true at the present.

[23] Hasting, P., Chaiyacupt, C.,Boonraksa, C., Chaiwara, T., 1989, *Identification of Potential Land Reform Areas in Chanthaburi Province*, In Proceedings TDRI organized seminar GIS Applications in Thailand. November 8, 1989, Bangkok.

[24] Log books record the field traverse (direction, angle, distance, etc.) of the RFD party that surveyed a forest reserve boundary.

[25] Being aware that the precision of the map product is still at the scale of 1:250,000, despite the map graphic being at 1:50,000.

around 5 billion *baht* per year[26]; the cost of mapping it represents a meager 2% of its total value.

Royal Irrigation Department

The Royal Irrigation Department (RID) also in the MAAC, records large amounts of data concerning water—irrigation infrastructure, river flow, river levels, and daily rainfall. Its main task is water resource development for agriculture, and it is also responsible for drainage systems, hydrology control, water resource development for industrial and public consumption, and implementing any large-scale irrigation system. The RID is responsible for maintaining irrigated area maps, as well as maps detailing its irrigation infrastructure.

With the support of the Japanese government, the RID has had a large and well-run integrated information center for several years. Its information policy has been very forward looking and is among the most liberal in the RTG. RID has been willing to provide data (climatic, daily rainfall, water flow, river levels, and so on) in **digital form** to most requesting agencies. RID's budget expenditures for assembling spatial information have been limited—only 2% of its total budget (1.618 billion *baht*).

National Rural Database 2

The National Rural Database II (NRD2C), maintained by Thammasat University for the Department of Community Development (DCD), is another major source of geographic information. This biannual, village-level database encompasses nearly every village in rural Thailand.[27] It began as an ad hoc survey funded by USAID in 1984 to identify poor rural villages. It has since expanded to include all rural villages, becoming a permanent socioeconomic survey by order of the Cabinet in 1987. The RTG assumed full financial responsibility for the survey in 1990. Socioeconomic data covering 1984, 1986, and 1988 is available.

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[26] Theodore Panayotou, personal communication, 1990, HIID.

[27] In 1988, over 56,000 villages were surveyed.

NRD2C records most of the important socioeconomic variables—including demographics, occupation and livelihood indicators, education, health, quality of life, income, and land tenure—for rural Thailand. In its original form, NRD2C is not strictly spatial data, as it does not contain coordinate locations for each village in the database. It is, however, a relatively simple matter to add a coordinate location to each of the villages recorded in this database.[28] Once this data become true spatial information, it unlocks a window into the socioeconomic and physical conditions existing in rural Thailand through which planners and policy makers can peer to develop objectives and agendas and assess their success or failure in human terms—Were people's lives really improved by what was done? Beyond its actual content, this database is especially useful because it is in digital form, making it potentially one of the most exciting databases in Thailand today.

The NRD2 database has been made widely available to most organizations requesting it, even to the extent of allowing the private sector to purchase copies at a nominal cost.[29] The budget allocated for the collection of the NRD2 was around 14 million *baht*—an information bargain for the amount and type of data it provides.

National Statistics Office

The National Statistics Office (NSO) is an additional source of spatial data. Besides taking the census, NSO is also responsible for maintaining political boundary maps. *Tambon, amphoe* and *changwat*[30] boundaries as well as *tesaban* and *sukapiban* are demarcated by NSO under the direction of the Local Administration Department, Ministry of Interior. This makes it an ideal source for demographic data from the tambon-level up when used in conjunction with registration data available from the National Registration Department, Ministry of Interior or its own census.

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[28] The Royal Thai Army is reported to hold a database with just such information.

[29] The entire database can be had for about 3,000 *baht*. This come to approximately 19 villages per baht!

[30] These Thai terms are equivalent to sub-district, district and province, respectively, while municipalities and sanitary districts are equal to *teasban* and *sukapiban* in urban settings.

National Research Council of Thailand

National Research Council of Thailand additional source of spatial information other than maps is data gathered by remote sensing. **Remote sensing** is a technique of collecting information from a distance—in this case a satellite in orbit around the earth. Remotely sensed data, although spatial data when properly geocoded, is **raw data**—it needs to be **interpreted** before it can become spatial information. The interpretation process can be long and involved, requiring practiced researchers and proper facilities to achieve a high level of accuracy.

The RTG agency responsible for remote sensing is the National Research Council of Thailand (NRCT).[31] Its satellite signal ground receiving station, supported at first by the American and later the Canadian governments, is among the most advanced in the world. Through it, NRCT receives LANDSAT, SPOT, and MOS-1 satellite imageries that are relevant to natural resources and environmental management. The following is a brief discussion of two of the more commonly used satellite imageries, LANDSAT and SPOT.

LANDSAT

The LANDSAT program had its start in 1972 with the launch of LANDSAT-1.[32] LANDSAT-1 was the first non-military satellite designed to provide systematic global coverage of the earth's resources. LANDSAT-1 was followed by LANDSAT-2 through LANDSAT-5, with NASA launching the TM (Thematic Mapper) sensor aboard the LANDSAT-5 satellite in 1984. In addition to the TM sensor, it also carries an MSS (Multispectral Scanner), which provides an 80 meter resolution over four bands (green and red in the visible range and two near infrared bands). The TM sensor has a resolution of 30 meters and covers seven spectral bands—a dramatic improvement in both spatial and spectral resolution over previous sensors. TM images normally cover a swath 185 km wide, but subscenes corresponding to 1:50,000 scale maps can be produced.

The LANDSAT program was originally developed under the ideal of the *Open Skies Policy*, where data that was collected from space was to be **freely** available to

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[31] Specifically the NRCT's Remote Sensing Division.

anyone, regardless of national interests. In 1984 it was commercialized and turned over to the Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA) as the Earth Observation Satellite Corporation (**EOSAT**), under a plan backed by the U.S. Congress and the Reagan administration. LANDSAT images are distributed under the auspices of EOSAT, which licenses the right to receive LANDSAT data to various ground stations around the world. NOAA's administration of the LANDSAT program has recently come under fire from the U.S. Congress, citing increasing data costs and overly long turnaround times on data requests. The undersecretary of oceans and atmosphere at NOAA, John Knauss, said in testimony before a Congressional hearing: *Our experience with the LANDSAT program has led us to believe that commercialization is not possible.* It has been suggested that LANDSAT be brought back under government control within the Interior Department.[33]

SPOT

SPOT (Systeme Pour l'Observation de la Terre) is a satellite program begun by France in 1978, with its first satellite, SPOT-1 being launched in February, 1986. In contrast to LANDSAT, **was designed from the start to be commercial**. Its pricing and copyright policy reflect this concept. It carries two identical HRV (High Resolution Visible) sensors which can operate in one of two modes. In **panchromatic** mode, visible light is detected and an image with a resolution of 10 meters is produced. In **multispectral** mode, three images (green, red, and near-infrared) are produced with a resolution of 20 meters. SPOT images usually cover a swath 60 km wide, but as with the LANDSAT, subscenes equivalent to 1:50,000 scale maps can be produced. SPOT-2, with the same sensor configuration as SPOT-1 was launched in January 1990.

Remote Sensing in Thailand

Within Thailand, TM and SPOT are most widely used for land use mapping, especially forested land—and as an aid in the assessment of natural disasters such as the landslides in southern Thailand in 1988 and the devastation caused by Typhoon Gay in

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[32] The LANDSAT program was originally called the Earth Resource Technology Satellite or ERTS.
[33] Porter, E, 1990, *United States Federal Agencies* Column in GIS World. Vol. 3 #4, pp 22-27.

1989. From the 1991 RTG budget, mineral resource assessment will become another major application of satellite imagery during the coming budget year.

In 1990 NRCT's LANDSAT license cost about 16 million *baht*, while it's SPOT fee was about 9 million *baht*. LANDSAT's fee remained relatively constant at 16 million *baht*; SPOT's costs, however, increased considerably to 21 million *baht* for the 1991 budget year. NRCT's total remote sensing budget for 1990 was 83 million *baht*. This will be increased by 53% in 1991 to 127 million *baht*, making NRCT the largest RTG agency gathering spatial data in terms of budget percentage.

An analysis of RTG budgets dealing with remote sensing (see *Table 2.3*, this is not an exhaustive list as some agencies receive funding for spatial data gathering from outside sources are not recorded by the Budget Bureau) indicates that NRCT can expect about 9 million *baht* of income from RTG sources in 1991. While NRCT's 53% budget increase is reflected by an expected 57% increase in imagery sales, it is apparent that its increased operating costs are not being met by an equivalent increase in sales of imagery within the RTG.

It is evident that the few RTG purchasers of satellite imagery contribute little to the fixed operating costs, let alone to the necessary system upgrades and thus are being **subsidized** by the NRCT. Part of the reason may be found in the pricing scheme established by the NRCT (*Table 2.4*), which reflects the fact that its main satellite imagery products are commercial products. Another reason is the lack of adequate image processing facilities in RTG line agencies, which limits the utility of the images it does sell and restricts its potential customers.[34]

While exact details of the imageries being purchased by RTG agencies are not known, if one assumes that it was all 3 band, color SPOT (@31,200 *baht*, the most expensive), the budget expended could be used to produce about 280 1:50,000 land use maps which would cover approximately one-third of the Kingdom. Thus, it would take DLD (the line agency responsible for land use mapping) three years or a tripling of the entire current RTG remote sensing budget to acquire data completely covering the

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[34] Atwell, B., 1987, *Government Policy Issues for Satellite Remote Sensing in Natural Resources Development: Thailand*. In Proceedings of Remote Sensing '87: Remote Sensing and Information System for Planning and Development. Songkhla Thailand.

Kingdom. This hardly seems likely in view of the overall decline in DLD's spatial data gathering budget.

Table 2.3 RTG Remote Sensing Budgets

Agency	1990 (*baht*)	1991 (*baht*)
RFD	3,710,000	3,157,000
DMR	300,000	5,000,000
DTCP	1,465,400	0
OAE	300,000	500,000
DLD	0	512,000
NEB	63,000	55,000

Source: Budget Bureau

Recommendations

If data from satellite remote sensing is important to the management of the Kingdom's natural resources, there are two possible courses of action for NRCT: (1) to fully subsidize its satellite imagery making it freely available to all users within the country (the ideal of the original *Open Skies Policy* of the LANDSAT program) or (2) to dramatically increase the remote sensing budgets (and consequently their spatial data gathering costs) for all RTG line agencies. Obviously, because RTG agencies are reluctant to spend money on gathering geographic information, it is unlikely that the latter course would be feasible. The relatively meager amounts that the NRCT normally receives for this spatial data might be better spent on upgrading each individual RTG agency's image analysis capabilities in terms of equipment and staff training.[35] This would tend to help develop a future market for satellite imagery as well as a market for NRCT's own skills in image analysis.

Cadastral and Urban Spatial Information

The above spatial information can usually be found at the RTSD base map scale of 1:50,000. Apart from this scale there exists another larger scale of data normally

[35] For example, DMR's 5 million *baht* remote sensing budget for 1991 should be able to purchase 3 to 5, state-of-the-art image analysis workstations.

found in urban surroundings. Two RTG agencies customarily gather spatial information in this environment: the Department of Land (DOL) and the Department of Town and Country Planning (DTCP), both within the Ministry of Interior.

The Department of Land

The DOL is legally responsible for gathering detailed cadastral information and recording it on large scale maps (scales ranging from 1:1,000 to 1:10,000). The DOL is responsible for maintaining the cadastre for all public and private non-forest reserve land in the Kingdom.[36] Specifically, its responsibilities include public land surveying, protecting public land, utilizing public land to benefit the RTG, land allocation, land parcel adjustment, issuance of land titles, land registrations, control of real estate business, as well land and property tax evaluation. Thus the DOL is the country's primary land management agency, except for land defined as forest reserve. The importance of spatial data to the DOL is reflected in the relatively large portion of its total budget that it sets aside for such purposes: 8% of its 1990 budget of 1.096 billion *baht*, further increasing to 9% of 1.456 billion *baht* for the 1991 budget year. Other than NRCT, it is the only RTG agency that actually increased its spatial data collection budget in 1991.

Table 2.4 NRCT Satellite Remote Sensing Data Pricing

Product	Price
TM subscene (1:50,000)	13,750
TM Computer Compatible Tape (CCT)	55,000
SPOT panchromatic (1:50,000)	26,000
SPOT panchromatic CCT	59,800
SPOT 1 band, black & white (1:50,000)	11,700
SPOT 3 bands,black & white (1:50,000)	23,400
SPOT color (1:50,000)	31,200
SPOT color CCT	46,800

Note: All prices in *baht* for geocoded product. NRCT adds a 50% surcharge for rush service.

Source: Thailand Remote Sensing Center, NRCT

[36] The term cadastre refers to the legally recognized register of quantity, ownership and value of land parcel.

Updating Cadastral Information

The DOL's cognizance of the importance of spatial information is driven by several factors. First, the cadastral information in Thailand is presently in a state of flux. Accurate land deeds (*chanote*) exists for a relatively small area of the country only. They are restricted mainly to the larger urban centers and their surrounding suburbs, and it is estimated that only one landholder in six possesses a land title.[37] Less accurately recorded land certificates (*Naw Saw 3 Kaw* or NS3K) cover a slightly larger part of the Kingdom, mainly the newer urban centers' surroundings. The remaining land area, mainly rural or encroached reserve forest land, is covered by even less legally binding land documents (*Bai jong*, STK, etc.) Financial institutions usually recognize only chanote and NS3 as collateral. DOL is currently embarking on an ambitious project to reform its land record system and to upgrade all present land titles by issuing chanote for the whole Kingdom. This massive undertaking is scheduled to take 20 years, with initial support coming from the World Bank and the Australian International Development Assistance Bureau.

Second, the Thai Cabinet established a Central Valuation Authority (CVA) as an impartial body to evaluate property values. The CVA will value land as a basis for DOL's transfer fees and taxes, as a basis for local taxes, and as a source of information when compensating land owners in cases of government land acquisition. Thus, the CVA has need of an accurate land record system to which it could link its property valuations.

Finally, concurrent with the enhancement of existing land titles is the changing nature of Thailand's land use. More and more suburban and rural land is becoming **urbanized**—creating a need for more accurate and legally acceptable cadastral information. Credible cadastral maps are required if urban managers are to keep pace with rapid development and subdivision. In Bangkok, the cadastral maps have been described as *unsatisfactory, old, and dilapidated.*[38] In most urban centers in Thailand, the cadastral maps have not been updated for decades.

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[37] Angus-Leppan, P. 1989, *The Thailand Land Titling Project: First Step in a parcel-based LIS*, Int. J. Geographical Information Systems. Vol 3, #1, pp 59-68.

[38] Angus-Leppan, P. 1989, *The Thailand Land Titling Project: First Step in a parcel-based LIS*, Int. J. Geographical Information Systems. Vol 3, #1, pp 59-68.

Drawbacks and Advantages

Cadastral information would form an excellent basis for managing other thematic data were it not for the large scale at which it is recorded.[39] Almost no other spatial information concerning natural resources or the environment exists at this scale. As we have seen previously, the majority of Thailand's natural resources and environmental information is found at the RTSD base map scale of 1:50,000 and thus cannot be accurately integrated with cadastral data. Land Information System (LIS) proposals based on the premise of integrating cadastral and environmental information are therefore technically untenable and bound to fail.[40]

In orthodox urban situations, however, cadastral data can and do form the base maps for other spatial information. This spatial data deals with all of the urban area's intricacies, from individual land tenure to the location of a city's infrastructure—its water mains, electric poles, fire hydrants, and so on. In the Bangkok Metropolis, DOL, the Bangkok Metropolitan Authority, Metropolitan Electrical Authority, Metropolitan Water Works Authority, and the Telephone Organization of Thailand have begun a joint pilot project in Phra Khanong district to establish a multi-theme Land Information System (LIS). This project will cover an area of about 25 km^2.

Urban or cadastral based information is generally of considerable size. Consider for example, land tenure or cadastral data, where on a day-by-day basis, the land ownership, land use or the actual shape of a land parcel, is changing.[41] Add to this the other information that a complex urban entity generates and you have a truly staggering amount of information. Because of the size and complexities involved in urban or cadastral situations, the cost-benefits of an LIS would be expected to be high.

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[39] In fact in the United States and Europe it does. For example, it forms the basis of county-level LIS or Land Information System in many state in the USA, San Diego County, California, being a good example.

[40] For example see the proposed LIS in TDRI, 1990, *A Land Policy Study* edited by T. Onchan. TDRI Foundation Research Monograph #3.

[41] Hunter, G.J. and Williamson, I.P., 1990, *The Development of a Historical Cadastral Database*, Int. J. Geographical Information Systems. Vol 4, #2, pp 169-179.

Department of Town and Country Planning

City and town planning for the Kingdom is the responsibility of the Department of Town and Country Planning (DTCP). While technically the DTCP is responsible for formulating regional, provincial, municipal, and rural plans, it customarily limits its planning activities to the municipal level and has only recently forayed into the provincial level (Samut Prakan province). The principal spatial information that DTCP creates is a map, zoning a municipality into areas of approved activities—areas reserved for agriculture, parks, nature areas, industry, housing estates, etc. The DTCP prepares these master plans for municipalities, but implementation and zoning enforcement resides with the local authorities. The DTCP, with the aid of JICA, is acting to improve and expedite its planning practices, which to date have not kept pace with the rapid changes in Thailand.

The DTCP's total budget increased 118% from 1990 to 1991, from 188 up to 410 million *baht*. The budget portion expended on spatial data gathering, however, fell as a result, from 7% (14 million *baht*) to 5% (20 million *baht*).

What Good Is Spatial Information to Managers?

The well-being of human societies has always been dependent upon their surroundings. From Thailand's early irrigation-based city-states to its present day urbanization and approaching NIC status, the geography of human communities has been important. It is becoming increasingly more important now that the world is becoming more crowded and its resource base is diminishing. Past laissez-faire attitudes that resulted in environmental degradation are no longer being tolerated, from grass-roots to international levels. Converting farm land to a new urban area, granting of mining concessions, constructing a dam, or building a hazardous waste disposal site are activities that are now being scrutinized by different regulatory agencies and are frequently the subject of vehement public opposition. Globally, acid rain, climatic changes, the specter of rising sea levels and tropical deforestation have been recognized by many as problems that affect the economic and social well-being of the entire human race. Indeed, geography and the very fabric of human societies are inextricably interwoven[42].

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[42] ESRI, 1991, *Understanding GIS*.

Today's managers are faced with solving complicated problems—that are no longer single-faceted or exclusive to one discipline. In addition to the complexities of the problems themselves, further complexity is introduced by diverse and sometimes contradictory government regulations and jurisdictions. Even the lack of regulations and jurisdictions can sometimes create an additional layer of difficulty. Complex interrelationships exist between the various components that comprise today's environmental and natural resources issues—geography, ecosystems, economics, and public opinion are all important factors. Success or failure in dealing with these issues will be determined by how well managers are able to integrate multidisciplinary knowledge and expertise.

Decision Making Under Uncertainty

Decision makers thus require detailed knowledge about the real, complicated world. As indicated previously, it is not possible to collect complete knowledge of our world. Realistically, we must accept some sort of contrivance that allows us to make judgments without complete information. We term this mechanism a **model** of the real world. The conceptual model we adopt will subsequently affect any decisions that are based on it.

Decision makers are thus forced to **operate under uncertainty**, while at the same time having to **avoid taking risks**. One way of reducing risks is to assess the problem in conjunction with other information that may only appear to be peripheral to it. Lord Chorley, president of the British Royal Geographic Society, has pointed out that, *the usefulness of one data set may be greatly enhanced by merging or linking it with other data sets*[43] and thus will result in better decisions. With each piece of information integrated into the decision making process, the uncertainty and thus risk is reduced. The confidence that the decision is correct increases as a consequence.

Diverse phenomena are sometimes best understood in terms of their geography. For instance, take the question of whether a proposed *Greenbelt* policy is feasible. The location and extent of the remaining suitable agricultural land would first have to be

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[43] Lord Roger Chorley, 1988, *Some reflections on the handling of geographical information,* Int. J. Geographic Information Systems, Vol. 2 #1, pp 3-9.

determined by examining land use and soil information. Its proximity to urban or urbanizing areas would also have to be taken into account, as would present land prices—is it really practical to acquire this land? The brief review of the spatial information gathered by various RTG agencies presented above also bears witness to the realization by many RTG agencies that spatial information is pertinent to the proper management of natural resources.

Spatial Information as a Social Commodity

Within the public sector, geographic information has been described as *a social commodity.* Its collection is legally mandated by political organizations for social needs, legal description of land ownership, assessment of forest and mineral resources, the determination of land capability, and so on. The *Land Development Act of 1983* illustrates this point. The Act transferred authority concerning land development from the Department of Land to the Department of Land Development, thus effecting a change in spatial information collection duties. It further stipulated that the Department of Land Development would be the responsible agency for mapping land suitability, current land use, planning land development and for the conservation of land and water resources.

There is also a trend for government agencies to collect more detailed, more precise and more current geographic information. This trend is being motivated in part by increased awareness of environmental concerns and by the simple fact that in order for organizations to function effectively, they require accurate and timely information. For example, the forest inventories now being collected by the Royal Forest Department have been driven by a need to more reliably and more promptly estimate forest reserves since the government's decision to close the nation's forests in 1989. Other RTG agencies are also a part of this trend: the Department of Land is in the process of upgrading and issuing precise land deeds for the entire country; the NRD2C village survey has grown progressively to include more detailed socioeconomic data and has now become a permanent feature of RTG data gathering practices.

Spatial Information Technology

Traditionally, paper maps have been used to hold spatial information, with the map acting like a *snapshot*, usually of a single set of geographic data at a single point in

Chapter 3

GIS: New Solutions to Old Problems

Background

Physical maps have been used to integrate spatial information for several years. *Light table gymnastics*[1] can be accomplished with paper maps, as pointed out in 1969 by the American landscape architect, Ian McHarg, in his work, *Design with Nature.*[2] But as noted previously, physical maps have practical limits that are quickly reached in complex analytical situations. Ways have been sought to apply computer-based techniques to the problems of handling and analyzing geographic information since the mid-1960s.

The first two GISes began about the same time in North America, in the United States and Canada . The Land Use and Natural Resources Inventory of New York State (LUNR) and the Canadian Geographic Information System (CGIS), both made heavy use of aerial photography, as well as existing maps, to develop an inventory of existing resources. The spatial information encoded into computer form in these systems included, agriculture, soils, forestry, wildlife and geology. These systems were also important in an institutional context. They had both recognized from the outset that a clear, well-defined **sponsor** would be a prime requirement for a successful system—the state of New York sponsored LUNR, while the Canadian Federal Government sponsored CGIS.

While these systems began in the 1960s it wasn't until the early 1970s that they became operational. The computer hardware of the 1960s was the main drawbacks, it simply wasn't powerful or inexpensive enough for this type of system to become

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[1] Berry, J.K., 1987, *Fundamental operations in computer assisted map analysis.* Int. J. Geographical Information Systems, Vol 1, #2.

operational.[3] While not entirely successful, these systems, served as a spur to stimulate technical creativity that later improved the viability of computer based geographic information systems.

From the 1960s on, the Harvard Graphics Laboratory, was one of the most active research groups in developing computer-assisted map analysis programs. It was staffed by an enthusiastic, internationally reputed and able staff. The early programs they created—SYMAP, GRID and IMGRID—performed overlay operations in a manner that was faster and more flexible than manual methods. These systems, with a little more effort, also allowed spatial information to be stored and organized in computers, allowing planners for the first time to make use of them.

In 1977, experiences using computer-based cartography had advanced to such a point that David Rhind, a British geographer, was able to compile a list of reasons for using a computer:[4]

- **To make existing maps more quickly**
- **To make existing maps more cheaply**
- **To make maps for specific user needs**
- **To make map production possible in situations where skilled staff is unavailable**
- **To allow experimentation with different graphic representations of the same data**
- **To facilitate map making and updating when the data are already in digital form**
- **To facilitate analyses of data that demand interaction between statistical analyses and mapping**
- **To minimize the use of printed maps as a data store and thereby minimize the effects of classification and generalization on the quality of the data**
- **To create maps that are difficult to make by hand, e.g., 3-D maps or stereoscopic maps**

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[2] McHarg, I.L., 1969, *Design with Nature*. Doubleday & Company, New York.

[3] Tomlinson, R.F. Calkins, H.W., and Marble, D.F., 1976, *Computer Handling of Geographical Data*. Natural Resource Research Series XIII. The UNESCO Press, Paris, France.

[4] Rhind, D. 1977, *Computer-aided Cartography*, Tran. Int. British Geographer, 2, pp 71-96.

- **To create maps in which selection and generalization procedures are explicitly defined and consistently executed**
- **Introduction of automation can lead to a review of the whole map-making process, which can also lead to savings and improvement**

Over the last decade or so, the rapid development of computer technology has enabled computer-based geographic information systems to flourish into what we now term GIS.[5] GIS technology has developed to such a point that current estimates indicate GIS expenditures total **billions of US dollars** in the United States alone.[6] It is being applied to tax planning, emergency vehicle routing, demographic research, environmental impact assessment, and more. Why is GIS such a fast-growing field? Why does GIS promise to be one of the largest and fastest growing computer applications ever to emerge?

Why GIS?

The answer to the question *Why GIS*? has much to do with the importance of spatial information in helping to solve problems. As we have seen, geography and the data describing it are a common part of the workaday world, each decision taken by human beings being governed by some aspect of geography. GIS technology helps to organize information about problems and allows humans to try to understand their spatial relationships. Sensitive and intelligent decision making stem from such an understanding.

Using a computer can profoundly accelerate the speed at which geographical analysis can be accomplished. Much as the printing press transformed the way information flowed through society by making the production of printed material faster and less expensive, a GIS will significantly change the rate at which geographic information is produced, updated, and distributed. GIS will change the way geographical analysis can be approached by changing the way we perceive and make use of spatial

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[5] This brief extract of GIS development is by no means a full history. For a fuller history see: Burrough, P.A. 1986, *Principles of Geographic Information Systems for Land Resource Assessment*, Clarendon Press, Oxford; *American Cartographer* July, 1988 issue; Marble, D.F., Calkin, H., Peuquet, D.J., Brael, K. and Wailenko, M., 1981, *Computer Software for Spatial Data Handling* (Three Vols.). Prepared by the International Geographical Union, Commission on Geographical Data Sensing and Processing for the United States Dept. of Interior, UG. IGU, Ottawa, Canada.

[6] Dr. David Rhind's address at the 1990 ESRI's Users Conference, held in Palm Spring, CA., USA.

information. Geographic data is more malleable, more easily shaped to best fit a user's application by using GIS technology. Geographic information can thus be custom-made, to an extent that was never possible before.

Perhaps the two most important advantages of GIS compared with physical maps is its ability to keep spatial information current and to efficiently synthesize multiple data sets into a single integrated database. The capacity to quickly update the geographic database and produce a physical map allows the production of *snapshots* of a continuously changing geographic database. Analyzing and re-analyzing the data is therefore relatively inexpensive and rapidly accomplished. Decision makers can progressively refine a planning scenario by re-analyzing the plan to assess any proposed changes. Several alternate proposals can be appraised by simply re-running the analysis and comparing the results offered by the different plans. Manual methods are generally prohibitively expensive for this **iterative** approach to planning. Planners can now easily play *what-if* games to assess impacts before a plan gets to the implementation phase—helping to reduce risks.

Today, the natural resources and environment field is on the frontier of a new, potentially revolutionary event—a technological and political development consisting of the convergence of a social and political need for rapid and complex analysis of the environment and resources, the swift evolution of GIS technology, and the dramatic advances in computer hardware and storage technology. GIS technology has come to be recognized by many as an important **tool** for managing the environment and resource base for sustainability—it is not just another passing fad. It is a **tool** that can be used to support timely and accountable decision making in an ever-changing world.

What is a GIS?

Background

A GIS has been variously described as:

- An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information[7]
- A data base system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the data base[8]
- An internally referenced, automated, spatial information system[9]
- A set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes[10]
- Is a tool for storing and manipulating geographic information in a computer[11]

From the above it is clear that a GIS is both a **tool** and a **database**. It is essentially a **data driven process**—that data being geographic data.

Vector and Raster Formats

Two distinct, basic types of GIS are recognized. The first type makes use of map-based data in a **vector** format.[12] The second type of GIS uses image-based data in a

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[7] ESRI, 1990, *Understanding GIS.*

[8] Smith and others, 1987, *Requirements and principle for the implementation and construction of large-scale geographic information system.* International Journal of Geographical Information Systems. Vol. 1, #1, pp 13-31.

[9] Berry, J.K., 1986, *Learning computer-assisted map analysis,* Journal of Forestry. Oct. pp 39-43.

[10] Burrough, 1987, *Principles of Geographical Information Systems for Land Resource Assessment.* (Clarendon Press Oxford).

[11] ESRI, 1988, ARC/INFO Training Manual.

[12] Vector data is a physical quantity having magnitude and scale or the directed line segment representing such a quantity. More simply put a vector is a bit of information going someplace. It has a direction and a length, it is not fixed.

raster format.[13] The vector type of GIS can be summarized very simply: **the map is a database and the database is a map**. The physical storage of the data is independent of its graphical representation. The raster type of GIS views the **map as a picture**. The vector based GIS approach of *map-as-database* will usually have more functions devoted to database management than the raster *map-as-picture* style.[14]

Building a Spatial Database

The first step in building a GIS is designing and creating a digital spatial database. For spatial information or maps to be automated, there must be explicit definitions of the information to be stored, the database's form or structure must be precisely defined, and the general applications or uses of the database must also be determined.

As stated before, there are three types of spatial primitives or entities on any given map: points, lines, and polygons. These entities can also be hierarchically related; that is points form lines which in turn form polygons. Wells, houses, and villages (at certain map scales) are point data. Streams, roads, and utility lines are line or arc data, while soils, land use and forest stands are polygon type entities. In order to take advantage of digital GIS, we must reduce our map data to terms that a computer can understand or *we must raise our own levels of definition and precision to that which the computer can accept.*[15]

The process of automating these spatial entities from map manuscripts or analog data to computer compatible form (digits) is called *digitization*. These is usually done by simply tracing the entities form on a digitizing tablet, which converts this tracing into a string or set of X,Y points of map-based coordinates. This is also perhaps the most critical part of the implementation of any GIS—what you input into the computer will subsequently effect any analysis made later.

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[13] Raster data can be considered as matrix of discrete, fixed sized cells covering a certain area.

[14] For a fuller description of the various types of GIS see Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective* or Burrough, 1987, *Principles of Geographical Information Systems for Land Resource Assessment*. (Clarendon Press Oxford).

[15] Parker, H.D., 1987 *What is a Geographic Information Systems*?, In Proceedings GIS'87-San Francisco, 2nd Annual International Conference on Geographic Information Systems.

Once we have reduced map spatial data to point, arc and/or polygon entities, and rendered these into computer-compatible format, three things must be further specified:

- **where each feature is geographically** (UTM, latitude and longitude, etc.). This can usually be accomplished during the digitization process but may be done at a later stage by transforming the raw digitizer coordinates to map coordinates using standard algorithms.
- **what each feature is** (roads, streams, soils, etc.). This is known as the feature's **attribute data**, including information that describes the major characteristics of the feature in question, such as depth of stream, stream name, annual flow, water quality, etc., etc. These attributes may also be used to manipulate the spatial features and vice versa.
- **what each entities relationship is to the other features on the map** (to-from, left-right, etc.). This is known as **topology**. While humans can intuitively grasp that a certain village is north of a particular stream, a computer has no such built-in recognition system—it must be taught these things from the spatial relationships encoded into the **spatial** database's structure. This is usually accomplished by computer edits, as experience has shown that manually assembling topology is usually a failure in terms of processing speed and time as well as error levels.

GIS Analysis Function

The data analysis needed by most users of GIS include: reclassification and/or aggregation of attribute data; overlaying operations including union and intersection, measurement of area; perimeter, distance, connectivity, neighborhood statistics and directions; and statistical analyses.

The first and in many ways the most rudimentary class of analytical operations involves the **reclassification** of map attribute data. A new map is created by assigning thematic values to categories of an existing digital map (or coverage). Reclassification merely repackages existing information on a single coverage and results in no new boundaries. It generally involves boolean querying of spatial and/or attribute data. An example of this is the creation of a crop suitability map from a soil map. Various levels of suitability would be assigned to soil polygons based on a particular crop's soil requirements.

Overlay processes, on the other hand, involve two or more maps and result in new boundaries. This class of operations has been aptly characterized as *light table gymnastics.*[16] Intersecting a soil and land use map to create a coverage containing both soil and land use, is an example of this class of techniques. The soil types and properties could be derived for each land use from the new coverage.

Reclassification and overlay processes address most GIS analysis requirements. However, in order to more fully integrate spatial data into the decision making process, other types of analysis are needed. Simple information (such as perimeter, area and distance between points) is frequently needed during resource allocation. Moreover, distance data often needs to be expressed in terms more relevant to the problem at hand—time or money. Delineation of paths or connectivity on a coverage is another distance-related operation useful in many GIS applications (such as delivery truck routing or police car dispatching). Another form of connectivity deals with the intervisibility among locations or **viewsheds.** The ability to determine whether a particular point is visible from another point is useful for example, in siting facilities in natural areas or in military applications such as locating *dead ground* in defense zones. These classes of GIS operations can be best characterized as *rubber rulers.* Operations which characterized neighborhoods can be thought of as *roving windows* and are often used in deriving slope, aspect, and profile from elevation data.

Statistical analysis, usually in the form of tabular summaries or listings, is a GIS operation whose concept is perhaps the most easily understood. Calculations of frequencies, averages, distributions, etc., of spatial entities or their attributes are regularly required by many GIS users. The frequency of particular soil polygons, the distribution of pH along a stream, and the average width of paved roads in a particular area are some examples of this class operations.

The GIS functions mentioned above are described in terms of map analysis. If one takes the computer science point of view, the answers provided by a GIS will usually fall into one of three categories:[17]

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[16] Berry, J.K., 1987, *Fundamental operations in computer assisted map analysis.* Int. J. Geographical Information Systems. Vol 1, #2.

[17] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

- **a presentation of the current data**, for example what is the land use like now, (storage and retrieval).
- **a pattern within the current data**, such as all abandoned land over 20 *rai* (constrained query).
- **predicting what the data could be** at a different time or place or given different present conditions, for example forecasting erosion after the conversion of forested to agriculture (modelling functions).

Components of a GIS

Many people getting their first taste of GIS, have a tendency to become infatuated with its hardware and software. The seemingly expensive price tags and the colorful displays and maps tend to lead people into assuming that these two components are the most important or that they are **all** it takes to implement a GIS. More GISes have failed because of this **misconception** than for any other reason. An improperly staffed, poorly managed, or underfunded GIS will surely fail, in spite of huge budgets expended on hardware and software. **A GIS without geographic information is useless**, the true value of a GIS is measured by the geographic data it contains. A *real* GIS must consist of five components:

- **hardware**—used to treat, store and display digital spatial data.
- **software**—performs GIS operations.
- **digital geographic data**—which the GIS manipulates and displays.
- **procedures**—are followed to accomplish various operations.
- **expertise**—the people who provide the underlying intelligence to develop, use and maintain the system. Of the five parts of a GIS, people who know how to use the system are the most important and the hardest to find

Users of the GIS, in fact, become a part of the GIS. They provide the intellect, the **genius** behind the system. This is especially true when complicated spatial analysis and modelling must be carried out. Expertise is required to select and to use the appropriate GIS tools as well as to understand the data being used. Advertising claims to the contrary, there is **no** off-the-shelf, general purpose GIS available today that is simply push-button—the users must know what they are doing.

Institutional Aspects of a GIS

To be effective, a GIS, must reside in an appropriate institutional framework. It is often pointed out that a GIS does not exist in a vacuum. The GIS must be properly staffed, managed, and funded; above all it must be given some type of **mandate** or goal. The GIS's management is mandated to service some **user community** within a government agency, a business, or some academic institute. Stan Arnoff summed up the institutional issue as follows, *ultimately, the purpose for the GIS facility is to assist the users in accomplishing the goals of their respective organizations.*[18] Thus, **a GIS is not an end in itself.**

Users of a GIS (and most other information systems) fall into two categories: internal and external users. **Internal** users are those users responsible to the same management as the GIS, while **external** users report to a management other that controlling and/or funding the GIS. Each must be treated in different ways. For example, consider a GIS built by a military organization, users with the proper clearances (generally military users) would have much freer access to the database than would some outside organization such as a university—access to the GIS would be rigorously controlled and restricted.

All GISes begin life performing old tasks in the old manner (organizations would like to continue doing what they do best or are most comfortable with because organizations do not readily adapt to change). Over time, however, the principal use of an information system will always tend to evolve. As users become familiar with the system's capabilities, new ways taking full advantage of the new technology will be developed to provide the same functions. Finally, new functions will appear and new technology will be used for new tasks. GISes normally develop from inventory systems, where emphasis is placed on building databases, to analytical systems, and finally to meeting management needs.

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[18] Aronoff, S., 1990, *Geographic Information System: A Management Perspective.* WDL Publications, Ottawa, Canada.

Implementing a GIS

The design and implementation of a GIS is a considerable undertaking, which may take a year or more. The issues having the most influence on the success or failure of a GIS are almost always related to **people**. The technology itself is concrete and therefore rational. Thus, its performance in a given situation can usually be predicted. Humans are, however, not as easily predictable as the technology they employ. Humans react not only to facts but to their context as well. Personality clashes and power struggles can result in seemingly irrational decisions. In arriving at a decision, people bring their own emotional and institutional baggage with them. Differing agendas are thus sometimes reconciled according to institutional or personal power.

The reason humans complicate the implementation process so much is that a GIS is where humans and technology meet (or sometimes, clash). The implementation of GIS technology within any organization is also a political process. The influence a GIS has on an organization has been described as *pervasive*.[19] In adopting this technology the organization itself must change because **information is power**. A GIS will cause a shift in the flow of information within an organization, with a different set of people now exerting control over the disposal of information. Power will be shifted into the hands of the organization that controls and generates information. Computer information systems are always political because control over centralized information almost always ends in the hands of the system administrators or technical experts who dominate the system at the expense of those without their technical know-how.

Decisions based on data generated by a GIS can made into impressive political weapons. Policy makers and the general public usually consider computer-derived information to be more accurate and credible simply because it was generated by a computer. Technical language used to describe the data and the decision generated from it usually sounds politically neutral and thus more objective. A technical expert can use a computer to conceal political choices beneath a veil of seemingly unbiased technology.[20] On the positive side, most GISes can usually keep a log, similar to the transactions in one's bank account, that is a faithful recording of the data and the analytical procedures

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[19] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

applied to it. While this log may or may not be publicly revealed, it can still be audited or *played back* by a technically capable person, thus maintaining some measure of **accountability** within the system.

Generally there are six steps or phases to implementing a GIS:

- **Knowledge of the GIS**: This is when an organization first becomes aware of the technology and its potential benefits to the agency. This may be suggested by someone or group within the organization itself, another GIS-experienced institution, or a third party such as a GIS vendor. Problems within the current system are identified and a GIS-based solution is proposed. Perceived problems may include poor data maintenance, non-standardized data, isolated data, or the assignment of new responsibilities to the organization.
- **System requirements**: After an agency becomes aware of and formally accepts the GIS idea, its own functional requirements in terms of the GIS technology must be appraised. Potential users and applications must be identified. This will usually require what is termed a *user survey*[21]. This process has political overtones to it because it will effect the specifications of the system—who has first priority, who has what equipment, who has access rights to what data, etc. The system sponsor is usually identified during this phase. The user survey is also a process fraught with pitfalls. If improperly done a user survey may arrive at system specifications too broad to be of use to the narrower institutional environment within some subgroup of the agency. On the other hand, too narrow a functional definition concentrating on one subgroup, may not serve the broader interests of the organization **as a whole**. It is important that the functional requirements reflect the needs of those who will actually use the system and that all interest groups within the organization have their needs equitably represented.
- **System evaluation**: Once an organization defines its functional requirements, it should evaluate several, competing solutions to these requirements. Benchmarks of required functions should be run, as well as evaluations of training, documentation, technical support, data entry, back-up and recovery systems, and overall system flexibility. **Data entry** functions are especially important in Thailand, where most GISes must begin from scratch. A system with slow or awkward data capture facilities may well doom a GIS to failure in Thailand, simply because it cannot keep up a steady supply of spatial data for analytical purposes. It will also prove more expensive in the long run, as the database

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[20] Kloterman, R.E., 1987, *Guidelines for Computer-Aided Planning Models*, In Proceedings of the URISA '87 Conference. Urban and Regional Information System Association, Washington D.C., Vol. 4, pp 1-14.

[21] For an example of a user survey carried out in Thailand see TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

development costs will usually account for 75% of the total implementation budget. This step will determine the go/no-go of the GIS.[22] If no system evaluates out to the required specifications within the available budget, then the system will not be feasible.

- **Implementation plan**: Following a go decision on establishing the GIS, a more or less formalized plan should be developed to implement it. This plan should address system acquisition, staffing and above all, the needed organizational changes and budgeting to implement the GIS. Technology, information and people will be molded into a single system following the scheme laid out in the implementation plan. Justification for the system, including cost-benefits, may be worked out during this phase. The plan should consider database development priorities in order to bring the GIS into operation as soon as possible. The plan should also thoroughly cover staffing requirements, as people will ultimately determine the success or failure of the GIS. It is critical that expertise, enthusiasm, and commitment should be built within the group chosen to implement the GIS.
- **System purchase**: After developing the implementation plan and **gaining the support of the organization**, the next step is to contract for equipment and services. The functional requirements considered critical to the organization should be unambiguously specified in the vendor's contract as specific guarantees of system performance . While pricing is important, **service, staff training, support, and delivery schedules** may prove critical to the overall success of the GIS, especially as the first products produced by the GIS will have an impact on how the GIS is perceived within the organization.
- **Operations**: The operational phase of a GIS implementation is defined as the point when users of the system begin to make satisfactory use of it. Although a GIS may have reached this stage, it may still fail if the system is not performing acceptably as intended by the organization. It must meet the information needs of the agency, even as the GIS itself effects changes in them. Operational issues include procedures to keep data and services up-to-date, procedures to keep staff up-to-date on new GIS developments, and guidelines to deal with the responsibilities arising from the effects of using the information provided by the system. Procedures that publicizes the GIS, should also be established, such as making known the successes of the system, tours of the facility, project highlights, proven benefits emphasized, etc.

Issues of Responsibility

Once a GIS begins to function in an operational sense, certain issues will begin to make themselves felt. These questions revolve around responsibility for the

[22] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

repercussions of providing spatial information. This is especially true of GISes within publicly funded organizations (such as the GIS within the Department of Land) or GISes operating within independent third party NGOs ostensibly acting for the public good (TDRI as a policy research institute, for example). Responsibility and liability may be one of the more serious issues facing GIS operators, planners and managers as these systems become operational.

While computer systems have well-developed security techniques, the voluntary distribution of information carries responsibilities that are more often than not vague or undefined. **Information is power**. Society often assigns to some professions, **legal** accountability for the quality of information these professions provides. Medical doctors for example, are held responsible for the diagnoses (information) they dispense to their patients. Recently in Bangkok several buildings under construction collapsed. One of the first persons usually sought by police in connection with these cases is the site or quality control engineer. An accident involving a ten-wheeled truck, will usually see the driver fleeing to avoid being held accountable. Thai society holds these occupations responsible for the information they provide or the tasks they perform. Thai society does not, however, hold producers of spatial information or analyses accountable. A researcher can often shirk responsibility by simply producing spatial information without any coordinate system, scale or attributable markings—it can thus be easily denied. In many cases, responsibility is disowned by the simple expedient of denying access to the information in the first place.

Within an operational GIS, critical information policy is often left by default to the discretion of the GIS operator or researcher, without any clear-cut responsibility being designated. Decisions involving the generation, distribution, and validity of data is often not explicitly assigned to any individual within the organization. Stan Aronoff has suggested the creation of a position entitled *GIS Information Officer*,[23] who would be ultimately responsible for the ways the GIS was used. It would be incumbent on this officer to seek advice on the technical, legal, economic, and political aspects of the data generated or released from the GIS.

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[23] Aronoff .S, 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

A good example of a system for responsibility is the engineering profession. The output from a design process is an engineering plan. While this plan may have been drawn by some draftsman, an engineer somewhere along the line will have assumed responsibility for this product by stamping and signing it. The engineer's signature on this document indicates that he/she assumes responsibility for its correctness, at least as far as its intended purpose.

Basically, there are four areas of responsibility that should be addressed in the context of an operational GIS:[24]

- **Content**: The reliability of spatial location or map attributes recorded in a GIS is important. The management of a GIS must therefore ensure that the data within the GIS accurately represents the **real conditions** that it is supposed to describe. The producer of spatial information should be held liable for its content. The U.S. federal government was held accountable for the **inaccurate** placement of a broadcasting tower on an aeronautical chart that resulted in a fatal plane crash.[25] Once accepted into a GIS, spatial information would then become the responsibility of the GIS organization. Responsibility for its original accuracy should therefore be assigned to the **original** producer of the information prior to being incorporated into the database—however, verification for this must be the task of the GIS management. Data standards are an attempt to ensure accuracy of content, with most efforts to date concentrating on the supply side of information. The consumers of spatial information should also be held responsible for knowingly using data beyond its level of accuracy. The concept of risk assessment may be used to determine and minimize potentially dangerous consequences of using maps. Stan Aronoff describes a system based on a **minimum accuracy value**, whereby the worst case map accuracies can be estimated and their consequences diminished.[26]
- **Context**: Users of spatial data can be mislead by the context of the information displayed on a map. Information from different sources depicted together on a map makes a statement about the spatial relationships among all the elements on that map. Elements that look adjacent to one another are assumed to be adjacent from the context of the map. Erroneous inferences can thus be drawn from information intentionally or inadvertently taken out of context.

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[24] Aronoff .S, 1990, *Geographic Information Systems: A Management Perspective*. WDL Publications, Ottawa, Canada.

[25] Epstein, E.F., 1987, *Litigation over Information: The Use and Misuse of Maps*, In Proceeding of the International Geographic Information System Symposium: The Research Agenda. Association of American Geographers, Washington, D.C.

[26] Aronoff, S.,1985, *The Minimum Accuracy Value as an Index of Classification Accuracy.* Photogrammetric Engineering and Remote Sensing 51(1), pp 99-111.

- **Data Format**: Once spatial information is transferred from physical maps into digital format in a GIS, querying or searching it becomes relatively quick and easy. While this change of data format may be a blessing to many, in some cases it actually lowers the protection of some types of information. For example, consider cadastral information in Bangkok. It is held in paper form scattered throughout the city in local offices of the Department of Land. If someone wanted to search for owners holding titles valued at 10 million *baht* and above, one would have to gain access to several different offices past several different officials, and search through perhaps hundreds or thousands of paper records—combined together, an almost impossible task. Once this information is stored in computer form and centralized, searching for these properties becomes almost child's play. In this case, the format of the information is a practical and effective form of protection. Steps must be taken to ensure that information that should rationally be protected is indeed secure once it becomes part of the GIS database.
- **Data Set Combination**: One of the main benefits of a GIS is its ability to combine different spatial data sets together to facilitate analysis. The users and operators of a GIS should, however, be aware that inaccuracies may be created or increased when synthesizing data sets. The accuracy of any product of combination functions (for example, intersection or union) is not more than that of the least accurate input data. Many times users of GIS will combine information of different scales, and make use of the product at the larger (better) scale. No assessment of the accuracy of the combined product is ever made. Data set combination can also take information out of context. One theme of data plotted on another map implies that the accuracy of both is the same. For example, plotting 1:50,000 scale geology map on a large scale cadastral map (1:10,000) implies that the geological information is as accurately represented as the cadastral data—something which is simply not true. In another example, a government agency uses forest, public land, soil, and political maps, to locate potential areas for its activities. This reconnaissance work uses information at a scale of 1:50,000. Once these areas have been located, it proceeds to intensively survey the terrain and cadastral information for these areas at a scale of 1:10,000 in order to plan and implement its assigned work. In creating its 1:10,000 scale plans, it uses the same scale soil information (1:50,000) used during its search for potential areas on the assumption that this information is accurate because it comes from a different government agency.

The above are only a few of the more important issues confronting those responsible for operational GISes. These questions will become troublesome later, if left unanswered now. GIS managers in Thailand can avoid any future problems if these issues are calmly and rationally addressed from the outset.

Errors in GIS

Errors of some kind are inherent to all geographic information. Every step in using geographic data introduces error. In managing error levels in a GIS, there is a trade-off between reducing levels of error in the database and the cost of creating and maintaining that database. Geographic errors can be grouped into six major types:[27]

- **Data collection errors** result from errors in the original map manuscripts, from field surveyed data, or from analysis of remotely sensed data.
- **Data input errors** ensue from inaccurate digitizing as a result of equipment or operator errors and the errors inherent in the map representation of certain natural boundaries such as soil or forest—which are never as sharp as depicted on the map.
- **Data storage errors** result from the way the information is actually represented in the computer. Inadequate numerical precision for vector type databases or insufficient spatial precision for raster type databases are sources of error.
- **Data manipulation errors** are byproducts of the selection of ill-suited class intervals, boundary errors, the propagation of errors from multiple overlays, and mixing radically different map scales.
- **Data output errors** derive from flaws in scaling, inaccuracy of the output device, and the instability of the output medium.
- **Errors from use of results** follow from misunderstandings of the actual information product generated by the GIS, accuracy levels ignored or when results are inappropriately used.

The objective in dealing with errors in a GIS should not be to altogether remove them but to manage them. It is an important responsibility for GIS managers to see that errors which cannot be eliminated are plainly known to the end users of GIS generated products.

[27] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

Cost-Benefit of GIS

Recently, there have been several efforts at preparing cost-benefit evaluations of GISes.[28] Generally these undertakings have been able to more or less precisely determine costs, but have not been as successful in estimating benefits. Several reasons have been cited for this:

- **it may be difficult or impossible to identify and describe the level of demand which the GIS is supposed to meet** (the very nature of the organization holding the GIS will change because of its presence)
- **the supply and demand of geographic information is not easily quantified** (a buyer-seller market may not exist, as some end users of spatial information are many times the GIS agency itself or that much of the spatial data collected is looked upon as a social commodity)
- **a realistic economic evaluation of some products may not be available** (how much is more realistic data worth in policy analysis)
- **the objectives of the GIS cannot be described as a discrete product** (assisting policy-makers in policy analysis)

GIS implementation costs have been estimated to consist of the following:

- **feasibility studies, including user surveys**
- **hardware and hardware maintenance**
- **software and software maintenance**
- **database entry or format transfer**
- **database maintenance**
- **training**

[28] For example see, Dickinson, H.J. and Calkins, H.W., 1988, *The economic evaluation of implementing a GIS*, Int. J. Geographical Information Systems, Vol. 2 #4, pp 307-327; Wilcox, D.L., 1990, *Concerning 'The economic evaluation of implementing a GIS'*, Int. J. Geographical Information Systems, 1990, Vol. 4 #2, pp 203-210; Dickinson, H.J. and Calkins, H.W., 1990, *Comment on 'Concerning "The economic evaluation of implementing a GIS"*, Int. J. Geographical Information Systems, Vol. 4 #2, pp 211-212; Kevany, M.J., 1986, *Assessing Productivity Gains in Advance: Feasibility Studies.* In Proceeding of the URISA '86 Conference, Urban and Regional Information System Association, Washington, D.C., Vol 2 pp 40-46; Laroche, . and Hamilton, A.C., 1986, *Unit Costs for Topographic Mapping.* In Proceedings of the URISA '86 Conference, Urban and Regional Information System Association, Washington, D.C., Vol.1 pp 150-158.

- **in-house software enhancement** (macros, interface, special data formats, etc.)
- **running applications** (salaries of system staff, applications specialists, etc.)
- **supplies** (paper pens, disks, tapes, etc.)
- **overhead** (air conditioning, building space, etc.)

These costs can be quantified with reasonable accuracy. Staffing costs are, however, harder to approximate because performance levels and training requirements can only be very grossly estimated. New staff may need to be hired, old staff will need re-training—some old staff may never *take* to the new system. Salary levels needed to attract new staff may cause salaries of existing staff to be raised. At present, the GIS personnel market is such that managers may earn considerably less than the more experienced GIS staff they manage—very few organizations could tolerate this situation for long.

The benefits derived from using a GIS are much more difficult to quantify. The Joint Nordic Project's survey of North American GISes concluded that there are two types of benefits, tangible and intangible.[29] The tangible benefits include:

- **saving time in map production and updating**
- **saving time in maintenance of facilities**
- **better maintenance**
- **better planning/engineering**
- **saving of time in administration**
- **more effective administration**
- **more up-to-date information**
- **quicker access to information**

This survey summarized the intangible benefits as:

- **more information**
- **better analysis in less time**
- **increased analysis capability**
- **introduction of analysis not possible before**

[29] Joint Nordic Project, 1987, *Digital Map Database, Economic and User Experiences in North America.* Publication Division, National Board of Survey, Helsinki, Finland.

- better decisions
- better planning
- increased understanding and better analysis of highly complicated systems

The tangible benefits are mostly related to cost savings. In many cases, the intangible benefits may be quite large—better analysis, planning and therefore decision making. *How much is a correct decision worth? How much is an incorrect decision worth?* Jonathan Raper of Birkbeck College, London, relates an incident from the Channel Tunnel project, Europe's largest infrastructure venture, where British Rail (BR) routed a high speed rail line, connecting London to the Tunnel, right through a recently completed housing project. This large and **public** mistake forced an admission from BR that *the relevant mapping had been done on grease-proof paper on a BR executive's kitchen table.*[30] If administrators focus solely on quantifiable benefits, they may significantly underestimate the potential total benefits of the GIS.

Stan Aronoff indicated that there are five types of benefits that need to be quantified:[31]

- **Increased efficiency**: An effective system will require less resources to accomplish any given assignment. The time saved is generally for an existing task. The time saved is assumed to be beneficial to the organization. Time-savings must, however, be looked at throughout a work day. If a savings in time can be affected on a series of **sequential** tasks, these savings will accumulate at the end of the day. The time saved in such circumstances can be usefully applied to other tasks. If these time savings are made on a more or less random basis throughout the work day, then this time saved will be of no benefit to the organization. No new work can possibly be scheduled into these time periods because they appear on a random basis.
- **New non-marketable services**: How valuable is it for an organization to be able to produce better graphics? A GIS can provide new, previously unavailable products. While some of these can be quantified, many more will appear unexpectedly.
- **New marketable services**: The GIS expertise that an organization develops is a marketable skill. If an organization charges for its products or services, the GIS will improve its efficiency leading to increased revenues.

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[30] Raper, J., 1990, *GIS's Impact on Society: A View from the U.K.* in GIS World, Vol. 3, #2, p 66.

[31] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publications, Ottawa, Canada.

- **Better decisions**: Predicting the value of improved decisions is a problematic task. The GIS will certainly provide more accurate information in a more timely manner and allow more flexible and iterative analyses, but how much is this worth?
- **Intangible benefits**: These differ significantly from the intangible benefits outlined by the Joint Nordic Project. These include better communications within an organization, improved morale, and a better public image. These benefits are hardly a concrete quantity, but will most certainly have a significant impact on an organization's proficiency.

In light of the above, applying strict cost-benefit analysis to GIS is plagued with problems. While its application to **directly** quantifiable costs and benefits must not be overlooked, it can give only a part of the picture, not the whole. In Thailand, with the lion's share of spatial information being collected by the government and thus a social commodity, the benefits of a GIS may largely be intangible ones and its justification requiring an *act of faith*.

GIS Databases

Lord Chorley, president of the British Royal Geographical Society, in his opening address at the first European GIS Conference (EGIS '90) stated that *GIS is not mapmaking, GIS is about spatial data analysis and adding value to spatial data.* This idea is not often understood by those considering GISes, especially those from agencies of the old and traditional mapping establishment. Their concept of GIS is closer to that of an automated drafting or mapping system—not a true GIS. In these types of systems, the map is a graphic and the information recorded in these systems is data about that graphic. For example, it might record that a certain line on a map is dashed and red, not that it represents a highway under construction. These systems simply cannot perform any serious spatial data analysis—they were not designed for it.[32] Any organization wanting a true GIS but somehow acquiring a mapping system instead, will be disappointed and frustrated with its *GIS*. The concept of the **map as a database** and the **database as a map**, is basic to a true GIS, there is no real substitute for it.

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[32] Phantumvanit, D., Vearasilp,T., and Hastings, P. *GIS in Traditional Engineering Applications.* Proceedings Computer Aided Engineering Conference. 11-12 February, 1988, Prince of Songkla University, Songkhla.

The principle asset of any GIS is its database. It is also its *raison d'etre*—without spatial information, a GIS is useless. Database creation generally accounts for the largest chunk of implementation budget. It involves organizing existing physical maps and converting them to digital form. While many may count it as an expense, the database is a very real and very valuable asset. The conversion process, from paper to digital form, will in many cases bring about actual improvements in the quality of the spatial data. Unlabeled or unclosed polygons, slightly shifted map entities, non-standard legends, and other *fuzzy* errors that humans are comfortable with, will be corrected when converted to digital form and entered into the GIS database. There is value in the data itself, which is increased as the data becomes more readily available, and multipurpose. The database's value will increase with time, as a GIS will facilitate data updating. Contrast this with hardware and software, which will depreciate over time. Historical data maintained in the GIS will also become more valuable as time passes, actually becoming a rare commodity as paper manuscripts deteriorate with time. Entering historical maps into a GIS database may, in fact, be the only solution for preserving their information content. An organization's or country's heritage may thus be safeguarded.

Given that **information is power**, the larger and more comprehensive an organization's GIS database, the more powerful that organization becomes. Once this is realized by an organization's management, support can be expected to crystallize for database development. However, there may be dangers resulting from this awareness. An organization may become possessive of *its* database and not allow others access to it—an exercise of negative power. This attitude will very much hamper or even retard the development of digital spatial databases. It will result in isolated islands of data surrounded by an ocean of institutional and technological barriers. For example, many European government agencies actively restrict access to both physical and digital data. A similar dilemma exists in the United Kingdom, where while the data is less restricted, it is held under **Crown Copyright** and thus end users are not able to make free use of it—also costs substantially more than comparable data in the U.S.[33] In contrast the United States has enacted **freedom of information** laws guaranteeing public access to government collected information. One result is that spatial data in the United States is

[33] Parker, H.D., 1990, *I am not a cartographer, but...*, in From The Publisher column in GIS World, Vol.3, #3 pp 9-10.

widely available at a modest cost.[34] Because of this, GIS development has progressed further, the databases are more comprehensive, and the general contributions of GIS to the United States's economy and society are more widely felt. Because of the overwhelming importance of databases to a healthy and successful GIS, **freedom of information** is one of the more crucial policy issues facing GIS in Thailand today.

Heterogeneous Data Integration: *The "I" in GIS*

Despite the large and growing number of databases in Thailand, it is still fairly rare to see them used in an integrated manner. As one can see from the major spatial data collectors mentioned above, it is evident that Thailand now possesses most of the databases needed to continue development. These databases are however, isolated, and will continue to be isolated because each organization's political climate is not conducive to integration. Each RTG agency will usually only collect data that is strictly necessary to its main task. This is because the term **development** means different things to different RTG agencies. For example, development to the Department of Land Development usually means improvements of land conditions in order to increase production, while development to the Office of Accelerated Rural Development typically means improvements to rural infrastructure, roads, canals, dams, and so on. Thus, socioeconomic and physical data are collected without regard to one another. It is very rare to see integrated surveys carried out simply because no one RTG agency has such an integrated responsibility.

Development, true development, must be carried out in human terms. The ultimate measure of success or failure should not be purely physical—how many kilometers of road were constructed or how many new telephones were installed, but rather in terms of people—*were their lives really improved by what was done*? If one takes this idea as the philosophical basis for all development work then it becomes clear that socioeconomic and physical data must, in some way, be integrated. Given that Thailand recognizes that it is now in the Information Age, then the solution might logically be found in some kind of information system—an **integrated information system**.

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[34] For example one can order digital elevation data for any part of the United States for US$90 from the USGS, and $7 for each additional one.

What, one might well ask, does socioeconomic and physical data have in common? **The answer is geography, these disparate types of information are united in space—they are spatial information.** The socioeconomic conditions that exist at some point on the earth's surface can, within a GIS, be readily matched to the physical conditions at that point. These data can be related at their intersection in space. Geography binds all data together, thus integration is not only possible but relatively simple within a system based on geography.

Thus, one of the strongest benefits of employing a GIS is its ability to integrate several different sets of data. In fact, the capacity to integrate socioeconomic and physical data is just now beginning to be recognized as an important and extremely powerful tool to planners with agencies such as the NESDB even now beginning to implement its own GIS.

What a GIS is not

Hopefully, the above has indicated *what a GIS is*. It is also important to define *what a GIS is not*. As Lord Chorley pointed out, a GIS is not simply an automated system for making maps. Although it can produce maps at different scales, in very colorful formats, it is not a system for merely making pictures. A GIS is a tool for analysis. Its main advantage over computer mapping systems is that it helps people to identify and understand spatial relationships between map features. It is a decision support system.

A GIS does not store a map in the conventional sense, nor does it store a particular image or view of any geographic area.[35] A GIS instead stores the **data** about that geographic area. From this data, a GIS user can produce any desired view of the information over that area, and it can be drawn to specifically suit a user's requirements.

A GIS has the ability to link geographic information with attributes or characteristics about each of the spatial features graphically represented on a map. An automated mapping or drafting system can not. A GIS can use the stored attributes to create new information about map features; for example, the length of a particular road,

[35] ESRI, 1990, *Understanding GIS.*

the time it takes to travel to a specific destination, the area of any soil type, or the area of a specific soil-land use combination. An automated mapping or drafting system can not. In short, a GIS does not hold maps or pictures—it holds a database. Despite advertising and salesmen's claims to the contrary, **without the spatial database you do not have a GIS**.

Remote Sensing and GIS

As mentioned before, the remote sensing arm of the RTG, NRCT, is by far the largest assembler of spatial information in terms of budget share. Logically, one could assume that this would be the place to turn to for most spatial information needs. Reality (in the form of RTG budgets) has been somewhat less than this optimistic idea. This is true for several reasons.

Image analysis equipment—the hardware and software to take full advantage of the information potential of remotely sensed data—is still extremely rare where it is most needed—within **line** RTG agencies. Budgets allocated for the purchase of remotely sensed data is still too low to fully support the costs of operating and upgrading a ground station in Thailand. Remotely sensed data must be interpreted and analyzed to be useful, this analytical skill or *art* is still not very widespread within line RTG agencies, especially in relation to the enormous data collection tasks facing these agencies. The situation is improving, but is hampered by the lack of image analysis facilities within line RTG agencies. Remote sensing has many times been used as the sole source of data and has thus been incorrectly labeled a failure when the remote sensing-based analysis turned out to be incorrect.[36] Remote sensing technology is primarily a data-gathering technology and attempts to use it analytically are thus encumbered with fairly primitive spatial analysis technology. Satellite-based remote sensing has been applied to situations where information requirements could not be properly met by remote sensing and where it should never have been used in the first place.[37] Its failure in these types of situations

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[36] For example, remotely sensed data may, at times, be able to pick out a road, but it would have a hard time determining the type of road or the amount of traffic flowing along it. This information must be gathered from another source.

[37] These types of situations are analogous to someone purchasing a Mercedes Benz to pull a plow—not the best use of automotive technology.

have led to feelings of disappointment, frustration and what Stan Aronoff has termed *myths*[38] about the failure and inappropriateness of remote sensing.

Nonetheless, remote sensing when properly used in the correct context can be an extremely valuable **adjunct** to GIS. **Remote sensing, like GIS, can not be an end in itself**. It must perform some useful function within the appropriate institutional context if it is ever to be considered successful. Despite the different technical view points of GIS and remote sensing users, GIS and remote sensing technologies are, in fact, complementary. Remote sensing analyses can be vastly improved by using data retrieved from a GIS for verification. For example, a 1987 land use map can greatly ease the analysis of an image from 1989 by helping to chose training classes, helping to evaluate hard-to-classify land covers (rice paddies versus fish ponds, for example), and so on. Similarly, GIS applications can benefit from remotely sensed information, which in most cases is the most up-to-date available.

The integrated use of GIS and remote sensing technology will improve the quality of the information produced, that in turn will enhance the decisions based on it. Thus reducing risks. It will also allow information not previously available to be economically incorporated into the decision-making process. Even now, GIS and remote sensing vendors are striving to further integrate these technologies. Their successful integration and use, however, remains in the hands of the users.

Global Positioning System Technology

There is another form of remote spatial data gathering technology that is now rapidly gaining wide usage—Global Positioning Systems or GPS. A GPS is a satellite-based navigation and positioning system that can accurately (from less than 1 meter to 12 meters) geo-reference any type of spatial information, almost any place on the face of the earth. Presently there are 13 active GPS satellites orbiting the earth, with another 11 more scheduled at 60 to 90 day intervals.[39] The orbital period of each satellite is about 12 hours, each orbiting at a height of approximately 20,000 km. Each satellite contains a very accurate cesium clock which is synchronized to a common clock by ground control

[38] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publications, Ottawa, Canada.

stations operated by the U.S. Air Force. Precise timing information is important as each satellite transmits timing and ephemeris information which, when received by a receiver, can be used to calculate the satellite's spatial location. A receiver can then decode timing data from the GPS satellites in view, and knowing their respective locations from the ephemeris information, calculate latitude, longitude, and altitude for the GPS's user. This position fix is continuously update once a second and can thus be used on the move.

GPS technology has existed for several years now but has been hampered by the relatively few GPS satellites in operation and the relatively primitive receiver technology employed, some of which needed a rather large truck to transport and constant attention to keep precisely referenced. The new generation receivers are now rugged and compact, some the size of a small car stereo and thus exceptionally portable. This new portability now sees a GPS that can be mounted in a vehicle, even on the back of a motorcycle, and driven along newly constructed roads or around an encroached forest to update a GIS database. GPS information gathering potential is enormous.

To understand the potential power of such a system, an example is in order. The Thomas Brothers Map Company, one of the world's foremost producers of maps, attempted a pilot project using GPS to map about 2,000 miles of roads in Imperial County, California, USA. The entire project took only five weeks, of which only three weeks were spent on field observations.[40] The GPS was mounted on a car's roof and driven over the county's roads at an average speed of 20 miles per hour. A project of this size would normally take about five to six months to complete using manual survey and mapping methods. The GPS was capable of simply and easily producing **directly** usable spatial information which was fed directly into the Thomas Brothers's GIS database.

At this point in time, one can see several potential applications for GPS technology in Thailand:

- **adding and verifying horizontal control points and benchmarks throughout the Kingdom** (densifying geodetic control points)

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[39] Lange, A.F., 1990, *GPS, A Revolutionary Tool for GIS*, In Proceedings Tenth Annual ESRI User Conference, Vol. 1, Palm Spring, Ca.

[40] Stutheit, J., 1990, *GIS/GPS Link Produces Map...Fast*, GIS World. Vol. 3, #2, pp 61-63.

- determining the exact position of forest reserve and national park boundaries
- establishing accurate and verifiable land marks for forest reserves and national parks
- forest inventories and land marks around forested land boundaries
- tracking and mapping ranges or migration routes for endangered species
- cadastral surveying
- updating rural infrastructure including bridges, canals, dams, roads, etc.
- precisely locating rural villages, especially in mountainous areas
- providing *on-the-fly* spatial locations for socioeconomic surveys
- locating and helping to efficiently route delivery vehicles
- locating and routing police patrol cars and emergency service vehicles
- exactly locating telephone poles, fire hydrants, street lamps, telephone booths, man holes, etc. in urban areas
- search and rescue operations

This is only a small sampling of the more obvious potential applications of a GPS. Presently, there are three RTG agencies that have begun to use GPS technology:[41]

- **The Royal Thai Survey Department** is using GPS for ground survey in establishing horizontal control points and in work along the Kingdom's international boundaries,
- **The Royal Irrigation Department** is applying GPS to its horizontal control points for irrigation projects,
- **The Royal Forestry Department** is using GPS technology in establishing starting control points for forest boundaries as well as in field surveying existing forest inventories.

These applications are for the most part devoted to precision surveying, that is the establishment of control points where the needed accuracy is measured in centimeters. These control points, in turn, would be used as a basis for further survey efforts. The real potential for GPS technology may, however, be in less accurate (2-12 meter accuracy) but more urgently required spatial information such as forested land boundaries, one of the applications that RFD is beginning to apply GPS technology to.

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[41] Personal communication, 1990, Digital Information Associates Limited.

The U.S. government charges no fees for using this service. However, permission for its use with Thailand must be obtained from the Thai Post and Telegraph Department which charges a small fee to inspect the receiver (about 100 *baht*) and must be renewed every six months. Today, there are little or no real obstacles to the spread of this important new technology.

Chapter 4

Present Status of GIS in Thailand

Introduction

Probably the most important information that this project collected concerns the existing GIS centers in Thailand. The proposed NGIS Center's relationship to these centers will be crucial to its long term success. A careful and in-depth survey must therefore be crafted if one hopes to gather pertinent and not misleading information.

TDRI has experience conducting two such surveys: in 1987 as part of the Songkhla Lake Basin Natural Resources Management Information System project using *on-site* interviews and in 1989 as part of TDRI's national seminar on *GIS Applications in Thailand* using participant filled-in questionnaires. The information gathered from *on-site* interviews was far more detailed and up-to-date than the user-supplied questionnaire responses. The researchers were far better able to pursue particularly relevant or subtle points using the *on-site* interview method. In addition, personal visits by GIS users (*i.e.* GIS peers) helped to promote public awareness of GIS technology and provided further encouragement to GIS users in that someone or some agency was seen to be taking an **active** interest in their work. The only drawback to the *on-site* method was in terms of time and manpower requirements. TDRI chose the *on-site* interview method in order to gather the most complete data.

The questionnaire used to conduct the interviews is included as ***Appendix I.*** The responses to this questionnaire were entered into a database, which is available from MOSTE.[1] These are summarized in ***Appendix II.***

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1 Three versions of this database will be available: Dbase III, Paradox 3.5, and ARC/INFO.

Map 1 indicates the distribution of GIS centers around the Kingdom. The vast majority are concentrated in and around Bangkok—facilitating *on-site* interviews. While there is a lack of GIS centers outside of Bangkok, it is **very encouraging** to see that at least one center can be found in each major region of the Kingdom. This is especially important in that these hubs are potential GIS support centers for provincial governors.

A reconnaissance survey was carried out to test the questionnaire, verify the applicability of the *on-site* interview method, and to begin to get a feel for the Kingdom's present GIS situation. Five areas were selected for this: within MOSTE, **NEB** was interviewed, from the private sector-**Siam Commercial Bank** was chosen, the BLIS project[2] from the urban sector, Chulalongkorn University from the educational sector, and finally the Agricultural Land Reform Office (ALRO) from the rural/RTG sector.

Results (see ***Appendix II***) confirmed the *on-site* interview method worked best and that the questionnaire covered most of the relevant topics. This methodology was therefore adopted for the remainder of the interviews.

As an example of a practical application of GIS technology, TDRI applied GIS-based network analysis in routing and scheduling the interviews. Estimated travel times and optimal paths were determined for the study team's visits. The first step involved zoning the GIS sites in Bangkok with respect to travel times to-from TDRI. ***Map 2*** details this, while ***Table 4.1*** shows the preliminary districting. The second step comprised determining optimal paths to each series of interview sites. ***Map 3*** provides an example of this application.

The following discussion is based on the extensive national survey of GIS users conducted by the action plan study team. This survey was part of its efforts to develop an understanding of the status of GIS in the Kingdom—who are its key players, what are the major applications, data suppliers, data consumers, etc. The survey was conducted using on-site interviews over the course of several months. The full results of the survey are detailed in ***Appendix II***.

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2 The Bangkok Land Information System (BLIS) is a joint project to establish a common digital GIS database for use within Bangkok. The project is composed of Bangkok Metropolitan Administration, Metropolitan Electricity Authority, Metropolitan Waterworks Authority, Telephone Authority of Thailand, and the Department of Lands.

Brief History of GIS in Thailand

The history of GIS in Thailand is a brief one. The first known application of GIS to Thailand was the World Bank study published in 1985, *A Geographical Information*

TABLE 4.1: Bangkok GIS Sites and Travel Time To-From TDRI

GIS SITE	Travel District
Agriculture Land Reform Office	4
Bangkok Metropolitan Administration	5
CCOP	5
Chulalongkorn University	4
Department of Land Development	4
Department of Lands	5
Department of Mineral Resources	3
Department of Town and Country Planning	2
FAO Kaset University	4
King Mongkut Institute of Technology	5
Mekong Committee	4
Metropolitan Electricity Authority	2
Metropolitan Waterworks Authority	5
National Economic and Social Development Board	4
National Environment Board	4
National Research Council of Thailand	4
Office of Agricultural Extension	4
Provincial Electricity Authority	5
Ramkhamhaeng University	3
Royal Forestry Department	5
Siam Commercial Bank	3
TEAM Consultants	3
Telephone Organization of Thailand	5
Thammasat University	5

Travel district notes: 1=0-30 minutes, 2=30-60 minutes, 3=60-90 minutes, 4=90-120 minutes, 5=more than 120 minutes from TDRI at rush hour traffic.

System for Land Policy Analysis in Thailand.[3] This study was carried out as a demonstration project to show the application of GIS to a land policy analysis. The project covered the whole of the Kingdom at a scale of 1:500,000. The analysis was however **not** carried out in Thailand, but in the U.S. by a consulting firm using a public-domain GIS package, AUTOGIS. Following this project, there were several feasibility and prefeasibility studies concerning GIS, but no actual GIS work was done until 1987. UNEP published a case study as part of its Global Resource Information Database (GRID) under the Global Environmental Monitoring System (GEMS) program, *An Analysis of Deforestation and Associated Environmental Hazards in Northern Thailand.*[4] Like the preceding World Bank study, it used fairly small scale data (1:250,000 and 1:500,000) with the actual work being done outside the country. The GRID unit, in Geneva, Switzerland, processed this data using a turnkey, professional GIS package.

It wasn't until 1988 that the first GIS work was actually carried out **in** Thailand, as part of the TDRI work *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resources Management of Songkhla Lake Basin.*[5] This work involved three GIS case studies covering land use planning and rubber plantation management (over an area equivalent to one RTSD 1:50,000 map sheet), as well as an urban planning exercise (over one city block at a scale of 1:1,000). These case studies conclusively demonstrated the applicability of GIS to natural resource and environmental planners in Thailand.

The pace of GIS growth in Thailand, while initially sluggish, has in recent years picked up considerably. Since 1988, the number of GIS users has grown dramatically—there are now about 30 agencies using GIS technology in Thailand with the number growing **constantly**—so fast that the study team had considerable difficulty in keeping pace with the new users in the given time frame. ***Table 4.2*** lists the known users of GIS technology in Thailand at the present time. ***Map 1*** shows the distribution of these users around the Kingdom, as expected the majority are concentrated in Bangkok.

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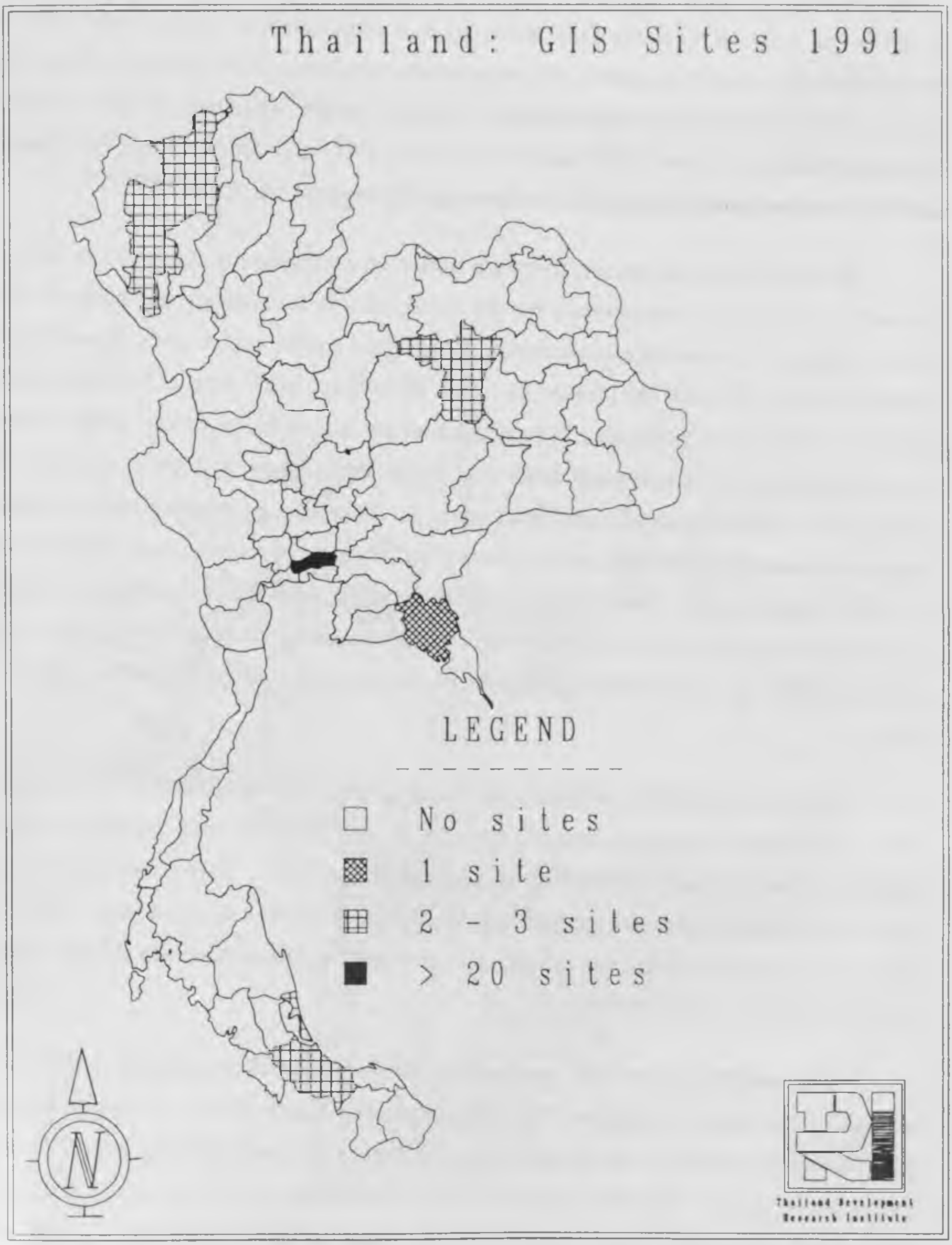
[3] World Bank, 1985, *A Geographical Information System for Land Policy Analysis in Thailand*, Country Program Department, East Asia and Pacific Regional Office.

[4] UNEP,1987, *An Analysis of Deforestation and Associated Environmental Hazards in Northern Thailand*, GRID Case Study Series, #3, United Nations Environment Program.

[5] TDRI, 1988, *Feasibility Study on the Establishment of an Information System for Natural and Environmental Resource Management of Songkhla Lake Basin.*

Map 1


Thailand: GIS Sites 1991
LEGEND
No sites
1 site
2 - 3 sites
> 20 sites
N

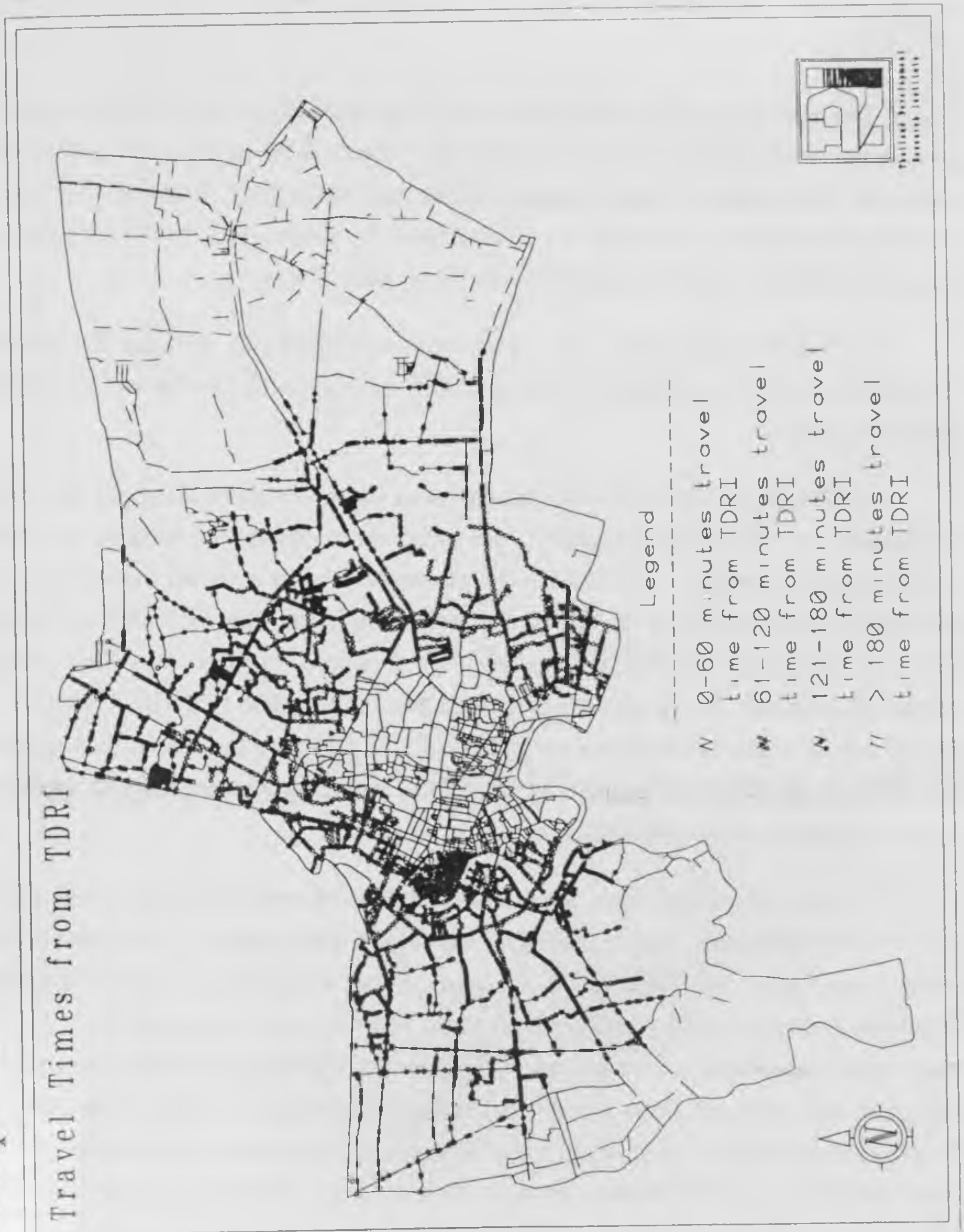
Presently, there are seven universities either teaching or using GIS. In the urban, utility, and cadastral fields, there are eight agencies applying GIS. Outside of these government agencies, there are another ten RTG agencies employing GIS in various fields such as town planning, land use planning, or rural development. At the present TDRI is the only NGO using GIS although it is expected that others, especially those involved in the natural resources and environment, will also soon institute GISes of their own. Four international organizations located within Thailand, FAO, CCOP, the Mekhong Secretariat, and GRID also utilize GIS. FAO and the Mekhong Secretariat are actively involved in promoting GIS technology throughout SE Asia.

Within the private sector, there are now five companies making use of GIS. This is a very encouraging development for the future of GIS technology in Thailand. Private sector budgets are generally considerably larger than public sector ones, thus stimulating many companies to *take the plunge* into GIS technology with what is for them relatively small investments on their parts. The private sector is also more *daring* when it comes to new technology—if a company feels that some technology will be of benefit, it will usually not hesitate to acquire and implement it. This also gives considerable impetus to human resource development, as the private sector becomes a large and lucrative market for GIS literate staff. With these positive benefits also comes a danger inherent to private sector participation in GIS—the first place many companies will look for GIS staff is within the government and universities, thus stimulating another area of *brain drain.*

If one were to make *artificial* divisions among GIS users within the Kingdom into urban and natural resources and environmental (NRE) fields, one would see GIS more often than not in urban applications (a ratio of almost 2:1). This is not surprising given the value of urban land and applications involving it relative to rural land. This trend is even more apparent within the private sector, where profit motive has driven the ratio of urban *versus* NRE users to 4:1.

The single largest GIS application within Thailand is cadastral—the real estate market in one form or another. The Department of Land (DOL), Treasury Department, Siam Commercial Bank, and Bank of Ayudhya are GIS users directly involved with land based applications. The DOL applies GIS in managing land titles, while the two banks are using GIS within their respective real estate credit departments. The Treasury Department will be using GIS in the management of the large amount of government-owned land holdings around the country. Within the urban arena, the organizations

Map 2


Travel Times from TDRI
Legend
0-60 minutes travel time from TDRI
61-120 minutes travel time from TDRI
121-180 minutes travel time from TDRI
> 180 minutes travel time from TDRI
N

involved with the establishment of the Bangkok Land Information System (BLIS) will all be relying on land based information provided by the DOL as a basis for their systems. The utilities, road networks, as built environment, etc. will use cadastral information as its base map. These agencies may be considered *indirect* users of land based information.

The next largest GIS application within Thailand today is in the field of rural or agricultural development and land use planning[6]. Several RTG agencies are active in this field, the Agricultural Land Reform Office (ALRO), the Department of Land Development (DLD), the Office of Agricultural Economics (OAE), Royal Irrigation Department (RID), as well as a private firm, Team Consultants.

The following discussion deals with some of the facts and opinions about GIS in Thailand that was gleaned from the survey of GIS using agencies conducted by the action plan study team.

In GIS, as in any other information-based operation, there are those that create information and those that consume it. As stated above, spatial information is in many ways a *social commodity*. In Thailand the government holds a virtual monopoly on the gathering and dissemination of this commodity. Within the Thai GIS user community, these two camps are divided not only by their functions, but also how they perceive spatial information. For example, when asked whether the MOSTE NGIS Center should be the one to create and disseminate a national GIS database, the spatial data suppliers overwhelmingly distrusted this role for the NGIS Center. In contrast, the data users were generally in favor, some even eager, of such a function.

In terms of staffing level, almost 75% of those interviewed felt that their present staffs were **inadequate**. This is troubling, but of even more concern is that most of these came from within the NRE fields, an area critical to Thailand's future well-being. Examining present staffing levels within those agencies with inadequate staff, we find that about 150 people are employed on GIS work. When asked what constituted an adequate staff, many of those interviewed replied *double* present levels. If we take this literally, this signifies that Thailand needs to come up with another 150 trained GIS staff **just to meet its present needs**. From interviews with academics involved in teaching

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[6] Land use planning certainly has urban applications, for instance the responsibilities of the Department of Town and Country, but for purposes of this discussion, urban and rural land use planning are treated as separate fields.

Map 3


Routing From TDRI
Legend
optimal route from TDRI to Siam Commericial Bank to DMR. 88 minutes travel time, non-rush hour.
Thailand Development Research Institute
N

GIS, at the present Thailand can only produce about **50 fully trained GIS graduates** per year. While short courses and ad hoc training can help supplement this figure, there will still be a **serious shortfall in GIS staff**.

Staff shortages, while serious in and of themselves, will also have adverse impacts on future policies of GIS using agencies. For example, 70% of the data supplying group indicated that they had policies to develop their databases **in-house**. The remaining 30% would use either outside contractors or outside contractors in some combination with in-house development. **Almost 60% of those with plans for in-house database development indicated they had inadequate staffing levels**. The majority of these are again in the NRE field. **Ominously** only 40% of these agencies agreed with the idea of a training role at the MOSTE NGIS Center. This would seem to indicate some lack of understanding, at the management level, of what is actually required for in-house database development.

Data standardization was one role for the MOSTE NGIS Center which received unanimous support among those interviewed. The data supplying group was especially vocal in their sponsorship of this function. Standard data dictionaries as well data exchange standards, were seen by all users as becoming more important as databases grew and GIS technology spread. Many expressed a desire to **actively** cooperate in this task.

Slightly more than 50% of Thai GIS users indicated a need for *expert advice* in developing their own GIS applications. The majority of these were within the NRE group. Many expressed the opinion that finding such individuals was presently extremely difficult, with most users feeling that this kind of help would need to be imported.

One common request from those interviewed during this survey was for sites to visit so that they might familiarize themselves, first hand, with GIS technology. This has also been TDRI's experience—during peak periods as many as one such visit took place a week. While these visits are somewhat flattering, they tend to interfere with regular work and are eventually discouraged. Deterring such visits may well solve an agency's time problem but will not help **promote** GIS technology.

Table 4.2 GIS Users in Thailand

USER	SYSTEM
URBAN/CADASTRAL/UTILITY	
Bangkok Metropolitan Administration	Arc/Info
EGAT	Arc/Info
Metropolitan Electricity Authority	Arc/Info
Metropolitan Water Works Authority	Arc/Info
Provincial Electricity Authority	Arc/Info
Telephone Organization of Thailand	Arc/Info
Department of Land	Arc/Info
Treasury Department	Arc/Info
UNIVERSITIES	
Asian Institute of Technology	Arc/Info
	PAMAP
Chiang Mai	Arc/Info
	ILWIS
	PAMAP
Chulalongkorn	Arc/Info
Khon Kaen	PAMAP
	Arc/Info
Prince of Songkla	Arc/Info
	SPANS
Ramkhamhaeng	SPANS
Thammasat	SPANS
RTG AGENCIES	
Agricultural Land Reform Office	Arc/Info
Department of Land Development	Arc/Info
	ILWIS
Department of Town & Country Planning	Arc/Info
Narcotics Office	SPANS
National Economic & Social Development Board	Arc/Info
National Environment Board	Arc/Info
National Research Council of Thailand	SPANS
National Operations Center	Arc/Info
Office of Agricultural Economics	SPANS
Royal Irrigation Department	Synercom
NGO	
TDRI	Arc/Info
INTERNATIONAL	
CCOP	Arc/Info
FAO	Arc/Info
GRID	Arc/Info
Mekhong Secretariat	Arc/Info
	SPANS
PRIVATE SECTOR	
Bank of Ayudhya	Arc/Info
Esso Standard Thailand LTD.	MapInfo
	Arc/Info
Louis Berger International Inc.	Arc/Info
Siam Commercial Bank	Arc/Info
Team Consultants LTD.	Arc/Info

Table 4.3 provides a summary of the GIS facilities throughout the Kingdom. In looking at the equipment for those agencies with a policy to develop databases **in-house**, we find 25 GIS workstations (both PC and Unix base), 39 digitizers, and 29 plotters. In terms of data capture and map hardcopy facilities, this amounts to a ratio of about **1.3:1** (digitizers to plotters)—somewhat on the low side[7]. A ratio this low will impede the development of databases, there is simply not enough digitizer time to go around. It may also imperil the success of some of these agencies' GIS projects as the low rates of data capture may not allow sufficient data to be input into their databases—**no data, no GIS**. This low ratio of input to output devices seems to reflect a **mapping** rather than a **database** orientation among these users of GIS. Users developing databases in-house within the NRE field also have a similarly low ratio, **1.5:1**.

There is also a striking difference in the basic GIS workstations among NRE and non-NRE users. PC-based workstations predominate among NRE users, while high-powered UNIX-based workstations are most common among non-NRE users, particularly those in the urban field (the ratio of UNIX-based to PC-based workstations is 4:1).

If one were somehow able to fully utilize all of the data capture systems in Thailand, the entire Kingdom, at a scale of 1:50,000, could be fully digitized in about two months time. Taking just the facilities available within the NRE group, this task could be accomplished in about four months time.

For the present, it is not possible to analyze RTG budgets for GIS technology applications because many RTG agencies do not separate GIS acquisitions from other computer purchases. Additionally many agencies are acquiring GIS through aid packages and are therefore not included in RTG budgets. In fact, there were only three agencies with specific line items for GIS: Royal Forestry Department, the Department of Land Development, and the Ministry of Science, Technology and Energy. As the various RTG agencies employing GIS begin to understand and appreciate it, one can expect it to find its way into future RTG budgets. ***Table 4.3*** provides some indications of the GIS facilities being used around the Kingdom. ***Figure 4.1*** gives an idea of the relative proportions of these GIS equipment. This information provides the first look, from a national perspective, of the approximate value of the various GISes being used in

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[7] For example, at TDRI the ratio of digitizers to plotters is 3:1.

Thailand. Note that if one were to **entirely replace** all of the GISes in use today, this would amount to slightly more than **90 million** ***baht***. This amount is on a par to what NECTEC **alone** spends annually on promotion of electronics technology. This amount shrinks to insignificance alongside budgets for large government departments, such as the Department of Land Development which **annually** spends almost 1.2 **billion** ***baht***. It becomes even more inconsequential when compared with what we are using this technology to manage, for example, the value of Thailand's soil has been estimated at **5 billion** ***baht*** **annually**. Nationally, annual maintainence expenditures amount to only about 9 million *baht*—a paltry figure.

Table 4.3 Summary of GIS Facilities in Thailand

Items	Number	Estimated Hardware Unit Costs	Estimated Software Unit Costs	Total Hardware Costs	Total Software Costs	Total Costs
Plotters	29	500,000		14,500,000		14,500,000
Digitizers	39	300,000		11,700,000		11,700,000
PC Workstations	54	200,000	300,000	10,800,000	16,200,000	27,000,000
Workstations	20	1,100,000	900,000	22,000,000	18,000,000	40,000,000
Totals				59,000,000	34,200,000	93,200,000

GIS Staffing

Interviews with RTG GIS managers indicate that staffing problems seem to be the major obstacle to successful use of GIS in most agencies. This stems from a shortage of computer-literate staff and inadequate salaries, specifically in relation to the private sector and other sections of the organization.[8] The root cause, however, would seem to be improper institutional planning for the GIS. Staffing levels and salaries were usually not considered, especially in relation to the rest of the organization and the booming private sector. GIS skills are highly marketable, and will become even more so as the

[8] In most spatial data gathering organizations in Thailand, GIS staff will almost always receive less overall salary than equivalent position outside the GIS unit. The reason being that the GIS staff do not participate in field survey work and hence do not receive per diem. Per diem can substantially supplement monthly salaries.

private sector begins to use GIS more widely. It is problematic that any RTG GIS unit can possibly retain trained staff, especially personnel required for database creation.

Staffing problems have also been cited for the glacial pace of database development within the major RTG GIS agencies. Among RTG agencies responsible for natural resources, none have built any substantial GIS databases to date. While this may change with time, it seems rather improbable in light of the difficulty in keeping trained GIS staff—which will only get worse with time. Capable personnel has been described as the greatest challenge to making GIS technology more widely available.[9] Thailand is not alone in facing a shortage of GIS staff, there is critical shortage of GIS personnel worldwide. Internationally, training institutes are not meeting the demand for GIS staff. If ignored, this problem may become critical in Thailand as well, as many teaching institutes have not developed GIS curricula and it is not yet clear what educational background is required.

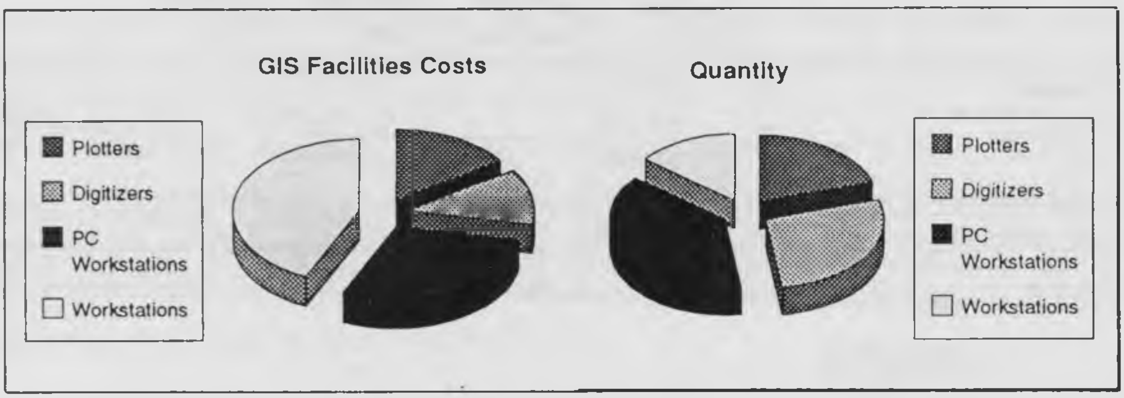

Figure 4.1: GIS Equipment in Thailand

The National Center for Geographic Information and Analysis (NCGIA) has a major educational initiative to develop a *Core Curriculum* for GIS.[10] NCGIA has developed a set of teaching materials to be used for a one-year introductory sequence in GIS at the undergraduate level. The curriculum covers 75 lecture topics, divided among three major sections, introduction to GIS, technical issues in GIS, and application issues

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[9] Aronoff ,S., 1990, *Geographic Information Systems: A Management Perspective.* WDL Publications, Ottawa, Canada.

[10] Kemp. K.K. and Goodchild, M.F., 1990, *GIS Testing Nearing Completion,* NCGIA Report, GIS World. Vol. 3, #2, pp 75-77.

in GIS. This curriculum, already available for $200 US[11], may serve as at least a starting point and perhaps a model for Thai educational institutes in GIS training. *Appendix III* provides the course outline.

The largest known (published) GIS databases are held by TDRI and Khon Kaen University. TDRI's database coverage, by far the largest and most extensive, is shown in *Map 4* while Khon Kaen University's database is said to hold about 150 RTSD 1:50,000 map sheets in the Northeast part of the country.

The following section deals with the status of the various educational institutes in Thailand that are either teaching or using GIS.

Education

One of the most encouraging facts uncovered during the course of this project was that each of the Kingdom's major regional universities had established or was planning to establish some sort of GIS training. Furthermore, all had some GIS activity. The importance of this for future GIS activities cannot be understated. Without a solid cadre of GIS literate and GIS aware staff, future GIS activities will most likely be limited, if not stagnant.

Appendix IV provides a list of some of the known educational centers (almost 300 world wide) which have GIS training. It is provided here as a resource for those wishing to pursue further education involving GIS.[12] It also serves as an indication of the state of GIS education globally. For example, of the 299 schools in this list some 22% are using the NGCIA core curriculum or acting as *beta* test sites . This is very promising as it indicates there is going to be some standardization of course material among GIS educational institutes in the near future. Those agencies employing graduates

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[11] The Core Curriculum can be obtained from NCGIA, Geography Dept., 3510 Phelps Hall, Univ. of California, Santa Barbara, CA 93106.

[12] Two version of this database, Paradox 3.5 and Dbase III, can be found at MOSTE and at TDRI (NRE program).

Map 4


TDRI GIS Database
LEGEND
Not finished
Completed
On-going
N
Thailand Development
Research Institute

from these institutions can, at a minimum, be assured of a basic knowledge of GIS technology.[13]

As to the debate of **where** GIS should be taught, some 58% of those educational institutes teaching GIS are located within **geography** departments (***Figure 4.2*** provides an overview of the locations of GIS educators within the schools covered in the list in *Appendix III* while ***Figure 4.3*** is a summary of the educational institutes within each of the countries in the list). This would seem to indicate that the majority of newer staff in the GIS field will have a *geography* outlook on the use of GIS. Those agencies expecting *hard-core* engineering or computer science based staff, for example within a public utility company, will be somewhat dissatisfied—additional training in these areas will most probably be needed.

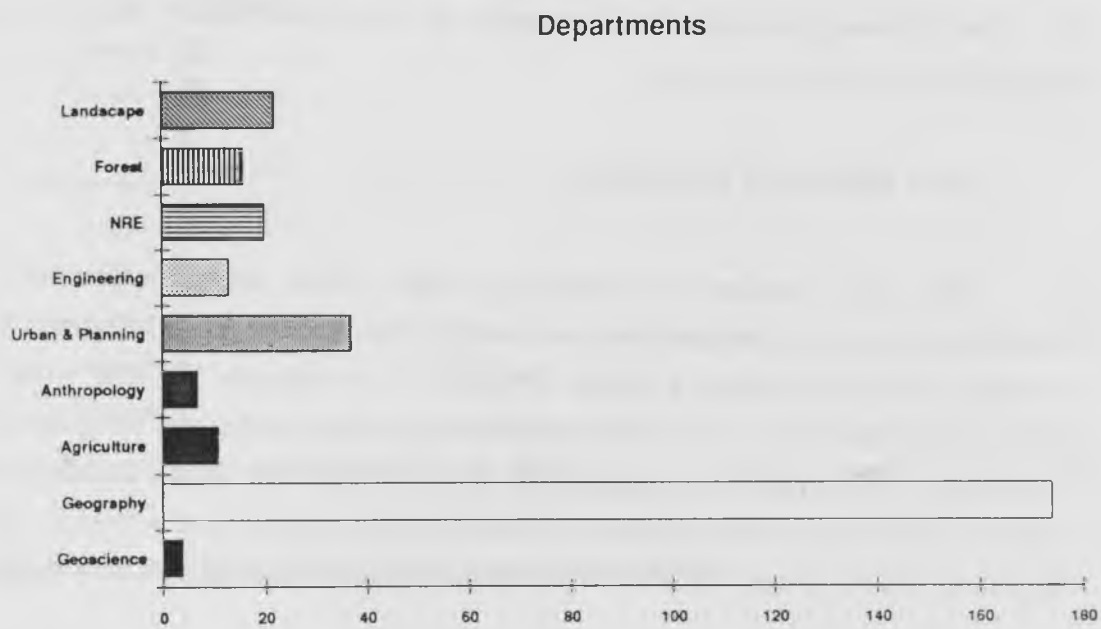

Figure 4.2: Departments teaching GIS

The main obstacles to GIS training, as seen by GIS educators in Thailand are:

[13] This is analagous to knowing that a high school graduate, at the least, will be able to read, write and do basic math. Presently, one has no clear idea of what is meant by *GIS training*. Many GIS *graduates* may know how to push the technology's buttons, but have no deep understanding of the technology it self. Furthermore, they may have no real knowledge of what a GIS really is—many confusing it with remote sensing, CAD or computer aided mapping.

- personnel
- budget (equipment as well as personnel)
- equipment
- technology transfer

It should be understood that these types of problems are universal—most universities around the world are also experiencing them, these are not Thai-only problems. These issues are also not unique to GIS, many other educational fields would also list the same sorts of problems. These questions are also not insurmountable, in fact many are self-inflicted and can be overcome with some simple public relations effort—the NGIS Center would be an appropriate vehicle for this sort of activity.

The availability of GIS training within the Kingdom is summarized in ***Appendix IV***. The following discussion is a summary of each of the major Thai educational centers covered during this survey.

Asian Institute of Technology

The Asian Institute of Technology (AIT), while not an exclusively Thai educational institute, is included here as it accepts Thai students. The Integrated Natural Resources and Development Program (INDRM) is the primary GIS site within AIT, though other departments, for example Human Settlements, will make some use of GIS. AIT teaches both remote sensing and GIS at the postgraduate level. It offers a short course 3 1/2 months *Natural Resources Information Management* and a from 3 week *GIS Workshop*. AIT provides a MSc in GIS. The following outlines this course's studies:

- Introduction
- Vector data and vector topologies
- Raster data and raster topologies
- Data entry; digitizing
- Miscellaneous *geometrical* topics on geodata
- Data quality: error sources
- Map algebra
- Flow charting
- Relational databases

- Linear models
- Digital Elevation Models
- Interpolation
- Remote sensing and GIS
- Classification
- Project work
- GIS project design
- System selection

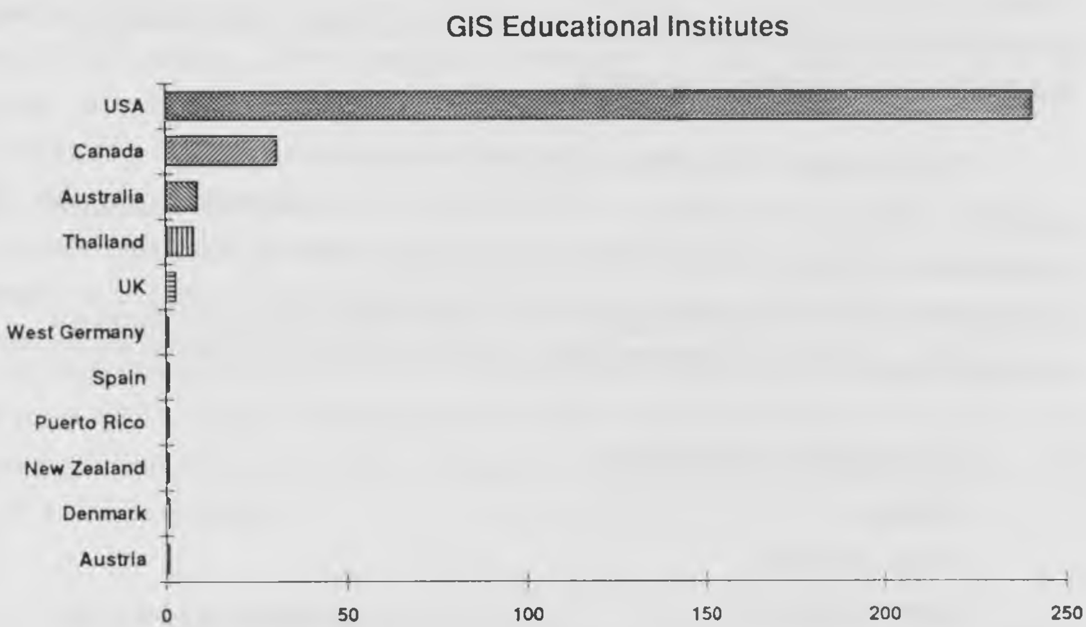

Figure 4.3: GIS educational institutes country summary

Chulalongkorn University

Within Chulalongkorn University (CU) there are two faculties involved in GIS education, Survey Engineering and Geography. CU is a perfect example of the current dichotomy within the GIS educational field concerning how GIS should be taught—as a computer/engineering or *hard* science disciplines or as a speciality of social/geography or the *soft* sciences.

Other faculties, such as Geology, Marine Science, and Urban Planning are now making use of GIS technology. In particular, the Urban Planning Department is now becoming very active in this field.

The Survey Engineering Department (SED) is heavily involved as a consultant in the Bangkok Land Information System (BLIS) project. The SED offers two courses in remote sensing as well as terrain analysis. The *flavor* of the GIS training offered within the SED is heavily oriented towards Land Information Systems (LIS)—the department centers upon **urban** GIS applications as befitting a Survey Engineering faculty within Thailand's largest city. The department has links to several universities teaching cadastral and land information systems—for example, Ohio State University in the U.S. and Melbourne University in Australia.

The Geography Department offers both remote sensing and GIS education. It has academic links to the University of Edinburgh—the department's faculty has the opportunity to further their education as well as gain hands on experience there. A Bsc in Geography with GIS courses is offered by the department, while it is planning to provide MSc education in the near future. The Bsc offers the following basic courses:

- Map Reading and Cartography
- Statistics
- Computer Science
- Operation Research
- Geography
- Remote Sensing
- Photogrammetry
- Surveying and Geodesy
- Mathematics
- GIS

The department has offered two GIS training course for RTG officials in the last year with plans to offer more in the future. The department is involved in two projects at the present—a land tax mapping project in Chonburi as well as a mapping project in Roi Et.

Chiang Mai University

Chiang Mai University (CMU) is the main educational institute in the northern region of the Kingdom. There are three sites within CMU using GIS: the Geography Department, the Agricultural Department (specifically the *Farming Systems* group), and within the Social Research Institute (SRI).

The Agricultural Department is offering international training in farming systems with GIS offered as a part of the course work. It is also involved in using GIS in various research projects. The Social Research Institute (SRI) is participating in a project *Rural Resources Development* with the University of Victoria. It as yet does not offer any official GIS training. The Geography Department is now beginning to offer GIS training, for example to RTG officials on a short course basis.

Kasetsart University

Kasetsart University's (KU) GIS unit is located within the Forestry Department, having been donated by FAO as part of a project to upgrade forest inventory capabilities within the ASEAN region. The department offers several short courses on GIS for forest inventory, mainly for students from within the ASEAN region. It plans to offer an MSc in GIS in the near future.

Khon Khaen University

Khon Khaen University (KKU) serves the northeastern region of Thailand's educational needs. KKU has two groups making use of GIS, both within the Agriculture Faculty: the *Remote Sensing Soil and Water Management in NE Thailand* group and within the *Farming Systems* group. It's future plans include teaching both remote sensing and GIS as well as promoting the use of GIS for rural development.

Mahidol University

Within Mahidol University there is at present no GIS education. Some faculty and students within the Faculties of Environment and Electrical Engineering do, however, make use of it in some small scale projects.

Prince of Songkla University

Prince of Songkla University (PSU) is the south's main educational center. While there are two groups making use of GIS within PSU, they are both from within, at least originally, the Engineering Department. Under the Songkhla Lake Basin Development Program a Songkhla Lake Basin Information Center was established under the Rector's Office. It offers no direct GIS education but is available for thesis research by graduate students throughout the university. An inter-faculty program offers a GIS-based MSc in *Environmental Information Systems*. Future plans are to increase the student output to meet the perceived increasing needs for GIS personnel. PSU has links to Australian educational institutes which provide GIS educators on an *ad hoc* basis.

Ramkamhaeng University

Within Ramkamhaeng University (RU), there has been established a *GIS Project*, with staff from the Geography Department, that is responsible for GIS training. However, this training is outside the normal education system—the project's main objectives being to make base maps of the entire Kingdom within ten years and develop standardized GIS training materials. Currently, the project is preparing a Bsc in GIS, which it hopes to begin in the near future.

Silapakorn University

Silapakorn University, at present, has no GIS activities. However, the university is interested in GIS technology and may begin applying it soon.

Sri Nakrinwirote University

Sri Nakrinwirote University has no GIS activities at the present time, but is beginning to introduce this technology within the Geography Department. It is limited by a lack of budget and personnel.

Thammasat University

Within the Faculty of Science and Technology, the Department of Environmental Science Bsc program provides courses on *Soil Resources Environment* and *Land Use Planning* which use GIS technology. GIS is used in special topics work as well. The department well recognizes the importance of spatial information and hopes to expand its GIS activities in the near future. It hopes to create a network of GIS educational institutes to overcome some of the equipment and staffing problems as well as to formulate standard GIS teaching materials and course content.

Chapter 5

GIS Policy Issues in Thailand

The preceding discussions have raised several issues that may have consequences for the further development of GIS in Thailand. These issues include:

- **remote sensing** and its relationship to GIS,
- **responsibility issues** for spatial data and its analysis,
- **institutional issues**, including staffing, education and the political implications of a GIS,
- **freedom of information** and **databases**, perhaps the most important issue of all.

To these, the needs of the private sector and its potential role in further developing GIS, might also be added.

Remote Sensing

Remote sensing is, in terms of budget share, the single largest spatial data gathering activity in Thailand. Remote sensing's potential to provide up-to-date data for a GIS is very large and will become even more important with time. There are, however, institutional issues that limit its applicability, these being mainly RTG budget shortcomings that so far have restricted the purchasing power of line agencies wishing to procure remotely sensed data. Those RTG agencies that are able to allocate budget for the purchase of remotely sensed data in no way offset the costs of running the ground receiving station and are thus, to some extent, **underwritten** by NRCT. It is suggested here that, at least for the short term, remotely sensed data be fully subsidized and budgets previously allocated to purchasing it be turned instead to the acquisition of image analysis systems and staff training in their use.

Another aspect of the remote sensing issue is its integration with GIS. To date, there has been no large-scale, large-area work done that has successfully combined, in an operational sense, GIS and remote sensing. Both technical and institutional efforts must be made to ensure that this linkage is realized for **production** purposes.

Responsibility

Issues dealing with the responsibilities or liabilities involved with using GISes have never been addressed in Thailand, even though Thai society commonly establishes **legal** accountability in many other disciplines such as engineering, medicine, even truck driving. Four areas of responsibility have been identified: content of the GIS data and analysis, its context, its format, and finally its use when combined with other data sets. These issues are, at times, subtle and require input from both GIS technical practioners as well as social scientists and jurists. If addressed today—while GIS is in its nascent stage in Thailand—these issues can be resolved in a calm and rational manner. If left for a later stage, at a minimum, litigation will result, damaging to the organization and the GIS within it. A worst case may see serious injury or even deaths as the aftermath of irresponsible use of GIS technology. It has been suggested that each GIS have a *GIS Information Officer* position to oversee the political, technical, legal, and economic aspects of using GIS generated data or analyses.[1]

Institutional Issues

Institutional issues begin with the start of the GIS. GISes do not exist in a vacuum, they must be placed in the proper institutional setting to be effective. Funding and staffing levels must be sufficient to ensure the healthy functioning of the GIS. Above all, a GIS must have some type of mandate or goal—a GIS is not an end in itself.

While an organization may have a specific task assigned to it by law, what role will the GIS play in meeting that task? Before a GIS is implemented this must be clearly defined within the environment of the institution that controls the GIS. Institutional issues also cover policies relating to data access by external users. How should access to

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[1] Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publications, Ottawa, Canada.

an organization's data be organized? If it is completely prohibited, how can one socially justify creating the database in the first place?

Staffing

Staffing problems are looming as one of the more serious issues facing RTG GIS agencies. Presently, there is a serious shortage of GIS staff for the established RTG GIS agencies that reflects a shortage worldwide. As the private sector discovers the benefits of GIS for itself and incorporates it into its normal business practices, the present GIS staff shortage faced by most RTG line agencies will only get worse. Experienced GIS personnel will find themselves with very marketable skills, thus making their retention by the government even more difficult.

Educational institutes, internationally, are not keeping pace with the rising demand for GIS personnel. Within Thailand there is no set GIS curriculum or even agreement upon educational background—one is apt to find GIS training in engineering, geography, computer science, social science, and agriculture faculties. It is suggested that those institutes providing GIS training come to some agreement on the form and content of GIS curricula to ensure a thorough founding in GIS principles. This is a basic form of insurance for organizations using GIS—can it count on the staff it hires to skillfully and responsibly run its GIS as much as it can count on engineering graduates to handle tasks within their field? The NCGIA has developed a *Core Curriculum* for GIS, that may serve as a starting point for Thai educational institutes.

Freedom of Information

It has been seen that GIS technology is most developed in the United States, a prime reason for this is the **public** access to government collected data provided by **freedom of information** laws in the United States Digital databases in the United States can be readily acquired at a nominal cost—there are virtually no restrictions on access to government data. This is in direct contrast to Europe and the U.K., where government control of data has been cited as actually retarding data distribution and hence the spread of GIS.[2]

Thailand is fortunate because most of the country and many of the important thematic data layers have already been mapped. Thus, there is a large, physical database already in existence. This is important because **databases** are at the very heart of any GIS; without a spatial database a GIS is nothing. Databases and the **free** flow of information are intimately linked. If information is restricted, its distribution will still proceed via informal channels, but at a very slow rate. This will in turn effect the development of GIS databases, as most RTG line agencies and those interested in using their data need to start from information contained on the existing stock of physical maps.

Spatial Databases

Another issue relevant to GIS databases is the **value** of such databases. In most cost-benefit analyses the database would be assessed as a **cost**, overlooking the very real value of the information contained in it. The principle asset of any GIS is its database, which should become more valuable as its information is becomes readily available because it is in digital form and as **historical** information becomes **rarer** with time. As of yet, there has been no successful attempts to establish the real **worth** of a GIS database in monetary terms. Some sort of fiscal yardstick is needed to measure, in well-accepted terms, the value of a GIS database.

Staffing and flow-of-information problems are seen as frustrating the development of GIS databases in Thailand. Among RTG natural resource and environmental line agencies possessing GISes, none have any serious databases on hand yet. The two largest and most comprehensive are held by an NGO (TDRI) and a university (Khon Kaen University). With the expected shortfall in GIS staff and the increasing allure of the private sector, is it reasonable to expect RTG line agencies to be able to realize these badly needed databases in a reasonable amount of time? It therefore seems prudent to offer that GIS database development be *farmed* out to the private sector. RTG line agencies excel in management, having educational backgrounds and

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[2] Lord Chorley, Opening Address at First European GIS Conference, EGIS'90, The Netherlands.

experience not often found in the private sector. They also are legally mandated to manage human and natural resources to the benefit of society. If RTG agencies can relieve themselves of the difficult and thankless task of database building, they can devote their scarce resources to **using** GIS technology.

Initial costs for database creation by outside agencies may seem high, but long term per user costs, user labor costs, required user technical skills, and use of existing resources are quite low. Risks to the user organization are also reduced, because the database completeness and accuracy can be clearly guaranteed through contractual obligations.

Another possible solution to this dilemma might be found in a multidepartment co-operative GIS. In this environment equipment, staffing, expertise, database construction costs and the database itself would be shared among several different government agencies. The political implications of this sort of arrangement necessitates it being hosted by a third-party organization seen to be without a vested interest.

One slight drawback of a multidepartment GIS is that users are at times united in an application in which they may find themselves diametrically opposed—friction is thus created. This suggests another form of GIS that is becoming increasingly popular in the United States, the **multiparticipant** GIS.[3] Users from both the public and private sectors, unite for a specific application that they tend to view in the same light. The private sector has the entrepreneurial drive and funding, while the government has the data and the legal mandate to manage this data. Both sectors bring their respective strengths together in such a project.

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[3] Montgomery, G.E., 1990, *Multiparticipant GIS Project*, GIS World, Vol. 3 #1, pp 79-81.

Chapter 6

National GIS Center Action Plan

Introduction

This chapter lays out the background and the conceptual framework from which the plan was formulated. Basically, the research team has seen the NGIS Center as a ***supporting*** rather than a ***watchdog*** agency. Its mandate would necessarily be to promote the use of GIS technology in Thailand not to curtail or restrict it. The Center was **not** seen as prohibiting the spread of GIS to new users or applications. On the contrary, the Center was seen as advancing and nurturing this new technology.

A basic tenet, held from the outset of the plan's development, has been that the hardware and software required for GIS should be allowed, even encouraged, to proliferate according to the perceived needs of the actual end users, rather than under the aegis of some centralized body. If we accept these ground rules, the roles of the NGIS Center would therefore need to be:

- to overcome the more obvious shortcomings in using this technology in the present situation in the Kingdom,
- to determine and develop strategies to overcome the subtler barriers to the continued development of GIS technology,
- to foster research into GIS technology and institutional issues,
- to promote new end users and applications,
- to provide an **unbiased end user**, rather than **vendor**, view of the technology's capabilities,
- to help provide GIS education to institutions at all levels.

Furthermore, given the present state of GIS development in Thailand which tends to be **technology driven** rather than **data and application driven**, the Center should also provide some sort of facilities, both hardware/software and qualified human resources, for GIS application development to help overcome this drawback.

As stated above, the study team's basic tenet has been that the proposed NGIS Center would be a ***supporting*** rather than a ***watchdog*** agency. Similar in concept to the United States' recently established **National Center for Geographic Information and Analysis** (NCGIA), its mandate must clearly **not** be to restrict the growth of GIS technology in Thailand. It was **not** seen as prohibiting the spread of GIS technology to new users and applications. On the contrary, its role has been seen from the beginning as nurturing and promoting this new and **proven** technology.

TDRI's previous research into GIS in Thailand together with the nation-wide survey of GIS users indicates the main GIS issues to be:

- Freedom of information
- Institutional support for GIS
- Responsibility of applying GIS
- Lack of GIS database development
- Little appreciation for value of spatial information
- Deficiency of specific GIS applications technology
- Shortage of GIS staff

Any GIS center within Thailand would need to seriously address these issues if it wanted to contribute to Thailand's continued development.

From the study team's extensive survey of Thailand's GIS users, the overwhelming majority presently **do not want a centralized GIS database**. Reasons given for this strongly held belief, ranged from *the NGIS would become much too big and powerful*, to *no **one** organization can understand all of the GIS data required for **all** of Thailand's GIS applications*. While it can be argued that it is perhaps **technically best** for Thailand if **one** agency develops all of the needed databases, institutionally this seems to be a losing proposition.[1] Without the full cooperation of the primary RTG spatial data-gathering agencies, the NGIS would wither away to the role of some hardware and software heavyweight, lacking any significant amount of spatial data—the real key to any GIS. It would be a simple matter for the primary data gathering agencies to ***starve*** the NGIS of data. Past experience with RTG institutes seems to indicate that there is no practical way to enforce this by administrative *fiat*—if it were to work, the various spatial data-gathering agencies must *want* to share their data. There must be some incentive for them to want to contribute *their data* to any centralized database. This kind of incentive necessarily involves serious administrative reform throughout the RTG, an issue that raises complexities far beyond the scope of this study. What is seen by many as **working** within the Thai *context*, is a **network of GIS users**. Each of the mandated spatial data-gathering agencies would be responsible for developing its own databases, while an *outside* agency would play the role of **catalyst and coordinator**. The main thrust of the NGIS's plan of action should therefore concentrate on this aspect, which was regarded by the present GIS user community as most suitable and most urgently required for the continued development of GIS technology in Thailand.

NGIS Center's Main Roles

It stems from the above discussions, that the NGIS's main role must encompass standardizing and coordinating functions. This is envisioned as the most appropriate in light of the present state of GIS technology and the given institutional conditions existing here in Thailand. Data indexes, data exchange standards, data precision standards, and standardized data dictionaries are seen as increasingly important tasks which no single data gathering agency is willing or able to assume. There is a definite need for a coordinating strategy among RTG agencies building GIS databases—it will help reduce duplication and improve efficiency; increase data accuracies; make spatial information more accessible; and ensure the potential value of each piece of spatial information is realized .

GIS training at all levels will also be an important role for the NGIS. Primarily, there is now a dearth of GIS operators, analysts, and managers that will only become

[1] One option that comes to mind is for a respected and neutral third party to construct the database. If all parties involved were to agree and accept this third party, Thailand's GIS database could conceivably be finished in short order.

worse as the private sector staffs up to meet its own GIS needs. More troubling, however, is the lack of understanding of GIS technology within the upper managerial levels of GIS-using RTG agencies. In the long term, this will result in a lack of institutional support for GIS within many RTG agencies, surely the death knell for this technology within those agencies. It also exacerbates the **information barriers** between RTG agencies as well as between the private and public sectors. Executive-level training and study tours are therefore prime requirements for continued development of GIS technology within Thailand.

Another role foreseen for the NGIS involves thoroughly acquainting potential or casual users with **real** GIS technology. Agencies wishing to get a *taste* of GIS technology are many times left at the hands of the vendors for an introduction to GIS—not an all together healthy situation. At other times, interested parties are often treated to GIS technology *shows* by users who may have little appreciation of the technology or who may have no understanding of what that particular user requires in the way of GIS. This can lead to misleading information, resulting in faulty decisions about whether to *go* for GIS technology.

While GIS technology is rapidly spreading throughout most RTG agencies and into the private sector, it is still in its infancy with regards to end-user applications. Most of the GIS seen now is more or less *vanilla-flavored* or generic GIS. This is partly due to the *toolbox* metaphor of the GIS software in the market, but also due to the lack of skills in developing specific end-user applications. The skills needed to develop successful end-user applications go beyond a basic understanding of GIS technology—a deep appreciation for a user's needs is also required. Since this combination of skills is extremely rare, it highlights another potential role for the NGIS, that of *hired-gun* for GIS application development. An end user, who brings with him a deep understanding of his application needs, would be teamed with a GIS application developer at the NGIS, who possesses the requisite understanding of GIS technology. This matching of skills should result in the development of successful end-user GIS applications.

Major research topics for the NGIS would include:

- Developing an administrative and political environment to facilitate inter-agency cooperation in terms of database development.
- Finding ways to promoting freedom of information.
- Assessing the value of spatial information.

- Education and training topics, specifically ensuring that the growing GIS industry's needs are met.
- Specific end-user applications development.
- Data integrity standards.
- Maintaining spatial data indexes.
- Development of data standards.
- National level spatial data issues.
- Development of a national forum for the exchange of GIS experiences and information at technical and policy levels.
- Help determine national priorities for basic spatial database development.
- Develop ways to promote Thailand's GIS strengths to the regional market.
- Pinpoint and promote development of technology relevant to Thailand's GIS needs.

Clearly, there is a significant role for another agency with respect to the **promotion and development of GIS technology.** This applies to within MOSTE in particular and over Thailand in general. Within MOSTE, there is already a precedent for this type of **technology promoting** agency—NECTEC has been playing a successful role in promoting computer and information systems technology within the Kingdom for the past several years. It would serve as a useful role model for the proposed NGIS.

Accordingly, the NGIS's functions would **not duplicate** any of the GIS roles now being played by the other two GIS-using organizations within the Ministry of Science, Technology and Energy (MOSTE)—the Office of the National Environment Board (ONEB) or the National Research Council of Thailand (NRCT). The roles of these two agencies have been clearly defined for some time now. ONEB is an **implementing** agency, primarily concerned with GIS applications involving natural resources and the environment. Its *niche* within MOSTE is fairly clear, it requires the development of a well defined suite of GIS data and applications. While NRCT is outwardly a research agency, it has been heavily involved in the *day-to-day* operations of Thailand's satellite ground station, one of the most advanced in the world. NRCT has played—and continues to play—a leading role in the development of Thailand's remote sensing technology. The state of remote sensing in Thailand is largely due to the role played by the NRCT. Its clear **leadership** role in remote sensing should not be watered down by including the **promotion** of GIS technology as another of NRCT's tasks.

TDRI, with the assistance of CIDA, is at the present compiling an index of spatial data throughout the Kingdom. This index will eventually be turned over to the NGIS Center who will be responsible for maintaining it. It will be an invaluable resource for those conducting research that involves spatial information.

Unbiased and up-to-date information concerning GIS technology is often hard to come by. Another role proposed for the NGIS Center would be the creation and maintainence of a simple, on-line information system in the form of an electronic bulletin board system (BBS). Users wishing news about GIS events, technology updates, GIS *who's who*, or simply technological *gossip*, would access this system through a modem. This BBS would function as a sort of communication hub for GIS users—it certainly help strengthen the GIS users network, simply by making it easier for people to communicate with one another. Access to the spatial index might be facilitated by placing it in this BBS.

The NGIS Center will also establish a library devoted to GIS literature. Technical journals, trade magazines, and textbooks related to GIS technology will be held there. While this may seem a rather trivial function, it is not to anyone who has attempted to find relevant GIS literature. One may find this literature scattered in Thai libraries, it is however, very difficult to find them all in one place. It is also suggested that this library act as a repository for all **Thai** literature involving GIS. The library will also sponsor translations of GIS references into Thai—it has been often said that computer technology in Thailand benefitted most from good translations of Dbase and AutoCAD manuals, than from anything else

During the initial establishment phase of the Center, much of the work would need to be contracted out—MOSTE does not yet posses sufficient GIS staff to fully undertake the necessary work. NGIS Center staff will be developed over this initial phase by in-house training, *training the trainers*, and Phd and MSc level graduate studies. It is expected by the end of the first five years that the majority of the Center's functions will be handled internally.

Whether GIS technology works or not is a moot point—its growing user community within Thailand certainly proves that it indeed does work. A more relevant question is how can we promote the use of this important technology, how can we encourage its **rational** application. The reseach team feels that the establishment of the MOSTE NGIS Center will make a significant contribution to answering this question.

NGIS Center Institutional Structure

The *expected* institutional arrangements are presented in this section. ***Figure 6.1*** presents an organizational chart for the NGIS Center as it stands within the Ministry, while ***Figure 6.2*** presents the organizational chart for the Center itself. It should be emphasized that this possible structure is at its **inception only**. The organization is expected[2] to evolve with time and in response to the changing GIS situation in Thailand. The final structure of this organization should not bear much resemblance to the structure presented here. The organizational structure suggested here is hoped to be flexible enough to provide a firm basis for the future growth of this Center.

The organization of the Center is divided into four sections: Administration, Training, Research, and Applications, which reflect the major functions of the Center as outlined above (***Appendix V*** gives details for each of the four sections within the Center). It is important to note that many of the staff within the Center would wear several *institutional hats*—that is they would participate in more than one of the Center's activities. For example, the GIS Information Officer would take part in the Center's administration, research, as well as engage in applications development, while the Center's Economist would participate in applications development, research, and training. In this case, the Center's **Coordinator** would play a very important role in the smooth functioning of the Center. As such, this position must be filled with extreme care—the efficiency and personality of the Center's Coordinator will be reflected in the Center's success or failure. The Coordinator's role will assume even greater importance as the Center's activities gear up towards full internal operational responsibility in the fourth year of the Plan. The proposed qualifications for these staff positions are discussed below.

As discussed above, the role of the Center will not duplicate the tasks of any of the existing GIS user agencies within MOSTE nor will it replicate the jobs of any of the other GIS using agencies within the Kingdom. Its primary role, that of GIS technology promotion, is currently unfilled within Thailand. In fact, the Center would act to support these GIS using agencies regardless of institutional arrangements—simply because GIS technology, in and of itself, cuts across many organizational boundaries, actually functioning as an integrating technology.

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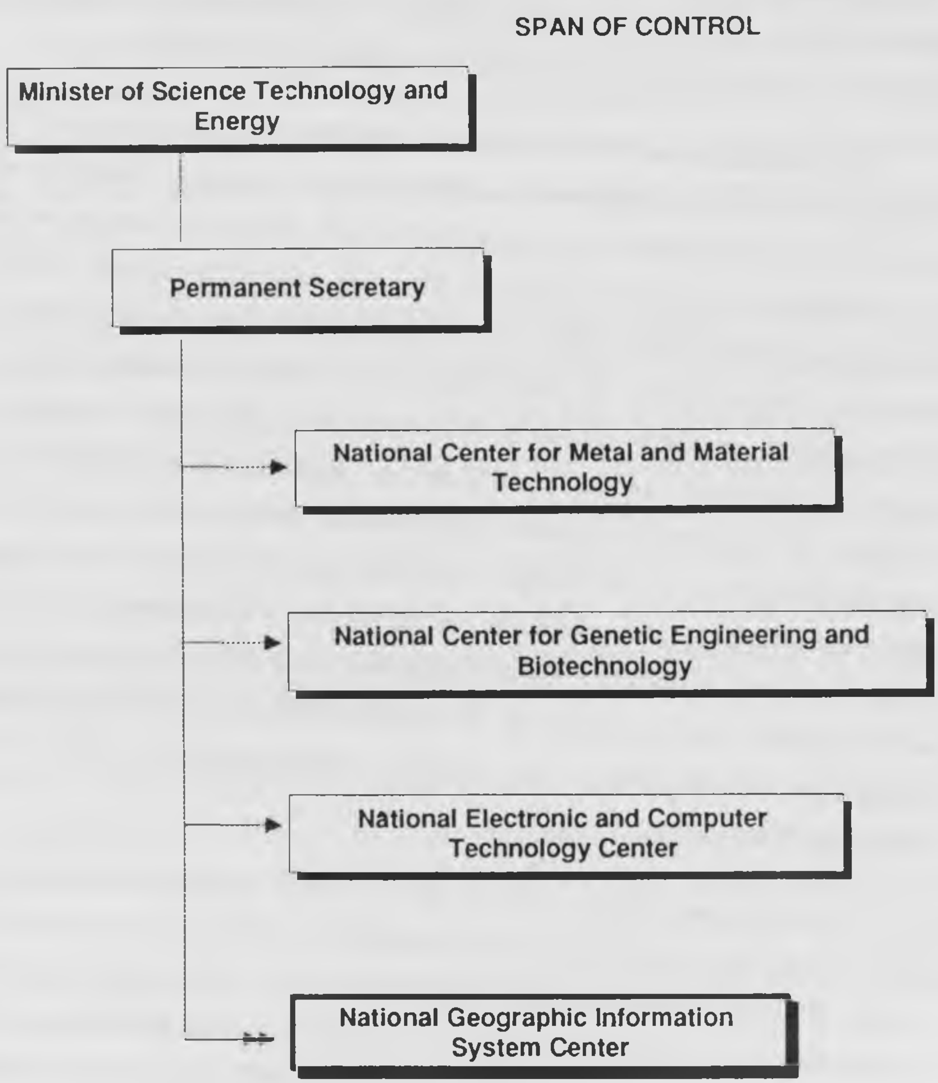
[2] It is fervently hoped that this will be the case.

The Center would need to actively pursue some kind of relationship, whether formal or informal is best decided on a case by case basis, with each of the GIS using agencies in the Kingdom. In particular, relationships with the Kingdom's universities would need to be carefully cultivated. In addition, other international GIS centers would need to be contacted and relations established—the sooner the better.

Figure 6.1: MOSTE Organizational Chart



Staffing Requirements

This section discusses the personnel for the Center in line with the major functions outlined above. From the inception of this project it has been recognized that there exists a serious lack of GIS staff throughout the Kingdom. Staffing for the Center is no exception—from the outset of the Plan, much of the Center's staffing **must** be contracted from **outside**. Fortunately, there is enough qualified staff in universities, RTG agencies, NGO's and the private sector to operate the Center, at least on a rotating, part time basis. At the Plan's inception, five (5) **full-time** staff would be required. At the third quarter of the Plan's fourth year (the beginning of full internal operations) another nineteen (19) individuals would be needed. When fully operational, the total staffing required for the Center would be twenty-four (24). The staffing requirements are outlined below:

- **Director**: This is a **full-time** senior position from the inception of the Center. The Director will be responsible for the day-to-day running of the Center as well as setting Center policy in response to the changing GIS situation in Thailand. The director would need to also maintain close contacts with the GIS user community as well as publicize the Center's activities. As such, this position requires strong managerial traits, long experience with RTG agencies (in particular MOSTE) , and, above all, a strong interest in GIS. A good background in cartography/mapping and/or computers is also desirable. At a minimum, a Masters Degree should be required for this position. This slot is perhaps best recruited internally from among MOSTE's division chiefs. It should be stressed that this would need to be a **full-time position** from the very outset of the Plan. While there may **seem** to be little activity within the first few years of the Plan, there is a considerable amount of planning and publicity efforts needed then, much of it crucial for the later stages of the Plan. Therefore the Director's time and attention would need to be focused exclusively on the Center rather than sharing with other responsibilities such as running an existing division. The Director would probably need to attend a management level GIS training course to prepare for running the Center. This might initially be given within Thailand at one of the universities or GIS vendors, or overseas—for example at SUNMAP in Australia, among one of the NGCIA's consortium in the U.S., or with one of the larger, more experienced GIS vendors. This training would serve a dual purpose in also establishing a close relationship with an international GIS center. **It is therefore strongly recommended that the Director attend such a course a soon as possible.**
- **Assistant Director**: This is another senior management position but would probably **not** be required full time at the Center's inception. This individual will assist the Director in managing the Center, the staff in particular. The Assistant Director would need some kind of background in GIS technology and its applications, as this position will be more of a *hands on* task than the Director's.

Qualified individuals for this slot already exist in Thailand today. They are all, however, fully employed and as such would need to be *head hunted* from within the GIS user community—something that is guaranteed to make the Center extremely unpopular. A better approach would be to recruit and **train** an individual from within MOSTE or better still, a recent graduate in Cartography/Geography/Computer. A Doctorate-level degree would be needed for this job—training would therefore have to take place overseas as none of the Thai universities contacted to date offer this level of *pure* GIS education. This position would need to be filled by or near the end of the Plan's fourth year. Ideally, the Assistant Director would be *seasoned* in this position and eventually advance to the Director's slot.

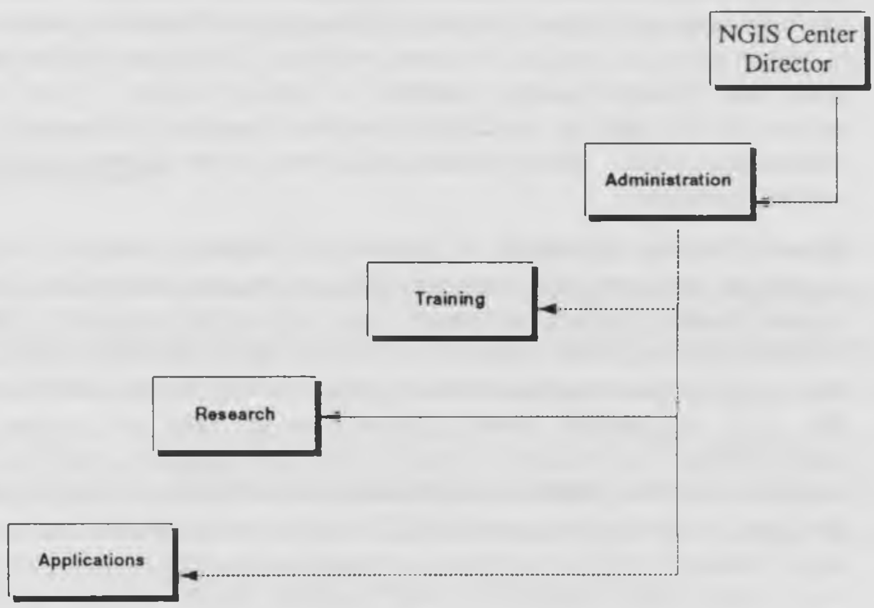
- **GIS Information Officer:** As mentioned earlier, this position is a relatively new idea based on suggestions by Stan Aronoff.[3] This individual would be a **professional, directly** responsible for the evaluation of technical, legal, economic and political factors involved in the use of GIS technology, with particular emphasis on the use or misuse of GIS data and analysis. Good knowledge and experience of GIS as well as a deep appreciation for the relevant issues is required for this position. Some background in law/political science/current affairs would also be desirable. Because of the sensitive nature of this position, overseas training is almost mandatory. A Master or Doctorate level degree would be needed. This job would need to be filled by the beginning of full internal operations (end of year four). This individual would also be involved in the Center's administration as well as research and applications development
- **Coordinator:** This position is required from the outset of the Plan. While the staff of the Center sounds sizable (24), the tasks needing to be fulfilled are also considerable. Staff time must therefore be split up amongst the various tasks. This not only makes the staff time more cost effective it will also improve the skills and experience of the Center's staff by *cross fertilization*—for example, an individual doing nothing but training will soon grow *stale* as well fall behind in knowledge of GIS technology. By taking part in applications development or other *creative* activities, this individual will remain *fresh* and on top of his/her profession. Coordinator is therefore a critical position and special care should be taken in selecting this individual. Strong inter-personal skills are required—in coordinating the various Center activities, friction between staff is best avoided and a certain amount of *hand holding* is also probably required. While no special knowledge of GIS is required, some sort of introductory training would help in understanding the needs of the Center's staff as well as its *clients*. This individual would also be involved in the Center's administration as well as in the Center's GIS training courses.
- **GIS Trainer:** This individual would be responsible for designing, implementing, and coordinating the Center's GIS training courses. The GIS Trainer would need a good background in GIS as well as some formal training in its teaching. This type of training may be best obtained at one of the major GIS

[3]Aronoff, S., 1990, *Geographic Information Systems: A Management Perspective*. WDL Publications, Ottawa, Canada.

vendors, especially one with a strong commitment to GIS education, while a regular degree course (Masters level or above) in GIS would be needed for technical knowledge of GIS and the issues relevant to its application. This position would be required by the beginning of third quarter in year four of the Plan.

- **Systems Analyst**: This job would need to be filled by the start of the full internal operations. It has been argued that any type of systems analyst would be suitable for this slot, but the study team's experience has been that a *normal* data processing systems analyst does not have an appreciation of the technical aspects peculiar to GIS, for example coordinate systems and scales are more often than not overlooked by most systems analysts during the course of a GIS design. Therefore formal education in GIS, with particular emphasis on spatial analysis and system design, is required for this position. A Masters Degree course, perhaps with some type of cooperative work at a GIS vendor or software house, would be best suited to the training requirements for this position. This person's duties would include application development and training.

Figure 6.2: NGIS Center Organization Chart



- **GIS Programmer**: This position would require an individual with a strong background in computer science, who would be sent for formal education in GIS with special stress on user interface design, geographic analysis techniques, spatial data structures, spatial algorithm development and artificial intelligence (AI) techniques. This person could probably be recruited among local computer science/engineering graduates and sent for a higher degree in GIS. This slot would need to be filled by start of full internal operations. The duties of this person would be to aid in application development, develop special case or *ad hoc* GIS utility software and to investigate the feasibility of developing commercial GIS software within Thailand. This person would also have some training duties.

- **GIS Applications Developers**: Five individuals are thought to be needed to develop GIS applications for the Center's clients. These individuals would have to be selected from among potential applications fields—for example forestry, agriculture, aquaculture, engineering, environment, and land management. Recent local graduates in these fields are perhaps the best resource pool to chose from. These people would be given formal GIS education (Masters Degree level) with emphasis on practical applications development. Their task upon returning to the Center would be to assist client RTG agencies in the development of GIS applications suited to their particular needs. Their initial background in these *end-user* fields would greatly assist them in developing the GIS applications required by client RTG agencies. In addition to their role as applications developers, these individuals would also have training responsibilities—each taking on a particular field of GIS end users.

- **GIS Researchers**: Five of these individuals would be needed to conduct **full time** research on relevant GIS issues. While there are some obvious issues that need further research, they would most probably need to develop these issues, in particular those most relevant to the GIS situation in Thailand. Masters Degree or higher would be required for these positions. These individuals would also make their research findings available in training courses. They would be assisted in this task by the Remote Sensing Specialist, Economist, and GIS Information Officer. These positions would have to be filled by the start of full internal operations.

- **Remote Sensing Specialist**: At present in Thailand, there are few if any production work that fully integrates GIS and remote sensing. A position of Remote Sensing Specialist within the Center is therefore mandatory. The task of this individual would be to operate the Center's remote sensing systems, assist in training, research, and applications development. The normal method of training this type of position would be to heavily rely on remote sensing methodologies—the research teams feels that this approach should be modified so that the main emphasis is on GIS, with stress on remote sensing techniques as they apply to solving some practical GIS application or problem, not as an end in itself. Masters Degree level education should be provided for this position. This slot would deal exclusively with satellite based remote sensing, the Photogrammetrist being responsible for aerial photo interpretation. This individual would need to be in place by the start of full internal operations.

- **Photogrammetrist**: This individual would need to be on board by the start of full internal operations. This position's duties include training and applications development—in many instances highly detailed land based information is required for some GIS applications work, for example in urban/near urban situations. In these cases, aerial photos are the only acceptable data source, therefore some individual at the Center must be well versed in developing aerial photo interpretations, control models, etc. In particular, this person would have to understand how to successfully integrate this sort of information into typical GIS applications. A Masters Degree education should be provided for this position. A graduate from a local survey engineering course would be an excellent choice for further education to fill this position.

- **Economist**: While many may express surprise at finding this position within a GIS Center, the research team has often seen the usefulness of having a fully trained economists aid in GIS research and applications development. Economic evaluations, particularly those intimately linked to spatial information and analysis, are powerful tools for understanding many basic socioeconomic processes, for example deforestation. The study team has therefore included this position in the overall make up of the Center's staff. This individual would have responsibilities for research, applications development as well as training. A Bachelor or Master's Degree in economics, perhaps with special emphasis on natural resources, would be a required background for this position. Formal GIS education at Masters Degree or above would be provided for this position. This job would need to be filled by the start of full internal operations.
- **Digitizer**: The position of Digitizer for the Center might possibly be filled by a technical school graduate or at most a Bachelors degree. This individual would be responsible for training and supporting application development. It has been the research team's experience that a high turn over rate should be expected for this position owing to the tedious and repetitious nature of the job. The only formal training needed for this position can be provided locally, either at a university or GIS vendor.

International GIS Centers

In order for the Center to be successful, it must have some sort of interaction with its peers, that is other international GIS centers. Contacts should be set up between these centers resulting in staff and research exchange, study tours, as well as joint research and seminars. Three major centers in the USA, Canada, UK are briefly described below in order to assist the Center's staff in understanding these types of centers and how best to approach them to initiate contacts. As an example of these types of contacts, ***Appendix VI*** details the results of the MOSTE-TDRI study mission to Australia.

NCGIA

In August 1988, the U.S. National Academy of Sciences awarded the National Center for Geographic Information and Analysis (NCGIA) to a consortium consisting of University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine at Orono[4]. Five major areas of GIS research were slated for investigation:

- spatial analysis and spatial statistics
- spatial relationships and database structures
- artificial intelligence and expert systems
- visualization
- social, economic and institutional issues

The research at the NCGIA was organized around a series of twelve research *initiatives* derived from these major areas—the basic theory of GIS. Research results are disseminated in a series of technical papers, international journal articles, and at major GIS conferences. An important point to note is that the NCGIA **actively encourages participation** from GIS research centers outside the consortium. As such, it is strongly recommended that the Center's Director, early on, establish contacts with the NCGIA towards developing joint research projects, staff exchanges, etc., as well as to take advantage of the NCGIA's experiences.

One of the NCGIA's main efforts has centered around the creation of a *Core Curriculum* for GIS education (see ***Appendix III*** for the course outline). The Core Curriculum is divided into three basic sections: *Introduction to GIS*, *Technical Issues*, and *Applied Issues*. A laboratory package for the *hands-on* teaching of GIS concepts is also being developed.

The NCGIA's policy on GIS hardware and software is one of neutrality. Original funding has been provided by the National Science Foundation (NSF). The NCGIA is however expected to develop additional sources of funding from the public and private sectors. Once the NSF's mandate expires, the NCGIA is expected to become fully funded by outside sources. While this institutional model might not be totally suitable for Thailand and the NGIS Center, the idea of soliciting funding from sources other than MOSTE's budget should be given serious consideration—the private sector is now awakening to the full potential of GIS technology and should thus be amenable to funding R&D efforts within the Center. It is strongly recommended that the Center's Director pursue further, outside funding during the initial start-up period.

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[4] NCGIA, 1989, *The research plan of the National Center for Geographic Information and Analysis*, International Journal of GIS, Vol. 3 #2 pp. 117-136.

The main NCGIA contact is:

Dr. Micheal Goodchild
Department of Geography
University of California,
Santa Barbara, CA 93106
Tel: 805-893-8224

RRL

The United Kingdom's Regional Research Laboratories (RRL) are a decentralized group of eight independent research centers. The general goal of the RRL's is the promotion of research and application of spatial data handling.[5] These research centers are based in academic institutes around the U.K., each of which, while funded by the Economic and Social Research Council (ESRC) and similar in organization and general goals, has its own **regional** research agenda. The ESRC's funding will run out in late 1991—by then it is expected that each of the RRL will have obtained other sources of funding.

This type of broad based approach was chosen because it was thought that the wide range of applications and research projects would result in a large *head start* in building a nationwide network of researchers and facilities for GIS development. In addition, the RRL will act as a resource base for private and public sectors wishing to make use of GIS technology. The initial ESRC funding was seen as an investment in the future as well as the promotion of applied research.

It is strongly recommended that the Center's Director make contact with, if possible, all of the RRL. As each RRL has its own individual research agenda and unique experiences gained from pursuing this agenda, these research centers should provide a good learning opportunity that the NGIS Center should take full advantage of.

[5] Parent, P 1990, *GIS in Higher Education*, GIS World, Vol 3 #6 pp. 74-75.

The main RRL contact is:

Dr. Ian Masser
Department of Town and Regional Planning
University of Sheffield
Sheffield, England
S10 2TN

IGISE

In direct contrast to the NCGIA and the RRL, the Institute for GIS in Education (IGISE) was established with the direct assistance of TYDAC Technologies Inc., a Canadian GIS vendor to promote Canadian technology.[6] The core product of the privately funded IGISE is the *Standard Laboratory Package* which is a lab kit based on TYDAC's SPANS software package. The toolkit consists of background units which introduce the user to the basics of geographical data processing and spatial analysis and case studies which are *real-life* problems requiring sophisticated analysis.

The main contact for the IGISE is:

Dr. Robert Rogerson
Institute for GIS in Education
PO Box 3737, Station C
Ottawa, Ontario
Canada K1Y 4J8

NGIS Center Five Year Action Plan

The following section provides the details of the Five Year Plan for the NGIS Center established at MOSTE. It is presented in chronological order. The flow of work for the entire life of the plan is laid out in ***Figure 6.3*** There are thirteen major tasks that need to be accomplished which are laid out in ***Table 6.1***. The assumed starting date for the Center is January 1992. The budget required to realize these tasks is shown in ***Table 6.2*** (***Appendix VII*** contains the full budget break down for each of the major and sub tasks as well as other information pertinent to the general Action Plan for the Center).

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[6] Parent, P 1990, *GIS in Higher Education*, GIS World, Vol 3 #6 pp. 74-75.

Overall, the amount required to set up and sustain the Center for the first five years is on the order of 60 million *baht* **total.**[7]

Year 1

This is the Center start up year. After selection of the Center's Director and other staff, the Center can proceed in fully establishing itself. Foremost among the Center's tasks is development of its own staff, therefore one of its first **priority** tasks is the selection of Center staff candidates that need further education (outlined in the section **Staffing Requirements** above). The selection process must take place beginning in the first quarter and be **finished no later than the third quarter** of Year 1. **The timing on this process is extremely important**—if these staff are not selected, trained and *back on the job* by the end of Year 4, the Center will not be able to take over full operations internally.

Another important consideration for a center that is assumed to be supporting some type of technology, is the **technology itself**. It is very difficult or even impossible, for such a center to be **credible**, let alone operate itself, without this technology being **in-place** at the center. The NGIS Center is no exception—if it has any hopes to act as a GIS technology promotion center then it must posses these technology and at a sufficient level and quantity to accomplish authoritative research. With this in mind hardware and software acquistion should be given top priority. ***Appendix VIII*** details the specifications for the Center's hardware and software.

The Center, in its first year of operations, must entirely depend on outside contractors to supply services. This dependence on outside researchers should not, however, be viewed as entirely negative. In addition to being a fact-of-life that the Center must learn to live with, it will also serve to catalyze these outside agencies—research projects and funding for them will be made available which should prove attractive enough to encourage these organizations to conduct work in directions that the Center thinks important. It will thus raise the general level of consciousness concerning GIS in addition to raising the presitge of these organizations, particularly within their

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[7] Using 1991 *baht* as a base. The research team would like to acknowledge the assistance rendered by Khun Poonsup Piya-Anant and Khun Pinida Lewchalermwong from the Bureau of the Budget in preparing this action plan—their input concerning practical budget considerations was invaluable.

own institutional settings. This should reflect upon the Center's own prestige and general acceptance—these agencies will act as *defacto* publicity agents for the Center.

Table 6.1 NGIS Center Major Task Summary

Task	Length	Start	End
Purchase Initial Hardware & Software	52	1 May '91	28 Apr '92
Hardware & software maintainence	222	2 Oct '92	31 Dec '96
Standardization work	248	3 Apr '92	31 Dec '96
NGIS training	214	1 Jul '92	9 Aug '96
Maintain spatial indexes	248	1 Apr '92	31 Dec '96
NGIS GIS research & coordination	222	1 Apr '92	3 Jul '96
NGIS staff development	191	1 Jan '92	1 Sep '95
NGIS applications work	65	1 Oct '95	31 Dec '96
Outside development of NGIS BBS	30	2 Jun '92	31 Dec '92
Maintain NGIS BBS	204	1 Feb '93	31 Dec '96
NGIS seminars	209	1 Sep '92	1 Sep '96
International GIS seminar	209	20 May '92	20 May '96
NGIS library	226	1 Sep '92	31 Dec '96
Routine work	261	1 Jan '92	31 Dec '96

***Note*: Length in weeks, rounded up**

The second quarter of Year 1 should see the beginning of the Center's research project on **GIS standards** (data dictionaries, data structures, data exchange standards, etc.) for the country. This year-long work will need to be contracted outside the Center to local universities, GIS vendor or consultants[8], or NGO. As this work will eventually impact almost all of the Kingdom's GIS users, it is suggested here that a **broad-based** consortium be established to undertake this project. This consortium should include the major GIS players led by one of the more experienced GIS using agencies.

Also beginning in the second quarter of Year 1 is the Center's basic research into GIS issues. It is foreseen that four such projects be undertaken, one per year. A suggested role model for this type of research is the NCGIA discussed above. The major research issues and research initiatives it has undertaken should be considered for research projects in Thailand, keeping in mind that these issues must be considered in the

[8] At present, this would seem unlikely as there is only one or at most two companies with the relevant GIS experience to undertake this sort of work.

Thai context. Again, this must be contracted outside the Center—local universities or NGOs being the best choice for this type of work.

TDRI, with CIDA funding, is assembling an index of spatial information over the Kingdom at a scale of 1:50,000. This index will be turned over to the NGIS Center which will then be responsible for maintaining it. Outside contract work, under the supervision of the Center, will be needed to update this index. After the initial construction of the index, it is thought that the additional work to keep the index up-to-date will be relatively minimal. A local university would be the best choice for this contract work.

The Center should contract out for the development of a Bulletin Board System (BBS) devoted to the exchange of information concerning GIS technology. This BBS should allow interested parties to more or less freely access it through a direct dial-in. A direct dial telephone number is therefore required. A local university would be the best choice to develop this system. It is suggested that a shareware or public domain BBS package be used to lessen development costs and start-up time.

Preparations should be made for the Center's Director to attend an international GIS users conference during the second-third quarters of Year 1, as well as some kind of management level GIS training.[9] The URISA, AutoCarto, GIS/LIS, International Geographical Congress, or ESRI User Conference[10] are suggested conferences that the Director might attend. The suggested pattern of seminar attendance is bi-annual, this is mainly to keep costs down.

In the middle to later part of Year 1 the Center should be functioning well enough to hold its inaugural GIS seminar. This seminar should serve as a focus for the Center's initial activities. In addition, it should be viewed as an unabashed publicity effort to make the Center and its activities better known to the GIS using public. These seminars will help the Center to maintain a high profile as well as act as a venue for disseminating the Center's research findings. As it will be its first such seminar, it is suggested here that the Center undertake this in conjunction with a well established GIS user. The topic

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[9] This might negoitated as part of the GIS hardware and software purchase agreement.

[10] The ESRI User Conference, while devoted to one GIS vendor, is well known for its high quality and relevancy. In particular, developing countries use of GIS is usually highlighted along with some central theme about applying GIS technology to specific environmental or social problems or how these problems impact GIS.

for this and subsequent seminars should be appropriate to the stage of GIS development in Thailand. One session of the seminar should be devoted to the Center's activities, the rest should feature GIS users—they should be made to feel that this is ***their*** seminar.

The Center should contract out for its first GIS training during the third quarter of Year 1. The most logical choice would be to develop a short course with the supplier of its GIS hardware and software, perhaps in conjunction with one of the local universities that is **presently** teaching GIS. The attendance set for this training should not be too ambitious—it is better to start off slowly and work out the training *bugs* as one goes along.

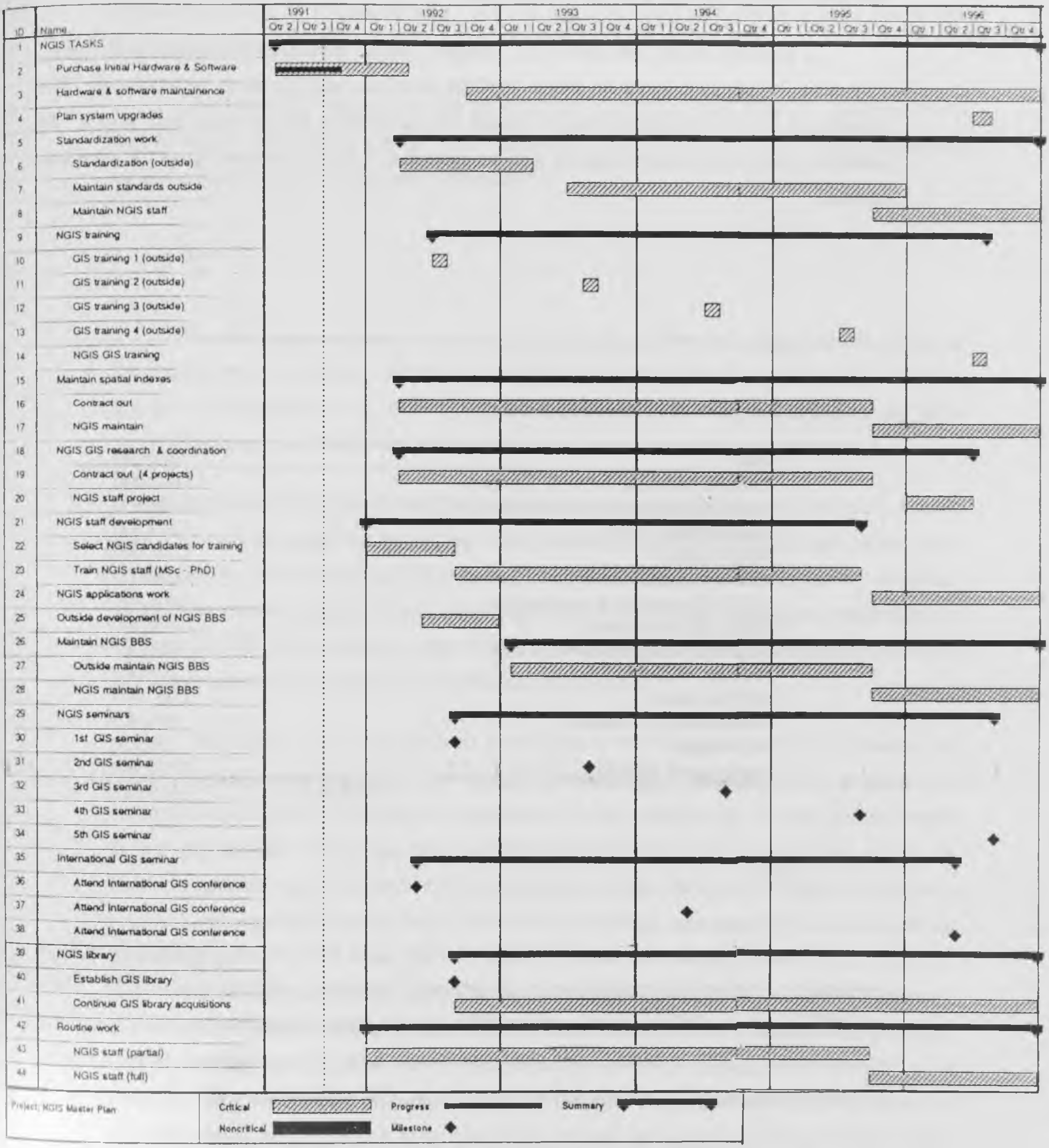
Another important activity for Year 1, one that is often overlooked, is the establishment of a good GIS technical library. This library should be physically located within the Center. It should subscribe to the leading GIS or GIS related journals and obtain as many GIS text books as possible. ***Appendix IX*** lists some of the suggested journals and titles for inclusion in the Center's library.

Year 2

The Center's second year will basically be a continuation of the activities initiated in the first year. The standards work should be completed in the second or third quarters of Year 2. The standards established during this project will have to be maintained, this activity will begin in the third quarter of Year 2. The Center's second research project on GIS issues should commence this year. Basic issues, if any, raised during the first project should be investigated as part of the second. The spatial index should also be re-surveyed and updated during Year 2. The GIS BBS and technical library established during Year 1 should also be maintained and updated. The GIS hardware and software acquired during Year 1 will need to be maintained and planned for. No international GIS seminar is scheduled for attendance this year.

The Center's second GIS seminar should be held this year, the timing should be approximately a year after the first. If thought appropriate, the Center should chose a co-host different than the previous year. Furthermore, the topic of this seminar must be

Figure 6.3 NGIS Center Master Plan



substantially different than the first seminar and it should be evolutionary as well, that is building on the previous year's seminar topic.

A second Center sponsored GIS training course should also take place this year. It is strongly suggested that no students of the previous year's course be admitted. The attendance for this training session should be set slightly higher than last year's. In addition, the topics covered should also be amended if found wanting from the previous course.

Table 6.2 NGIS Center Major Budget Items

Task		Amount
Purchase Initial Hardware & Software		13,000,000
Hardware & software maintainence		6,500,000
Standardization work		3,300,000
NGIS training		1,344,000
Maintain spatial indexes		1,600,000
NGIS GIS research & coordination		9,000,000
NGIS staff development		15,000,000
Outside development of NGIS BBS		350,000
Maintain NGIS BBS		200,000
NGIS seminars		2,000,000
International GIS seminar		840,000
NGIS library		250,000
Routine work (salaries)		5,543,748
	TOTALS	58,927,748

Year 3

Year 3 is more or less a reprise of Year 2 in that no new initiatives will be undertaken, rather the maintainence of previous activities will be continued. These activities include GIS research project (#3), spatial index maintainence, GIS standards maintainence, BBS maintainence, and continued library acquisitions. The Center's Director is expected to attend another international GIS seminar as well.

The third GIS seminar is also scheduled to take place this year. If appropriate and the Center's international reputation warrants it, this year's GIS seminar should be held in conjunction with one of the international GIS research centers. If this seminar is successful, it will be a large and visible boost to the Center's status both inside of Thailand as well as internationally. As such, its planning and arrangements should be approached carefully.

The third GIS training course should take place this year, again no students from **any** of the previous year's course's should attend. The training course's class size should again be increased from last year's attendance.

Year 4

Year 4 is again a year of activity maintainence. Year 4 is significant in that it is the final year in which the Center must entirely depend on outside contractors to supply services to the Center. It is also significant in that the staff candidates selected for MSc and PhD training will begin returning.

Returning Center staff will begin to take over responsibility for all of the Center's research activities, with the exception of the training course which will have taken place before they return and the last GIS research project which should be allowed to complete, in the later part of Year 4. The Center staff will have to begin taking responsibility for maintaining the GIS standards, spatial index, and the BBS. No provision for attending any international GIS seminars are scheduled this year.

The Center's GIS applications development will begin in earnest following the return of the Center's staff. The freshly returned staff should not be expected to acomplish much during their first months back, but serious work should at least **begin** during this period. The stage for this development work should have been set by the Center's research activities as well as its seminars. The idea of the Center acting as a source of serious GIS applications work should be firmly implanted in the minds of the GIS-using public by this time. By the end of Year 4, the Center's staff should reach its full complement of twenty-four highly trained and hopefully, highly motivated individuals. These people will form an excellent core for the continued development of GIS technology in Thailand—with these individuals at the Center, there should be no GIS problem that is *insurmountable*. There is no equivalent, anywhere in S. E. Asia, for the intellectual weight which they can bring to bear on any given GIS research topic. With these individuals, the NGIS Center would become a true Center of *Excellence*.

Year 5

In Year 5 actual **operations** are slated to start. The Center will be fully functional, that is more or less self sufficient in terms of staff and equipment. The Center's own staff should now be entirely responsible for maintaining all of the Center's activities—all training and research activities will now be carried out internally. Contacts with previous research groups should be maintained in order to benefit from their experiences. The Center's hardware will be approaching obsolecence in Year 5, plans for upgrading the system should therefore begin to be formulated keeping in mind the future needs of the Center. It is expected that most or all of the Center's technical staff will attend international GIS conferences this year—this is an opportunity to further publicize the Center's now that it is fully functional.

Human Resources: A Potential Problem

There is one potential problem related to the **Action Plan** outlined above—human resources. **If the Center cannot maintain its staff it will fail.** A technology center without technologists is nothing more than a roomful of useless machines. The importance of this cannot be over emphasized. The private sector is now becoming aware of the real potential of GIS technology and competition for human resources is beginning to heat up. The public sector is an excellent resource pool for the private sector, therefore some poaching of GIS staff can be expected. The GIS job market has been described as a *seller's market*[11], a fact of life that the Center must contend with.

MOSTE, therefore, must take special pains so as to insure that it maintains adequate professional staff at the Center. By maintaining close contacts with the commercial side of GIS technology, the Center will help itself keep abreast of the real trends in GIS—things that people are willing to pay for. The government's present efforts to increase salary levels for technical staff is a step in the right direction, however MOSTE may need to take additional steps and should begin **now** to seek solutions to this pressing problem.

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[11] Hughes, J. 1990, *GIS Job Opportunities Abound*, GIS World. Vol 3 #6, pp.63-68.

Chapter 7

Conclusion

GIS is a technology that works, coming at a time in Thailand's growth when it is almost essential to the further, prudent development of the Kingdom. However, inherent to any technology are problems or obstacles that may inhibit its future development. MOSTE perceived early on that some sort of technology promoting center, along the lines of NECTEC, might be needed to encourage the further growth of GIS technology, hence this study.

As mentioned above, the research team has seen the NGIS Center as a ***supporting*** rather than a ***watchdog*** agency—it was **not** going to be another National Computer Committee. The Center's charge would be to promote the use of GIS technology in Thailand rather than curtailing or restricting it. The Center was **not** seen as inhibiting the spread of GIS to new users or applications, on the contrary, the center was seen as advancing and nurturing the application of this new technology.

A basic tenet, held from the outset of the plan's development, has been that the hardware and software required for GIS should be allowed, even encouraged, to proliferate according to the ***perceived*** needs of the actual end users. This contention is supported by the study team's survey of GIS users, which has indicated that there is **not** a surplus of GIS equipment in Thailand—on the contrary the actual number is quite small as is its monetary value, around 90 million *baht* for the whole Kingdom.

If we accept these ground rules, the roles of the NGIS center would therefore need to be:

- to overcome the more obvious shortcomings in using this technology in the present situation in the Kingdom,
- to determine and develop strategies to overcome the subtler barriers to the continued development of GIS technology,

- to foster research into GIS technology and institutional issues,
- to promote new end users and applications,
- to provide an **unbiased end user**, rather than **vendor**, view of the technology's capabilities,
- to help provide GIS education to institutions at all levels.

Furthermore, given the present state of GIS development in Thailand which tends to be **technology driven** rather than **data and application driven**, the center should also provide some sort of facilities, both hardware/software and qualified human resources, for GIS application development to help overcome this drawback.

The Action Plan presented here is really nothing more than paper and some initial logical ideas about how to proceed with establishing the Center—much of it common sense derived from the research team's extensive knowledge of the GIS situation in Thailand. MOSTE and the Center's professional staff will, ultimately, be the ones that bring the Plan to life. They and the GIS users in Thailand are what this plan is really concerned with—logically, how can we assist GIS technology to further, rationally develop? What steps do we need to take? What are the pitfalls that we must be aware of and try to avoid? What are the actual facts concerning the GIS using community in Thailand, i.e. what do de really want and need? This study has attempted to faithfully answer these questions.

The research team feels that the establishment of the MOSTE NGIS Center will make a significant contribution to promoting the growth of GIS technology in Thailand. This Action Plan is the first step in the establishment of this Center.

Appendix I
GIS Survey Questionnaire

The following section details the questionnaire that the research team used during its survey of the GIS users in Thailand. This questionnaire only served as a guide, much of the information gathered by the study team, resulted from informal questioning.

วันที่ __/_____ /____ /

แบบสำรวจข้อมูล

โครงการจัดตั้งศูนย์ระบบข้อมูลสารสนเทศภูมิศาสตร์แห่งชาติ

เลขที่ ________

ชื่อ ____________________ สกุล __________________________

ตำแหน่ง ________________ ฝ่าย _________________________

สังกัด ____

หน่วยงาน ____

ที่อยู่ ____

โทรศัพท์ ________________

๑. ประเภทหน่วยงาน [ ] ราชการ [ ] รัฐวิสาหกิจ [ ] เอกชน [ ] อื่นๆ

๒. ลักษณะงานโดยสังเขป ______________________________

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____

____

๓. ข้อมูลที่มีในรูปต่างๆ พร้อมทั้งที่มาของ

GIS ____

RemoteSensing _____________________________________

แผนที่ ____

คอมพิวเตอร์ ______________________________

เอกสาร ______________________________

อื่นๆ ______________________________

๔. ซอฟท์แวร์ที่มีใช้

GIS ______________________________

RemoteSensing ______________________________

อื่นๆ ๑ ______________________________

อื่นๆ ๒ ______________________________

๕. ข้อมูลชนิดต่างๆที่จัดเก็บ

๑. ______________________________

๒. ______________________________

๓. ______________________________

๔. ______________________________

๕. ______________________________

๖. ______________________________

๗. ______________________________

๘. ______________________________

๙. ______________________________

๑๐. ______________________________

๑๑. ______________________________

๑๒. ______________________________

๖. มาตราส่วนของแผนที่ที่ใช้ ________________________________

๗. ข้อมูลที่มีอยู่แล้วครอบคลุมพื้นที่ ____________________________

๘. พื้นที่เป้าหมายครอบคลุม ________________________________

๙. งบประมาณที่ได้ในปีนี้ขอไว้ ____ บาท ได้ _____ บาท โดยแบ่งเป็น

GIS ____

RemoteSensing ____________________________________

ฝึกอบรม/ดูงาน _____________________________________

ศึกษาต่อ ____

อื่นๆ ____

๑๐. งบประมาณปีที่แล้ว ขอ บาท ได้ ______ บาท [ ]พอ [ ] ไม่พอ

๑๑. งบประมาณปีหน้า ขอ _ บาท ได้ _______ บาท [ ] พอ [ ] ไม่พอ

๑๒. วิธีดำเนินการเพื่อให้บรรลุตามเป้าหมาย [ ] ดำเนินการเอง [ ] โดยการว่าจ้าง

โดยกำหนดระยะเวลาดำเนินไว้เป็นเวลา _______________________

๑๓. ความคิดเห็นในการว่าจ้างเอกชนดำเนินการ [ ] เห็นด้วย [ ] ไม่เห็นด้วย เพราะ

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๑๔. ขั้นตอนในการดำเนินการ ________________________________

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____

๑๕. กำลังคนขณะนี้มีอยู่ ____ คน เทียบกับงานรับผิดชอบแล้วคิดว่า [ ]พอ [ ]ไม่พอ

วุฒิการศึกษา ต่ำกว่าปริญญาตรี ____ คน

ปริญญาตรี ________ คน

ปริญญาโท ________ คน

สูงกว่าปริญญาโท ____ คน

การศึกษา GIS ______________ คน

RemoteSensing ____ คน

คอมพิวเตอร์ ______ คน

อื่นๆ (ระบุ) ______ ______ คน

๑๖. โครงการขยายกำลังคน

[ ]ไม่มี

[ ] มี วุฒิการศึกษา ต่ำกว่าปริญญาตรี คน ปริญญาตรี ____ คน

ปริญญาโท _____ คน สูงกว่าปริญญาโท ___ คน

๑๗. ระบบคอมพิวเตอร์ที่ใช้งานอยู่มี ___ ระบบ แบ่งเป็น (รายละเอียดดูที่เอกสารแนบท้าย)

ประเภท MicroComputer จำนวน ______ ระบบ

ประเภท MiniComputer จำนวน _______ ระบบ

ประเภท MainframeComputer จำนวน __ ระบบ

ประเภทอื่นๆ (ระบุ) ____ จำนวน _ ระบบ

๑๘. นโยบายการให้บริการเกี่ยวกับข้อมูล

[ ] ไม่มี [ ] มี โดยมีเงื่อนไขการให้บริการคือ ___________________

____

____

๑๙. นโยบายการให้หน่วยงานอื่นยืมใช้ระบบคอมพิวเตอร์ที่มีอยู่

[ ] ไม่มี [ ] มี โดยมีเงื่อนไขการให้บริการคือ ____________________

____

๒๐. นโยบายที่จะเผยแพร่ความรู้ด้านระบบสารสนเทศภูมิศาสตร์ของหน่วยงาน

[ ] ไม่มี [ ] มี โดยมีนโยบายพอสังเขปคือ ____________________

____

____

๒๑. ปัญหาที่พบและการแก้ไข

____

____

____

____

๒๒. ความคิดเห็นเกี่ยวกับโครงการศูนย์ระบบข้อมูลสารสนเทศภูมิศาสตร์

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๒๓. หมายเหตุ

____

____

____

____

ประเภท ______ ยี่ห้อ ______________ รุ่น ______________________

งานที่ใช้อยู่ประจำ ____

ขนาดหน่วยความจำ _______________ ขนาดฮาร์ดดิสค์ ______________

อุปกรณ์ต่อพ่วง ๑. ____

๒. ____

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๔. ____

๕. ____

๖. ____

ประเภท ______ ยี่ห้อ ______________ รุ่น ______________________

งานที่ใช้อยู่ประจำ ____

ขนาดหน่วยความจำ _______________ ขนาดฮาร์ดดิสค์ ______________

อุปกรณ์ต่อพ่วง ๑. ____

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๕. ____

๖. ____

Appendix II

GIS Survey Results Summary

This appendix contains a summary of the project's national GIS user survey. It is by no means a compete, 100% coverage of all of the Kingdom's GIS users—the number of users is expanding faster than the time allowed to complete the total interview process. It does, however, provide an overview of the majority of the country's GIS users. It also serves as a base for the next round of surveys—it is not necessary to begin from scratch.

The full survey database (in Paradox 3.5 format) is on file with MOSTE. Some information provided during the survey was given on condition that its source not be named, that information is not contained in this summary or in the database.

Asian Institute of Technology (AIT)

Name: Dr.Kaew Nualchawee
Description: International post-graduate institute
Staff: 6
Plotters:1
Digitizers: 8
GIS Workstations (PC): 8
GIS Workstations (UNIX Box): 0
GIS Software: Arc/Info
GIS Budget: Not described
Source: Na

AIT did not see the Center as having any training role, nor did it agree with the idea of it being a national GIS data bank. AIT agreed with GIS data standards work at the Center. The role of the Center in maintaining a set of GIS experts was also thought worthwhile. AIT also thought that more emphasis should be placed on remote sensing—even going so far as to ask that the Center be renamed the *National Remote Sensing Center (* One could argue that the NRCT already fills this role). AIT's GIS staff (6) was thought to be inadequate. AIT's data policy was described as limited and to be set up as a fee-for-information basis. AIT plans to develop their own databases in-house, but did see the benefits of an outside contractor.

Agriculture Land Reform Office (ALRO)

Name: Khun Chaiwat Chaiyakupt
Description: Agricultural land reform planning
Staff: 9
Plotter: 1
Digitizers: 3

GIS Workstations (PC): 3
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
GIS Budget: Amount not described
Source: Foreign aid, grants

ALRO generally agreed to **all** of the main functions of the NGIS Center. It thought that the Center should provide training, standards work, as well as GIS experts. It did not, however, agree with the Center maintaining a national GIS database. ALRO thought that its GIS staff was not adequate for its on-going and planned GIS activities. It planned to develop its database in-house, but agreed that private sector should be involved, if budget could be found. ALRO's data policy is decided on a *case-by-case* basis, the final decision resting with ALRO's upper management.

Faculty of Agriculture Khon Khaen University (KKU)

Name: Dr. Charat Mongkolsawat
Description: Teaching, research, services
Staff: 4
Plotters: 3
Digitizers: 3

GIS Workstations (PC): 2
GIS Workstation (UNIX Box): 0
Other GIS Hardware: MicroVAX 2 & graphic terminals.
GIS software: PAMAP
GIS Budget: Amount not described.
Source: NA

KKU agreed with the Center providing training and expert GIS services. It did not feel that a national database was a suitable role for the Center. KKU thought that the Center should promote GIS activities. KKU is developing its database in-house and didn't agree with contracting out database development. KKU will provide spatial data on an at cost basis.

Bank of Ayudhaya

Name: Khun Piphat
Description: Loan
Staff: 7
Plotter: 1
Digitizers: 1

GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 2
GIS software: Arc/Info
GIS Budget: 4,000,000 baht
Source: Bank

The Bank indicated agreement with the Center's role of training and expert advice as well as in the general promotion of GIS technology. The Bank felt its staff was adequate for its planned GIS activities, which are at the moment mainly pilot studies. It planned on contracting out its database development. The Bank will only provide its spatial data to its own branches or perhaps customers.

Bangkok Land Information System (BLIS)

Name: Khun Apiwat Kunarak
Description: Pilot project,Klongtoei 3 km square
Staff: 36
Plotters: 2
Digitizers: 6

GIS Workstations (PC): 4
GIS Workstations (UNIX Box): 5
Gis Budget: 25,000,000 baht
Source: 5 BLIS agencies (BMA, MEA, TOT, MWA, DOL)

BLIS agreed with all of the Center's proposed functions with the exception of the national GIS database. BLIS is now developing its database in-house (over its pilot study area), however it was favorable to outside contractors further developing its database. At present, BLIS has no firm policy on sharing data outside of BLIS members—BLIS's purpose is to develop and maintain a standardized base map for Bangkok. It felt that the GIS staff were insufficient for its planned activities.

Department of Town and Country Planning (DTCP)

Name: Khun Supachai Saengnak
Description: City planing
Staff: 5
Plotter: 3
Digitize: 3

GIS Workstations (PC): 5
GIS Workstations (UNIX Box): 0
GIS Budget: Amount not described.
Source: JICA
GIS software: Arc/Info

DTCP agreed with all of the Center's main functions with the exception of it acting as a national database. DTCP felt its GIS staff was inadequate and would become critical with its planned GIS expansion. DTCP is developing its database in-house at present, but saw the benefits of private sector developing GIS databases. It suggested the idea of the Center acting as part of a network of GIS users, perhaps in the form of some type of distributed database.

Department of Land Development (DLD)

Name: Khun Taweesak Verasilp
Description: Soil survey, suitability classification
Staff: 1
Plotter: 1
Digitizer: 1

GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
GIS Budget: Amount not described
Source: Government

DLD voiced no opinions on the roles for the NGIS Center. DLD felt its GIS staff was not adequate. It is now developing its database in-house, but agreed with the idea of the private sector being involved in developing GIS databases. It indicated that it would provide GIS data to only other RTG agencies.

Department of Mineral Resource (DMR)

Name: Khun Buncherd Arampravun
Description: Mineral Resource Works
Staff: 7
Plotter: 1
Digitizer: 1

GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 0
GIS software: SPANS, Easi-Pace
GIS Budget: Amount not described.
Source: Government

In general, DMR agreed with all the functions of the Center, with the exception again being a national database. It felt that its GIS staff was adequate. It does not have any plans to distribute its digital spatial information when it becomes available. It plans to develop its database in-house and did not agree with outside contractors developing its database.

Survey Engineer Department Chulalongkorn University

Name: Khun Suttipong Winyapradit
Description: Teaching in survey engineering department
Staff: 5
Plotter: 1
Digitizers: 2
GIS Workstations (PC): 0

GIS Workstations (UNIX Box): 0
Other: Graphic terminal (8), PRIME Mini
GIS software: Arc/Info
GIS Budget: Amount not described.
Source: Faculty

In general, those interviewed at the Survey Engineer Department (SED) agreed with the roles of the Center, including the national database. However, it was pointed out that this function of the Center could probably not be carried out for practical reasons. SED was willing to provide digital information at cost dependent on the regulations governing the project under which the data was gathered. SED felt its staff was sufficient for its purposes—teaching and research of GIS in relation to surveying.

Engineering Department, Prince of Songkla University

Name: Khun Sunthorn Vitosurapoj
Description: Teaching, research, academic services
Staff: 8
Plotter: 1
Digitizer: 1
GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
GIS software: SPANS 5.0
GIS Budget: 600,000 baht
Source: University

The Engineering Department at the Prince of Songkla University (PSU) disagreed with all of the Center's roles with the exception of GIS expert services. PSU is building its database, starting with the Songkhla Lake Basin, in-house. It agreed with the idea of private sector participation in GIS database building. It felt its GIS staff was inadequate. PSU has plans to market its data and thought that perhaps the Center might be able to aid it.

Forest Management Division, Royal Forestry Department

Name: Khun Boonchana Klunkumsorn
Description: Forest operation, KIFM, land for the poor
Staff: 6
Plotter: 1
Digitize: 0
GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
GIS software: Easi Pace
GIS Budget: 1,000,000 *baht*
Source: RTG

The Royal Forestry Department (RFD) agreed with all of the Center's roles—including the national database. The RFD will provide information on a *case-by-case* basis, particularly for other RTG agencies. It felt that its GIS staff was inadequate.

GRID

Name: Dr. Gary Johnson
Description: Global environmental database development
Staff: 7
Plotter: 1
Digitizer: 1
GIS Workstations (PC): 5
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
GIS Budget: Not described
Source: UN

GRID expressed no opinions on any of the Center's roles. It plans to develop its database in-house. GRID felt its GIS staff was insufficient.

Geographic Division, Royal Thai Survey Department

Name: Prapas Yodusa
Description: Making basemaps
Staff: 200 (not all directly GIS)
Plotter:
Digitize:
GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 0
Sufficiency: y
GIS software: In the process of deciding system specifications.
GIS Budget: Not described
Source: Military

The RTSD agreed with all of the Center's functions, again with the exception of the national database. It will provide information to any RTG user, provided the information requested is not secret. While its own plans were for in-house database development, it also saw the need for private sector participation. RTSD felt that its staff was sufficient, but needed more intensive and GIS-specific training.

Geography Department, Chulalongkorn University

Name: Ms. Srisaart Tungprasert
Description: Teaching in GIS, remote sensing, database management
Staff: 4
Plotter: 0
Digitizer: 0
GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
Other: Graphic terminal
GIS software: Arc/Info, also in process of additional software purchase
GIS Budget: 3,000,000 *baht*
Source: RTG and aid.

The Geography Department at CU agreed with the Center's role in establishing data standards and providing expert GIS services. It did not accept the idea of the Center providing training, seeing this as the exclusive domain of the Kingdom's universities, nor did it agree with the Center holding the nation's database. It will provide information on a *case-by-case* basis. It felt that its staff was not sufficient. It is developing its databases in-house and did not see the need for a private sector role.

King Mongkut Institute of Technology (KMIT)

Name: Dr. Fusak Cheewasuvit
Description: Education & research, no GIS activities at present
Staff: 0
Plotter: 0
Digitizer: 0
GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 0
GIS software: None
GIS Budget: None
Source: NA

KMIT at present has no GIS activities. However, it plans to begin in the near future if budget is available. It saw the Center acting as an advisor to provide *start-up* information institutes such as KMIT, who would need this kind of advice.

Mekong Secretariat

Name: Khun Boonyakiet Sangwat
Description: Just coordinator
Staff: Not known
Plotter: 1
Digitizer: 1
GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 1
GIS software: SPANS , Arc/Info
GIS Budget: Not mentioned
Source: UN

The Mekong Secretariat agreed to all of the Center's roles with the exception of national database. It felt that its GIS staff was insufficient. The Mekong Secretariat is willing to provide what information it has, but on conditions set by the member countries.

National Research Council of Thailand (NRCT)

Name: Ms. Darasri Srisaengthong
Description: Joint research, data service, making database
Staff: 20 (most in remote sensing)
Plotter: 1
Digitizers: 4
GIS Workstations (PC): 2
GIS Workstation (UNIX Box): 1
Other: Graphic terminals
Sufficiency: n
GIS software: SPANS, PAMAP
GIS Budget: Not mentioned
Source: RTG, aid

NRCT only disagreed with the Center acting as a national database, it agreed with all the other major functions. The NRCT will provide data on a commercial basis. It is developing its database in-house and disagreed with the private sector being involved. NRCT suggested that its GIS was not adequate.

National Environment Board (NEB)

Name: Dr. Ratisak Polsri
Description: Creating digital database for the whole kingdom in 5 fiscal years
Staff: 6
Plotter: 1
Digitizers: 2

GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 1
GIS software: Arc/Info,ERDAS
GIS Budget: 13,000,000 *baht*
Source: Government

NEB agreed with all of the Center's functions with the exception of national database—it has embarked on its own by contracting out database development to regional GIS users. It therefore saw the benefits in using outside contractors to develop GIS databases. NEB felt that its own GIS staff was insufficient. It plans to make its national environmental database freely available when completed.

Office of Agricultural Economics (OAE)

Name: Dr. Apichart Pongsrihadulchai
Description: Remote sensing, GIS for agricultural development planning
Staff: 20
Plotter: 2
Digitizer: 1

GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
GIS software: SPANS
GIS Budget: 800,000 *baht*
Source: Government

OAE expressed no opinions about the potential roles of the Center. OAE will provide remotely sensed data **only** to other agencies within the Ministry of Agriculture and Cooperatives. It is against private sector development of databases, preferring to do this themselves. It felt its GIS staff was not adequate.

Research and Development Office, PSU

Name: Dr.Ruj Supavilai
Description: Natural resource, environmental database of Songkhla Lake Basin
Staff: 3
Plotter: 1
Digitizer: 1
GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
GIS Budget: 800,000 *baht*
Source: Government

The R&D Office at PSU agreed with **all** of the roles of the Center, with the exception of a national database. It will provide spatial information on a *case-by-case* basis depending on recommendations from the Songkhla Lake Basin Information System Committee. It felt that its staff was not adequate for its present GIS tasks.

Provincial Electricity Authority (PEA)

Name: Khun Pongsakorn Tuntivanichanont
Description: Provide electricity to customers
Staff: 40
Plotters: 2
Digitizers: 2
GIS Workstations (PC): 2
GIS Workstations (UNIX Box): 4
GIS software: Arc/Info
GIS Budget: Not described
Source: PEA

PEA agreed with all of the Center's roles. It is planning to develop its database with a combination of in-house and outside contractor work. PEA's staff is thought to be adequate for its responsibilities.

Royal Irrigation Department (RID)

Name: Khun Sirirat Temiyanond
Description: water resource development for agricultural sector
Staff: Not described
Plotters: 2
Digitizers: 2
GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 0
Other: VAXstation, VAX cluster, Synercom Workstation
GIS Software: Synercom
Gis Budget: Not described
Source: NA

RID agreed with all of the Center's roles, including national database. RID felt its staff was in adequate. Its data policy is to provide information freely providing it is not related to national security. It plans to develop its database in-house.

Siam Commercial Bank (SCB)

Name: Khun Chaiwat Yamkate
Description: credit-loan, liability/asset surveys
Staff: 4
Plotter: 1
Digitizers: 2
GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 2
GIS software: Arc/Info
GIS Budget: Not described
Source: Bank

SCB agreed with all of the Center's roles. It felt that its staff was satisfactory for the pilot phase of its operations but was not enough for its work when actual operations began. SCB will only provide its information to its own branches and its customers. SCB plans on developing its database in-house and with outside contract work. SCB is the **first** financial institute in Thailand (perhaps the world) to **directly** apply GIS to its work.

Team Consulting Engineer Ltd. (TEAM)

Name: Khun Satit Malaitham
Description: Water resource, civil engineer,env.engineering consultant
Staff: Not described
Plotter: Not described
Digitizers: Not described

GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
Gis Budget: Not described
Source: NA

TEAM agreed with all of the Center's functions. It also added that the Center should provide remote sensing expertise as well. TEAM thought that its GIS staff was insufficient.

Thammasat University (NRD2)

Name: M.R. Pongsawat Sawatdiwat
Description: Maintain NRD2 for NESDB
Staff: 20
Plotters: 0
Digitizers: 0

GIS Workstations (PC): 0
GIS Workstations (UNIX Box): 0
GIS software: Arc/Info
GIS Budget: Not described
Source: NA

Thammasat University is presently beginning GIS activities. It has plans to link its NRD2 database to a GIS to create a nationwide spatial database of village socioeconomic data. It felt that its staff while adequate for its NRD2 work would not be sufficient when it began full GIS operations. It agreed with all of the Center's roles, again the sole exception being a national database.

Thammasat University (Rangsit Campus)

Name: Khun Bandit Anurak
Description: Education, research, & service
Staff: 2
Plotter: 1
Digitizer: 1

GIS Workstations (PC): 1
GIS Workstations (UNIX Box): 0
GIS software: SPANS
GIS Budget: Amount not described
Source: NA

The Rangsit Campus of Thammasat University only agreed with the Center's training role, it offered no comment on the other roles. It was generally in favor of the Center. It felt that its GIS staff was insufficient.

Appendix III

NCGIA Core Curriculum Outline

The following is an outline of the National Center for Geographic Information and Analysis (NCGIA) Core Curriculum. It is provided for information purposes only. The full and most up-to-date curriculum can be obtained from:

NCGIA
Geography Department
3510 Phelps Hall
University of California
Santa Barbara, CA 93106
USA

Course I: Introduction to GIS

A. Introduction
1. What is a GIS?
2. Maps and map analysis
3. Related technology

B. Hardware/ System Software
4. Output peripherals
5. Input peripherals
6. System software

C. Raster-Based GIS
7. The raster GIS
8. Raster GIS capabilities
9. Raster GIS

D. Data Acquisition
10. Socio-economic data
11. Environmental data

E. Nature of Spatial Data
12. Spatial databases
13. Spatial database models

F. Spatial Objects and Relationships
14. Relationships among spatial objects
15. Spatial relationships in spatial analysis

G. GIS Functionality
16. The vector or object GIS
17. Vector GIS: Using the data
18. GIS products
19. Current market for GIS
20. Generating complex products
21. Modes of user/GIS interaction
22. GIS for archives

H. Raster/Vector Contrasts and Issues
23. Raster/vector/object database debate
24. History of GIS

I. Application Areas and Techniques
51. GIS application fields
52. Application paradigms
53. Applications to spatial search

J. Project Lifecycle
58. GIS project lifecycle
59. Start up and analysis
60. System choices
61. Benchmarking for GIS
62. Pilot project, full implementation
63. Costs and benefits of GIS

K. Impact of GIS on management, economics and institutions
66. GIS and society
67. GIS in management
68. Legal aspects of GIS

L. Impacts and trends
75. The history and impacts of GIS
25. Trends in GIS

Course II: Technical Issues in GIS

A. Coordinate Systems and Geocoding
26. General coordinate systems
27. Map projections
28. Affine and curvilinear transformations
29. Discrete georeferencing

B. Data Structures & Algorithms: Vector
30. Storage of complex spatial objects
31. Storage of lines: chain codes
32. Simple algorithms I: line intersection
33. Simple algorithms II: polygons
34. Polygon overlay operations

C. Raster Data Structure Algorithms
35. Raster storage

36. Hierarchical data structures
37. Quadtree algorithms and indexes

D. Data Structures and Algorithms for Surface Volumes and Times
38. Digital elevation models
39. TIN data structures
40. Spatial interpolation I
41. Spatial interpolation II
42. 3D and temporal databases

E. Databases for GIS
43. Database concepts I
44. Database concepts II
69. Database design I
70. Database design II

F. Error Modeling and Data Uncertainty
45. Accuracy of spatial databases
46. Managing error
47. Feature geometry
48. Line generalization

G. Visualization
49. Visualization of spatial data
50. Color theory

H. Data Exchange and Standards
71. Standards for spatial databases
72. GIS and global databases

I. The Mulit-purpose Cadaster
64. The multi-purpose cadaster
65. Case study of a GIS multi-purpose cadaster

J. New Directions in GIS
73. GIS and perception of spatial information
74. GIS and spatial cognition

K. Decision Making in a GIS Context
54. Multiple criteria method
55. Example of multicriteria decision-making
56. Applications of GIS to planning
57. Implementation of an SDSS

L. Advanced Computational Techniques
49. Computational geometry and complexity
50. Parallel and vector computation

Appendix IV

GIS Educational Sites

The following provides a list of some of the known GIS educational institutes around the world. While this list is certainly not complete, it should at least provide a view of the major educational sites.

This list was compiled from the research team's literature review[1], experience and surveys within Thailand, the MOSTE-TDRI GIS study tour in Australia, as well as its contacts throughout the world. The list is grouped by countries in the following general format :

- Institute name
- Department
- Institute address
- Contact
- Contact telephone number
- Site using NGCIA curriculum or is a *beta* test site [Y/N]

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[1] Primary source for this list was *GIS World*, December 1990, Vol. 3 # 6, pp 69-72.

Australia

Curtin University of Technology
Surveying & Cartography
Perth
WA 6001
G.D. Lodwick
009-351-7565
NCGIA: N

Griffith University
School of Environment Studies
Nathan
QLD 4111
G.T. McDonald
007-875-7378
NCGIA: N

James Cook University
Geography
Townsville
QLD 4811
P.C. Catt
617-781-4794
NCGIA: N

Queensland University of Technology
Built Environment
Brisbane
QLD 4001
J. Davie
007-223-2111
NCGIA: N

Royal Melbourne Institute of Technology
Land Information
Melbourne
VIC 3001
R. Grenfell
003-660-2213
NCGIA: Y

University of New South Wales

Geography
Sydney
NSW 2033
B. Gardner
NCGIA: N

University of Queensland
Geographical Sciences
Brisbane
QLD 4072
G.E. Hill
617-365-6522
NCGIA: N

University of Sydney
Urban & Regional Planning
Sydney
NSW 2006
T. Wu
612-692-3606
NCGIA: N

University of Western Australia
Geography
Nedlands
WA 6009
D. Murray
619-380-2713
NCGIA: N

Sites for Australia: 9

Austria

Universitat Salzburg
Geography
Salzburg
A-0520
J. Strobl
NCGIA: Y

Canada

British Columbia Institute of Technology
GIS
Burnaby
BC V5G 3H2
R. Miller
604-432-8737
NCGIA: N

Brock University

Geography
St. Catherines
Ont L2S 3A1
A. Hughes
416-688-5550
NCGIA: N

Carelton University
Geography
Ottawa
Ont K1S 5B6
M. Fox
613-231-2641
NCGIA: N

Laurentian University of Sudbury
Geography
Sudbury
Ont P3E 2C6
J.R. Pitblado
705-675-1151
NCGIA: N

McGill University
Geography
Montreal
QU H3A 2K6
J.E. Lewis
514-398-4347
NCGIA: Y

McGill University
Urban Planning
Montreal
QU H3A 2K6
D. Brown
514-398-4078
NCGIA: Y

McMaster University

Geography
Hamilton
Ont L8S 4K1
J.M. Taylor
416-525-9140
NCGIA: Y

Memorial University of New Foundland
Geography
St. John's
NF A1B 3X9
C. Gold
709-737-4733
NCGIA: N

Canada

Novia Scotia College of Geography
Computer Science
Lawerencetown
NS B0S 1M0
D. Colville
902-584-2226
NCGIA: N

Queen's University
Geography
Kingston
ONT K7L 3N6
R.R. Tinline
613-547-2796
NCGIA: N

Ryerson Polytechnic Institute
Geography
Toronto
ONT M5B 2K3
D. Banting
416-979-5000
NCGIA: Y

University of Alberta
Geography
Edmonton
ALB T6G 2H4
V. Noronha
403-433-5228
NCGIA: N

University of British Columbia
Geography
Vancouver
BC V6T 1W5
B. Klinkenburg
604-228-3534
NCGIA: N

University of British Columbia
Soil Science
Vancouver
BC V6T 1W5
H. Schreier
604-228-4898
NCGIA: N

University of Calgary
Urban and Regional Planning
Calgary
ALB T2N 1N4
W. Jamieson
403-220-6604
NCGIA: N

University of Guelph
Agricultural Engineering
Guelph
ONT N1G 2W1
W. James
519-824-4120
NCGIA: N

University of Guelph
Landscape Architecture
Guelph
ONT N1G 2W1
J. Taylor
519-824-4120
NCGIA: N

University of Guelph
Urban & Regional Planning
Guelph
ONT N1G 2W1
J.E. Fitz-Gibbon
519-824-4120
NCGIA: N

Canada

University of Lethbridge
Geography
Lethbridge
ALB T1K 3M4
E.A. Ellehoj
403-329-2016
NCGIA: N

University of Manitoba
Geography
Winnipeg
MAN R3T 2N2
M. Panzer
204-474-6602
NCGIA: N

University of Regina
Geography
Regina
SASK S4S 0A2
306-585-4222
NCGIA: N

University of Saskatchewan
Soil Science
Saskatoon
SASK S7N 0W0
E. de Jong
306-966-6827
NCGIA: N

University of Toronto
Geography
Toronto
ONT M5S 1A1
A.M. Baker
416-978-3375
NCGIA: N

University of Victoria
Geography
Victoria
BC V8W 2Y2
C.P. Keller
604-721-7333
NCGIA: N

University of Waterloo
Geography
Waterloo
ONT N2L 3G1
B. Hall
519-885-1211
NCGIA: N

University of Western Ontario
Geography
London
ONT N6A 5C2
C.M. Pearce
519-679-2111
NCGIA: N

Universite Laval
Geography
Ste-Foy
QUE G1K 7P4
T. Mauris
418-656-5899
NCGIA: N

Universite d'Ottawa
Geography
Ottawa
ONT K1N 6N5
C.R. Duguay
613-564-9942
NCGIA: N

Canada

Universite de Montreal
Geography
Montreal
QUE H3T 3J7
F. Cavayas
514-270-4713
NCGIA: N

Universite de Montreal
Landscape Architecture
Montreal
QUE H3T 3J7
B. Lafargue
514-343-6111
NCGIA: N

Universite de Sherbrooke
Geography
Sherbrooke
QUE J1K 2R1
M. Rheault
819-821-7191
NCGIA: N

Sites for Canada: 31

Denmark

University of Copenhagen
Geography
Copenhagen K
OK-1350
T. Balstrom
453-313-2105
NCGIA: N

New Zealand

University of Auckland
Geography
Auckland 1
D.V. Hawke
649-737-0999
NCGIA: Y

Puerto Rico

University of Puerto Rico
Planning
Rio Piedras
00931
R.L. Irizarry
809-765-5244
NCGIA: N

Spain

Universid del Pais Vasco
Geography, Prehistory & Archaeology
Vitoria, Gasteiz
01006
J. Juaristi
048-139-0811
NCGIA: N

Thailand

Asian Institute of Technology
INRDM Program
Bangkok
10501
K. Nualchawee
002-529-0100
NCGIA: N

Chulalongkorn University
Geography
Bangkok
10500
S. Tangprasert
NCGIA: N

Khon Khaen University
Remote Sensing, Soil & Water
Khon Khaen
40002
C. Mongkolsawat
66-43-241-216
NCGIA: N

Ramkhamhaeng University
Geography
Bangkok
S. Rojanadist
NCGIA: N

Chiang Mai University
Geography
Chiang Mai
50002
NCGIA: N

Chiang Mai University
Multiple Cropping Center
Chiang Mai
50002
M. Ekasingh
053-221-275
NCGIA: N

Chulalongkorn University
Survey Engineering
Bangkok
10500
S. Winyoopradist
662-251-1933
NCGIA: N

Prince of Songkla University
Engineering
Hat Yai
90112
W. Musigasarn
074-235-800
NCGIA: N

Thammasat University
Rangsit
NCGIA: N

Sites for Thailand: 8

UK

The Polytechnic
Geographic Science
Queensgate, Huddersfield
HD1 3DH
D.E. Reeve
048-442-2288
NCGIA: N

University of Leicester
Geography
Leicester
LE1 7RH
D.J. Maguire
053-352-3832
NCGIA: Y

University of Liverpool
Civic Design
Liverpool
L69 3BX
P.J.B. Brown
051-794-3122
NCGIA: N

Sites for UK: 3

USA

Appalachian State University
Geography and Planning
Boone
NC 28608
A. Rex
704-262-2657
NCGIA: N

Arizona State University
Geography
Tempe
AZ 85287
F.T. Aldrich
602-965-5023
NCGIA: N

Auburn University
Geography
Auburn
AL 36849
D.R. Hicks
205-844-3420
NCGIA: N

Augustana College
Geology & Geography
Rock Island
IL 37044
J. Corgan
309-794-7303
NCGIA: N

Ball State University
Geography
Munice
IL 47306
K.M. Turcotte
317-285-1776
NCGIA: Y

Ball State University
Landscape Architecture
Munice
IL 47306
D. Ferguson
317-285-1971
NCGIA: Y

Ball State University
Urban Planning
Munice
IL 47306
D.A. Schoen
317-285-5871
NCGIA: Y

Bemidji State University
Geography
Bemidji
MN 56601
C.G. Parson
218-755-2805
NCGIA: N

Boston University
Geography
Boston
MA 02215
A.H. Strahler
617-353-5984
NCGIA: N

Bridgewater State College
Earth Sciences
Bridgetwater
MA 02325
M.N. Rao
508-697-1390
NCGIA: N

USA

Brigham Young University

Geography
Provo
UT 84602
P.J. Hardin
801-378-6062
NCGIA: N

California Polytechnic State University Pomona
Social Sciences
Pomona
CA 91768
C. S. Miller
714-869-3581
NCGIA: N

California Polytechnic State University San Luis Obispo
Landscape Architecture
San Luis Obispo
CA 93407
G.L. Smith
805-756-1319
NCGIA: N

California State University (Chico)

Geography
Chico
CA 95920
G. King
916-895-4083
NCGIA: Y

California State University (Hayward)

Geography and Environmental Studies
Hayward
CA 94542
V.K. Shaudys
415-881-3193
NCGIA: N

California State University (Long Beach)
Geography
Long Beach
CA 90804
F. Gossette
213-985-4977
NCGIA: N

California State University (Los Angeles)
Geography and Urban Planning
Los Angeles
CA 90032
S. LaDochy
213-343-2220
NCGIA: N

California State University (Northridge)
Geography
Northridge
CA 91330
E. Turner
818-885-3532
NCGIA: Y

California State University (San Bernadino)
Geography
San Bernadino
CA 92407
L. Dexter
714-887-7232
NCGIA: N

Carrol College

Geography
Waukesha
WI 53186
D. Block
414-524-7144
NCGIA: N

USA

Central Conneticut State University
Geography
New Britain
CT 06050
J.E. Harmon
203-827-7218
NCGIA: N

Central Michigan University
Geography
Mt. Pleasant
MI 48859
J. Grossa
517-774-3220
NCGIA: N

Central Missouri State University
Geography
Warrensburg
MO 64093
K.W. Engelbrecht
816-429-4827
NCGIA: N

Central Washington University
Geography and Land Studies
Ellensburg
WA 98926
N. Hultquist
509-963-3571
NCGIA: Y

Clark University
Geography (Graduate School)
Worchester
MA 01610
J.R. Eastman
508-793-7321
NCGIA: N

Clemson University
Planning Studies
Clemson
SC 29643
K.R. Brooks
803-656-3926
NCGIA: N

Cornell University
City and Regional Planning
Ithaca
NY 14853
D.B. Lewis
607-255-6843
NCGIA: N

Cornell University
Landscape Architecture
Ithaca
NY 14853
A.S. Lieberman
607-256-4487
NCGIA: N

Dartmouth College
Geography
Hanover
NH 03755
R.E. Huke
606-646-6087
NCGIA: N

Dillard University
Urban Studies & Public Policy
New Orleans
LA 70122
G.L. Rochton
504-286-4706
NCGIA: Y

USA

East Carolina University
Geography and Planning
Greenville
EC 27858
C.T. Ziehr
919-757-6087
NCGIA: Y

East Central University
Geography
Ada
OK 74820
V.A. Murray
405-332-8000
NCGIA: N

Eastern Michigan University
Geography and Geology
Ypsilanti
MI 48197
E. Jaworski
313-487-3140
NCGIA: N

Eastern Washington University
Geography and Anthropology
Cheney
WA 99004
L. Child
509-359-7962
NCGIA: N

Edinboro University
Geosciences

Edinboro
PA 16444
P.S. Knuth
814-732-2840
NCGIA: N

Elmhurst College
Geography and Environmental Planning
Elmhurst
IL 60126
K.R. Brehob
312-617-3595
NCGIA: N

Florida State University
Geography
Tallahasee
FL 32306
G.P. Hepner
904-644-1706
NCGIA: Y

Framingham State College
Geography
Framingham
MA 01701
M.G. White
617-620-1220
NCGIA: N

Frostburg State University
Geography
Frostburg
MD 21532
C. Caupp
301-689-4755
NCGIA: Y

George Mason University
Geography
Fairfax
VA 22030
J.S. Wood
703-323-2272
NCGIA: N

USA

George Washington University
Geography & Regional Sciences
Washington
DC 20052
A. Viterito
202-994-3966
NCGIA: N

Georgia Institute of Technology
City Planning Program - Architect
Atlanta
GA 30332
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404-894-2351
NCGIA: N

Glassboro State College
Geography and Anthropology
Glassboro
NJ 08207
R.A. Scott
609-863-6341
NCGIA: Y

Humboldt State University
Geography
Arcata
CA 95521
J.S. Leeper
707-826-3950
NCGIA: N

Humboldt State University
Natural Resource Planning
Arcata
CA 95521
S.A. Carlson
707-826-3438
NCGIA: N

Humboldt State University
Wildlife
Arcata
CA 95521
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NCGIA: N

Hunter College CUNY
Geology & Geography
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NCGIA: N

Illinois State University
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NCGIA: N

Indiana State University
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IN 47809
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NCGIA: N

Indiana University
Geography
Bloomington
IN 47405
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NCGIA: Y

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Indiana University
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Bloomington
IN 47405
812-855-7802
NCGIA: Y

Indiana University at Indianapolis
Geography
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Indiana University of Pennsylvania
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NCGIA: Y

Iowa State University
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NCGIA: N

Iowa State University
Fisheries, Wildlife Biology & Animal Ecology
Ames
IA 50011
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NCGIA: N

Jacksonville State University
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205-231-5781
NCGIA: N

Kansas State University
Geography
Manhattan
KS 66506
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913-352-6727
NCGIA: N

Kansas State University
Landscape Architecture
Manhattan
KS 66506
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913-352-5961
NCGIA: N

Keene State College
Geography
Keene
NH 03431
K.J. Bayr
603-352-1909
NCGIA: N

Kutztown University
Geography
Kutztown
PA 19530
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USA

Lousiana State University
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Baon Rouge
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Lousiana State University
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Mankato State University
Geography
Mankato
MN 56001
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NCGIA: N

Mansfield University
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NCGIA: Y

Memphis State University
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Metropolitan State University
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Miami University
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NCGIA: N

Michigan State University
Fisheries & Wildlife
East Lansing
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517-353-9811
NCGIA: N

Michigan State University
Geography
East Lansing
MI 48824
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517-353-9811
NCGIA: Y

Michigan State University
Resource Development
East Lansing
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G. Schultink
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NCGIA: N

USA

Michigan Technical University
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NCGIA: N

Middle Tennessee State University
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NCGIA: Y

Middlebury College
Geography
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VT 05753
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NCGIA: N

Mississippi State University
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Mississippi State
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NCGIA: N

Montana State University
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Bozeman
MT 59717
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NCGIA: N

Montana State University
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NCGIA: N

Murray State University
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Murray
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NCGIA: Y

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NCGIA: N

New Mexico State University
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NCGIA: N

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NCGIA: Y

North Arizona University
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Rutgers - The State University of New Jersey
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NCGIA: N

South Western Texas State University
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NCGIA: Y

Southern Connecticut State University
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NCGIA: N

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NCGIA: Y

Southern Illinois University
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NCGIA: Y

Southern Oregon State College
Geography
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State University of New York
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Albany
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State University of New York
(Buffalo)
Geography
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NY 14260
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State University of New York
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NCGIA: Y

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State University of New York College
(Geneseo)
Geography
Geneseo
NY 14454
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NCGIA: N

State University of New York College
(Oneonta)
Geography
Oneonta
NY 13820
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NCGIA: Y

Stockton State College
Environmental Studies
Pomona
NJ 08201
R.G. Mueller
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NCGIA: N

Syracuse University
Geography
Syracuse
NY 13244
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NCGIA: N

Tennessee Technical University
Wildlife Biology & Fisheries
Cookeville
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NCGIA: N

Texas A&M University
Forest Science
College Station
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NCGIA: N

Texas A&M University
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College Station
TX 77843
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NCGIA: N

Texas Christian University
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Fort Worth
TX 76129
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NCGIA: N

USA

Texas Technical University
Park Administration & Landscape Architecture
Lubbock
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NCGIA: N

The Ohio State University
Geodetic Science & Mapping
Columbus
OH 43210
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NCGIA: N

The Ohio State University
Geography
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D.F. Marble
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The Ohio State University
Landscape Architecture
Columbus
OH 43210
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The Ohio State University
Natural Resources
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NCGIA: N

Towson State University
Geography & Environmental Planning
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MD 21204
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NCGIA: Y

U.S. Airforce Academy
Economics & Geography
Colorado Springs
CO 80840
B.J. Cullis
719-472-3067
NCGIA: N

U.S. Military Academy
Geography
West Point
NY 10996
L.S. Thompson
914-938-4265
NCGIA: Y

Uni. of Hawaii (Honolulu)
Agronomy & Soil Science
Honolulu
HA 96822
S.A. El Swaify
808-948-8708
NCGIA: N

Uni. of Hawaii (Manoa)
Geography
Manoa
HA 96822
B. Murton
808-948-8465
NCGIA: N

USA

University South Carolina
Geography
Columbia
SC 29208
D.J. Cowen
803-777-6803
NCGIA: N

University of Alabama
Geography
Tuscaloosa
AL 35487
S.A. Samson
205-348-5047
NCGIA: N

University of Arizona
Arid Land Studies
Tucson
AZ 85721
M.C. Parton
602-621-7896
NCGIA: N

University of Arizona
Landscape Architecture
Tucson
AZ 85721
M.T. Deeter
602-621-3948
NCGIA: N

University of Arizona
Renewable Natural Resources
Tucson
AZ 85721
M.C. Parton
602-621-7896
NCGIA: N

University of Akron
Geography
Akron
OH 44325
T.L. Nash
216-375-7620
NCGIA: N

University of Arizona
Agriculture
Tucson
AZ 85721
J. Regan
602-621-2134
NCGIA: N

University of Arizona
Geography & Regional Development
Tucson
AZ 85721
G. Mulligan
602-621-1917
NCGIA: N

University of Arizona
Mining & Geological Engineering
Tucson
AZ 85721
M.M. Poulton
602-621-8391
NCGIA: N

University of Arkansas
Geography
Fayetteville
AR 72701
R.M. Smith
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NCGIA: Y

USA

University of California (Berkeley)
Architecture & Urban Planning
Berkeley
CA 94720
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NCGIA: N

University of California (Berkeley)
Forestry & Resource Management
Berkeley
CA 94720
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NCGIA: N

University of California (Berkeley)
Landscape Architecture
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NCGIA: N

University of California (Riverside)
Earth Sciences
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714-787-3434
NCGIA: Y

University of California (Santa Barbara)
Geography
Santa Barbara
CA 93106
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NCGIA: Y

University of Cincinnati
Geography
Cinncinnati
OH 45221
Z. Xia
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NCGIA: N

University of Colorado (Boulder)
Geography
Boulder
CO 80309
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303-492-8310
NCGIA: N

University of Colorado (Colorado Springs)
Geography
Colorado Springs
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719-593-3166
NCGIA: N

University of Conneticut
Geography
Storrs
CT 062669
J.W. Meyers
203-486-3656
NCGIA: Y

University of Conneticut
Natural Resource Management & Engineering
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NCGIA: Y

USA

University of Delaware
Geography
Newark
DE 19716
C.J. Willmott
302-451-2294
NCGIA: N

University of Denver
Geography
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CO 80208
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NCGIA: Y

University of Florida
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NCGIA: N

University of Florida
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NCGIA: N

University of Idaho
Geography
Moscow
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University of Idaho
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NCGIA: Y

University of Illinois (Urbana)
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Urbana
IL 61801
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NCGIA: N

University of Illinois (Urbana)
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NCGIA: N

University of Iowa
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IA 52242
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NCGIA: N

University of Kansas
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NCGIA: N

USA

University of Kentucky
Geography

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KY 40506
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NCGIA: N

University of Kentucky
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KY 40506
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NCGIA: N

University of Louisville
Geography
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KY 40292
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NCGIA: N

University of Maine (Orono)
Forest Engineering
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207-581-2846
NCGIA: N

University of Maine (Orono)
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NCGIA: Y

University of Maryland
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NCGIA: Y

University of Massachusetts
Geology & Geography

Amherst
MA 01003
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NCGIA: N

University of Massachusetts
Landscape Architecture & Regional Planning
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NCGIA: N

University of Miami
Geography
Coral Gables
FL 33124
J.D. Stephens
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NCGIA: N

University of Minnesota (Duluth)
Geography
Duluth
MN 55812
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NCGIA: N

USA

University of Minnesota (Twin Cities)
Forest Resources
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University of Mississippi
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NCGIA: N

University of Missouri (Columbia)
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University of Montana
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NCGIA: Y

University of Nebraska (Lincoln)
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NE 68588
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University of Nebraska (Omaha)
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University of New Mexico
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NM 87131
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NCGIA: N

University of New Orleans
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USA

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University of North Carolina (Chapel Hill)
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NCGIA: N

University of North Carolina (Chapel Hill)
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NCGIA: N

University of North Carolina (Charlotte)
Geography & Earth Sciences
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NCGIA: Y

University of North Dakota
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ND 58201
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NCGIA: N

University of Northern Iowa
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University of Oklahoma
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University of Texas (Arlington)
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University of Texas (Austin)
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University of Texas (San Antonio)
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NCGIA: N

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University of Washington
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University of Washington
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NCGIA: N

University of Wisconsin (Parkside)
Geography
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NCGIA: N

University of Wisconsin (Platteville)
Geosciences
Platteville
WI 55818
NCGIA: N

University of Wisconsin (Stevens Point)
Geography & Geology
Stevens Point
WI 54481
K.W. Rice
715-346-4454
NCGIA: N

University of Wyoming

Geography
Laramie
WY 82071
D. Grasso
307-766-3311
NCGIA: N

USA

Utah State University
Geography
Logan
UT 84322
T.J. Alsop
801-750-1290
NCGIA: N

Villanova University
Geography
Villanova
PA 19085
J.H. Leaman
NCGIA: N

Virgina Polytechnical Institute & State University
Civil Engineering
Blacksburg
VA 24061
S.D. Johnson
703-231-7147
NCGIA: N

Virgina Polytechnical Institute & State University
Forestry
Blacksburg
VA 24061
J.L. Smith
703-231-7147
NCGIA: N

Virgina Polytechnical Institute & State University
Geography
Blacksburg
VA 24061
L.W. Carstensen
703-231-5774
NCGIA: N

Virgina Polytechnical Institute & State University
Landscape Architecture
Blacksburg
VA 24061
P.A. Miller
703-961-5506
NCGIA: N

Virginia Commonwealth University
Urban Studies & Planning
Richmond
VA 23284
R.D. Rugg
804-367-1134
NCGIA: N

Wasington State University
Environmental Science
Pullman
WA 99164
D. Wherry
509-335-6439
NCGIA: N

Wasington State University
Horticulture & Landscape Architecture
Pullman
WA 99164
W.G. Hendrix
509-335-3623
NCGIA: N

Weber State College
Geography

Ogden
UT 84403
W. Wahlquist
801-626-6207
NCGIA: N

USA

West Carolina University
Earth Sciences & Anthropology
Cullowhee
NC 28723
R. Triplette
704-227-7268
NCGIA: N

West Chester University
Geography & Planning
West Chester
PA 19383
W. Thomas
215-436-2343
NCGIA: N

West Virginia University
Geology & Geography
Morgantown
WV 26506
G.A. Elmes
304-293-5603
NCGIA: Y

Western Illinois University
Geography
Macomb
IL 61455
L.T. Lewis
309-298-1764
NCGIA: Y

Western Kentucky University
Geography & Geology
Bowling Green
KY 42101
S.A. Foster
502-745-5976
NCGIA: N

Western Michigan University
Geography
Kalamazoo
MI 49008
D.G. Dickson
616-383-1839
NCGIA: N

Western Washington University
Geography & Regional Planning
Bellingham
WA 98225
D. Mookherjee
NCGIA: Y

Worcester State College
Natural & Earth Sciences
Worcester
MA 01602
R.G. Hunt
508-793-8583
NCGIA: N

Wright State University
Geography
Dayton
OH 45435
K.K. Oshiro
513-873-2845
NCGIA: N

Yale University
Forestry & Environmental Studies
New Haven
CT 06511
NCGIA: N

USA

Youngstown State University
Geography
Youngstown
OH 44555
D. Stephens
216-742-3317
NCGIA: Y

Sites for USA: 240

West Germany

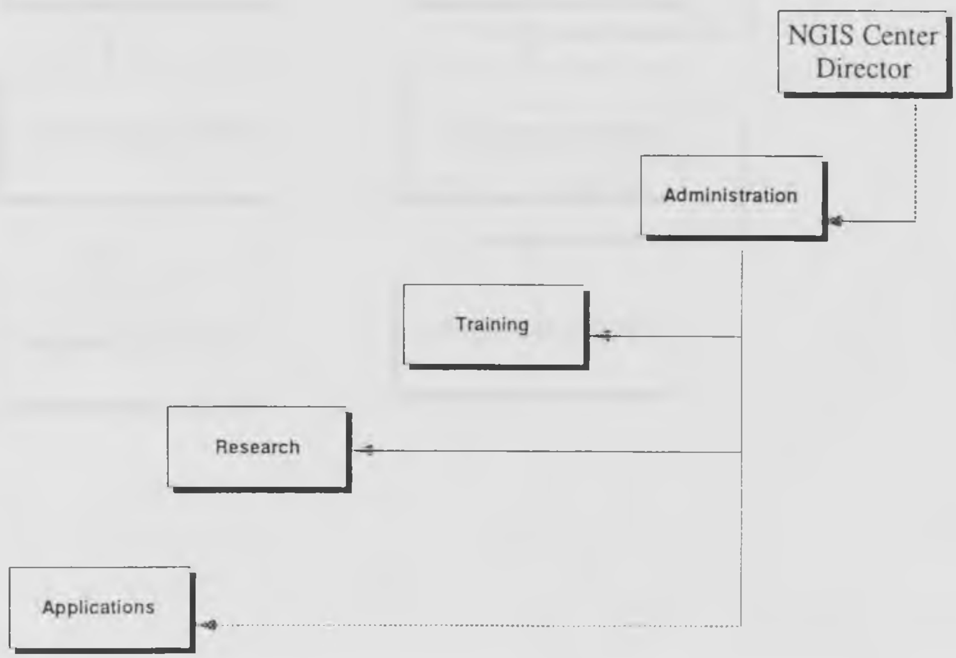
Univeristat Hannover
Institute fur Photogrammetrie
Hannover
D-3000
NCGIA: N

Appendix V

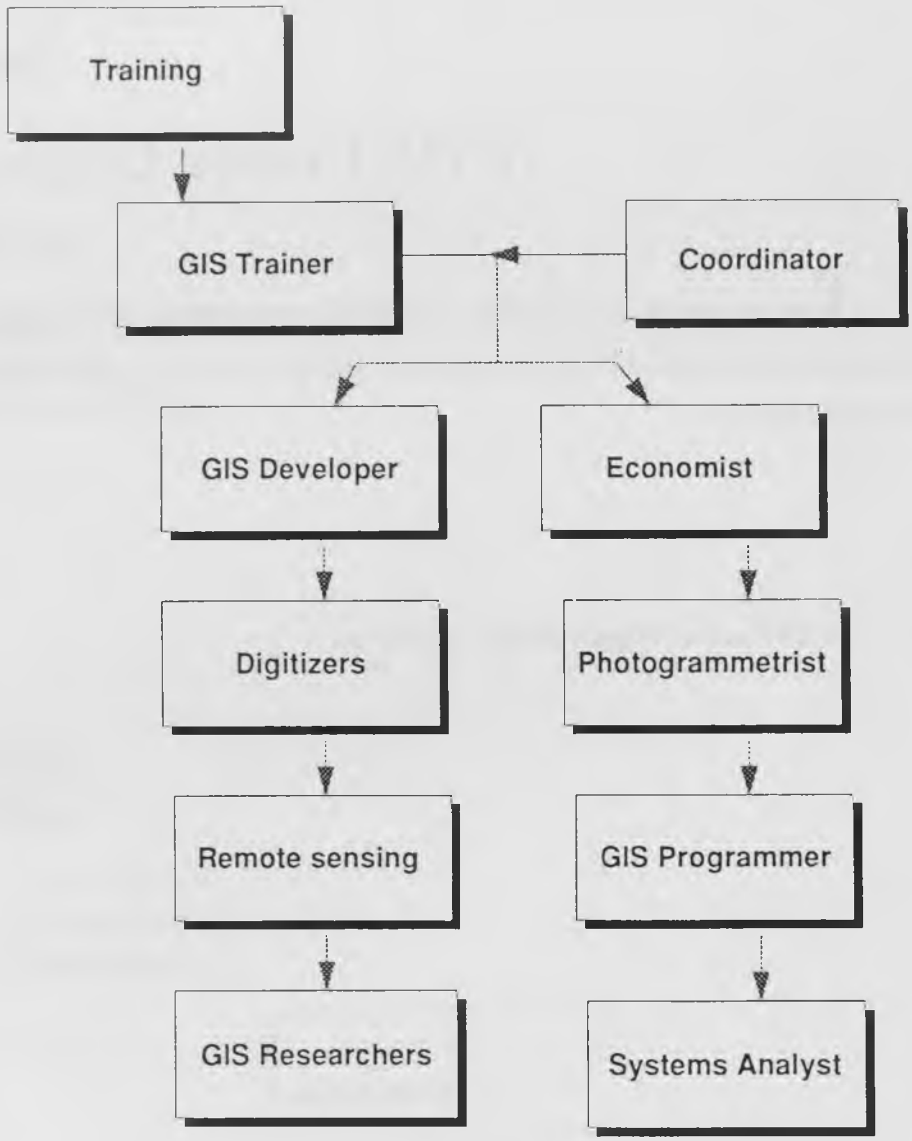
NGIS Center Organization

The following charts outline the general organization of the Center. Each chart corresponds to the sub-unit of the Center: training, research, applications development, and administration.

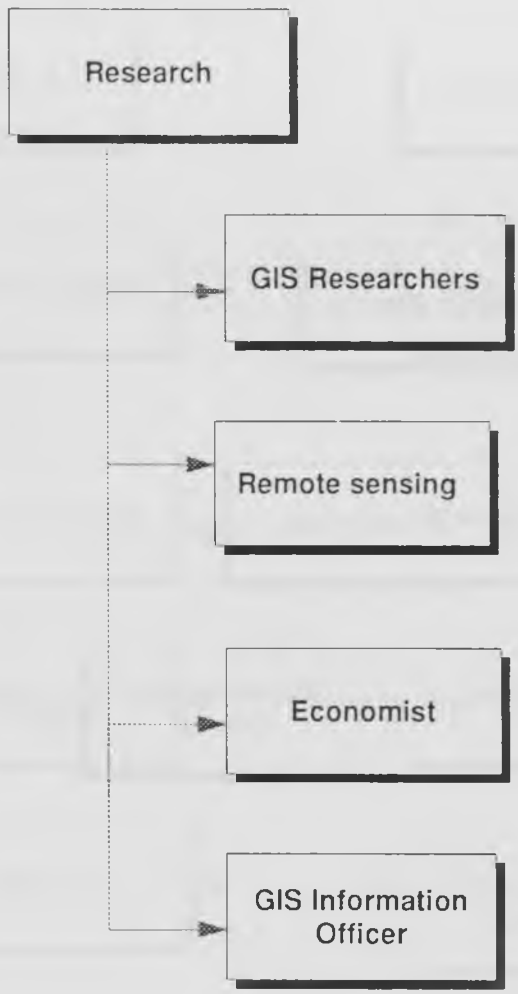
NGIS Center Organization: Top Level



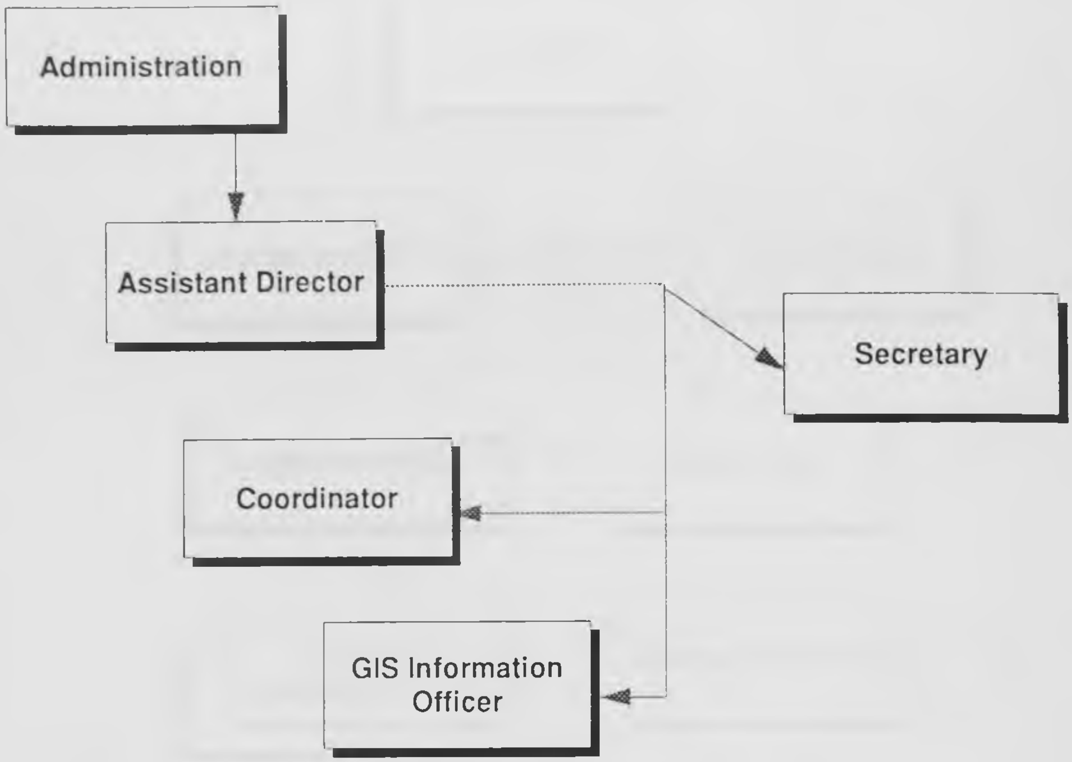
NGIS Center Organization: Training Unit



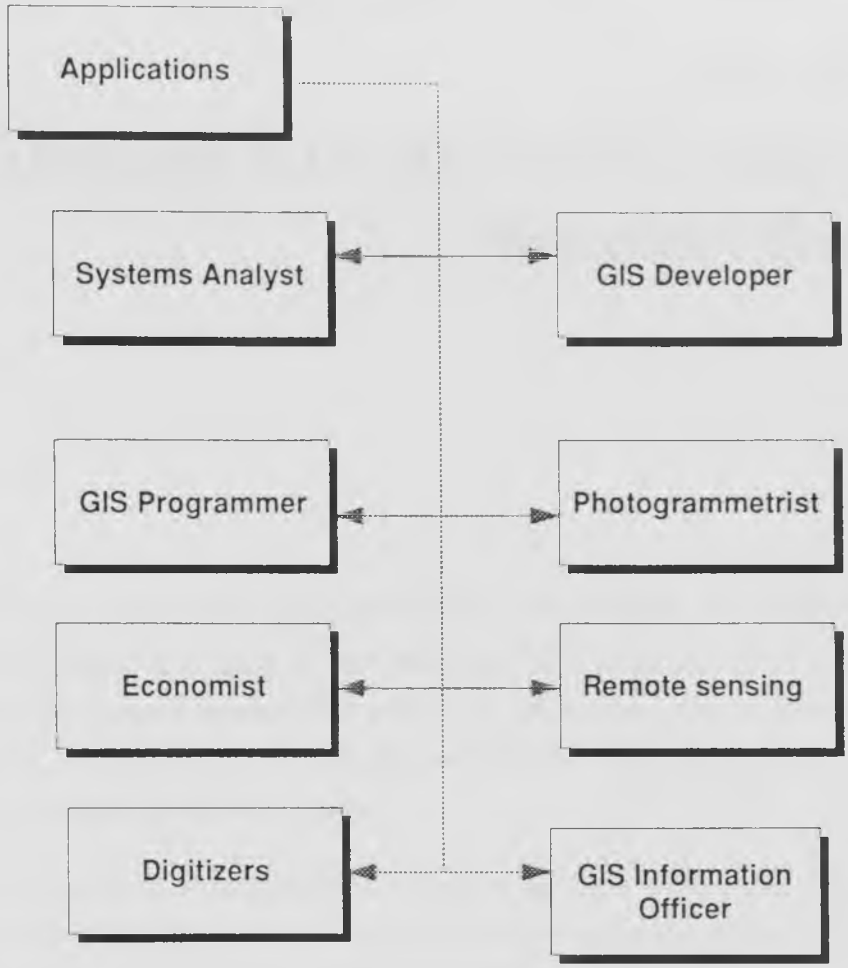
NGIS Center Organization: Research Unit



NGIS Center Organization: Administrative Unit



NGIS Center Organization: Applications Development Unit



Appendix VI

Thailand GIS Mission To Australia Summary Report

Summary of Trip

The trip has been successful in introducing the Thai Mission to Australia's GIS capabilities and its major GIS players. As Thailand's GIS activities are in a relatively embryonic state, this type of introduction will be of value to any future Thai-Australia GIS cooperation. Additionally, the display of the uses that Australians put GIS technology is, in a general way, very helpful.

While Australian GIS technological achievements were impressive, the mission felt that these were overshadowed by the high degree of cooperation shown by various government agencies visited. These institutional linkages, while peculiar to Australia, were very good examples of what can be achieved once similar arrangements have been made in Thailand. As such, these types of activities should be followed up in future Thai-Australian cooperation efforts in the field of GIS.

The Thai delegation was most impressed by the honesty and dedication of the officials that it met during the course of the mission. It is indeed rare to find this level of excellence so pervasive.

The following provides a few highlights of each stop on the mission.

Perth

Department of Land Administration, Remote Sensing Applications Center
Contacts: Henry Houghton, Ken Dawbin, Peter Davison, Alex Wyllie. Maintains cadastre for WA using DB2 and in-house GIS. Also responsible for topographic maps and aerial photos coverage over WA. An interesting note is that this agency holds a cadastral database for WA from the year 1829 to the present.

Department of Planning and Urban Development
Contact: Ian Elliot. Agency responsible for urban and coastal planning in WA. Impressive use of GIS technology in planning for future development of Perth and surrounding coastal areas.

CSIRO
Contacts: Brian Embelton, Andy Gabell, Norm Gabell. Reviewed past CSIRO-Thai cooperative project about land use planning in Rayong province. Demonstration of CSIRO remote sensing projects, including CSIRO image analysis software. Met with various representatives of private sector GIS agencies, including two with experience in Thailand, *Dames and Moore* and *AAM Surveys.*

Wallace Secretariat
Contacts: Andrew Burke, Brian Walsh. Concept of a network of digital databases under Wallace leadership. Wallace sets digital data exchange standards, based on modified USGS standard. Maintains digital land information directory to assist private sector in accessing government held data.

Department of Agriculture
Contacts: Mick Poole, Greg Beeston, Andy Linahan. Demonstration of agriculture and land use applications using Intergraph Tigris system. Particularly sustainable agriculture and livestock on fragile Australian soils.

Canberra

Australian Space Office
Contacts: Ed Cory, Don Scavone. One of Mission hosts. Discussed Australian space development plans such as communications satellite launches and potential for Thai-

Australian cooperation in field of remote sensing and space. Discussed support of CSIRO work in Thailand. An interesting aspect of this agency is that it is under industry ministry, where it is treated as an industrial agency, rather than as a *pure science* one.

DITAC

Contacts: Kym Fullgrabe, Mike Perri, Mark Hyman. Discussion of DITAC's role in Australia. Presentation of marine work within DITAC and in Australia in general. Of interest to Thailand may be work on valuing marine resources and coral reef management.

ACRES

Contacts: Carl McMaster, Dennis Puniard. Toured receiving station, impressive *factory*-like working environment, with heavy emphasis on quality control and service. Using concept of *shire-in-a-box* (similar to the US's *county-in-a-box* concept, where all necessary data for one county is sold to local government agencies and companies) to provide ready-made package of processed and geo-coded remote sensing data ready to be integrated into a GIS. Demonstrated innovative computerized image ordering system. Discussed ACRES's upgrading its facilities to access the new radar satellites. This may be of some use to Thailand.

AUSLIG

Contact: Brian Burbidge. Demonstration of koala habitat mapping project. Most of the databases held by AUSLIG are cartographic databases, as its main focus in the past has been on automated mapping. Some of its current projects include Great Barrier Reef and flood planning (prediction) for damage estimation, postal zones mapping (routing, allocation, direct mail, etc.), and national parks.

Sydney

University of New South Wales

Contacts: Bruce Forster, Prof. Trinder, Prof. Gamner, Prof. Taylor. Toured future sites of GIS facilities. Presentation of UNSW's future GIS plans. UNSW will be developing GIS along lines of expert systems, with problem solving being stressed. Heavy emphasis was placed on surveying. Witnessed demonstration of Geology Department's PC-based image analysis software. Met two Thai students currently enrolled at UNSW.

Land Information Center

Contacts: Jim Mitchell, Lewis Haley. Presentation of LIC's organizational structure, past and future work, as well as its cooperative projects with Thailand. The New South Wales Natural Resource Inventory (NRI) was also presented.

Brisbane

SUNMAP/Department of Lands/University of Queensland

Contacts: Gail Kelly, Graeme Lacey, David Midson, Gerry Wedderburn-Bishop, Brian Wendt, Graham McColm, Greg Hill. Toured SUNMAP's facilities. Discussion of SUNMAP's organization and role in promoting the use of GIS and remote sensing technology. SUNMAP is the trading arm of the Department of Lands, it is promoting the use of GIS and remote sensing technology through pilot studies and introductory demonstrations and sessions for various potential users. Presentation of University of Queensland's GIS and remote sensing study program. The university has been designated as an Australian Key Center in land information studies and as such is able to offer a rigorous training in GIS and remote sensing fundamentals. The Department of Lands offered several interesting GIS demonstrations, for example, the Noosa flood modelling project and Russell Island GIS.

Queensland University of Technology

Contacts: Jim Davie, Kurt Kubik, Russel Priebbenow. Toured Faculty of The Built Environment. Witnessed demonstrations of scanned aerial photograph use in coral reef management.

Townsville

Mapping and Monitoring Technology

Contact: Debbie Kuchler. Demonstration of remote sensing technology, emphasis on coral reef and shallow water mapping using MicroBrian.

James Cook University

Contact: Pauline Catt. Toured Center for Remote Sensing, including training facilities.

CSIRO

Contact: Ross Coventry. Toured facilities of Division of Soils. Demonstration showing application of remote sensing to detection of land degradation.

Cairns

Department of Land

Contacts: Earl Saxon, Peter Ray. Toured department's GIS and remote sensing facilities. Demonstration of application integrating remote sensing and GIS in mapping forest in Cairns. A thorough assessment of strengths and deficiencies of these technologies was also presented. Another interesting application presented was in the management of sugar cane plantations at the mill or regional level. This demonstration was particularly relevant to Thailand. A field trip to the demonstration study areas was arranged, which also covered a view of rural Australia. Also of interest was the organizational structure of the Department of Lands, which now includes the former Department of Geographic Information. This indicates the importance of spatial information and its management to the Queensland state government. Presentation of use of GIS and remote sensing technology in the management of Queensland's world heritage rainforest. An application mapping forest type distribution by terrain was also presented.

Existing Thai-Australian Cooperation

It should be emphasized from the outset that Thailand and Australia have a long history of cooperation in the fields of GIS and remote sensing. Future cooperation efforts will therefore enjoy already established channels of communication and cooperation, it will not be starting from a vacuum. The following information is derived, in part, from an on-going TDRI survey of GIS technology in Thailand.

For example, Australia is assisting Thailand's Department of Land (DOL) in its effort to develop a cadastre for the whole of the Kingdom. In this project, which covers two phases (1985-1990 and 1990-1994), several experts from state land administration agencies have been advising the DOL as well as helping develop strategies to implant GIS technology within DOL.

Another successful example of Thai-Australian cooperation is in the field of land use planning. CSIRO has been assisting the Department of Land Development (DLD) in realizing remote sensing and GIS technology in preparing up- to-date land use maps as well as land use plans. Australian assistance is also being rendered in helping to create a land use plan for the typhoon devastated province of Chumporn.

Australia is also supporting the Bangkok Metropolitan Administration in establishing the Bangkok Land Information System (BLIS). This project (1989-1992) is attempting to incorporate all cadastre and utility information for Bangkok and involves several Royal Thai Government (RTG) agencies: DOL, BMA, Metropolitan Water Works Authority, Metropolitan Electricity Authority, and the Telephone Organization of Thailand.

A further example of Thai-Australian cooperation lies in opium crop substitution, the Thai-Australia Highland Agriculture and Social Development project (TA-HASD) in joint cooperation with the Thai Department of Public Welfare. The project has covered two phases, 1982-1989 and 1989-1993. The Thailand Development Research Institute (TDRI) has been cooperating with the TA-HASD project in creating a Management Information System (MIS) over its 12 project zones. This MIS is being used by project staff in rationalizing the hilltribe's land use and in selecting appropriate crops to replace opium. This highly regarded project has recently received some international attention for its success.[1]

Following these established cooperation efforts, the mission feels further action is necessary to sustain the momentum of GIS cooperation between Thailand and Australia.

Potential Technical Cooperation

From the experiences of the Thai Mission and knowledge of the GIS situation in Thailand, several potential areas of cooperation immediately come to mind. The areas outlined below should only be seen as examples of cooperation, more areas will surely come to light as Thai and Australian GIS agencies become more familiar with one another.

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[1] TIME, May 6, 1991 #18, pp 31-32.

Education stands out as the area with the highest potential for cooperation. Thailand, while rapidly developing as a GIS-using country, has a severe lack of GIS trained staff as well as GIS aware managers. Priorities in this area are: executive-level, operator-level, and management-level.[2] Top executives in GIS-using organizations must fully and deeply appreciate GIS technology. A widespread understanding of this technology would prevent failures of GIS due to lack of institutional support. Bi-lateral scholarships are seen as the main sources of funding for GIS education and training. The main participating Australian agencies are universities. It should be pointed out that this is envisioned as long-term training. An additional priority might be a training-of-trainers program. Australian technical and administrative expertise would also be needed to assist Thai universities in setting up MSc and Phd level programs in GIS.

A further area of Thai-Australian cooperation appears in the development of specific GIS applications. The mission has seen some fairly sophisticated GIS applications, which indicates a comparably sophisticated understanding of GIS technology and how it can be applied to solving real world problems. Priority areas include: urban planning, habitat mapping, coastal management, coral reef management, scanning technology, and the application of Artificial Intelligence (AI) to GIS, especially in the field of human interfaces. TDRI is particularly interested in this area, as it is at present developing GIS as an everyday policy tool and sees AI as the best potential route for this.

Remote sensing, including air-borne surveys, is another area with high potential for successful cooperation. Australia has been successful in the application of remote sensing. In particular, its production and service environment[3] at the Australian Center for Remote Sensing (ACRES) receiving station was most impressive. ACRES might therefore play a role in management training as well as in specialist training, particularly production geo-coding. As Thailand is a country covered for much of the year by clouds, the production usage of remote sensing has been limited. With the launch of the European Space Agency's ERS-1 radar satellite, this obstacle to Thailand enjoying the full benefits of remote sensing may at last be removed. Australia has already upgraded

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[2] It should be noted that management in this case means real working management in the operational sense, e.g. managers of GIS centers.

[3] ACRES's motto "Service is our business" emphasizes this concept.

its receiving station to capture data from this satellite. This might be a further area of cooperation, with MOSTE being the Thai participant.

In the realm of commercial ventures, there are several outstanding opportunities. Particular areas of interest include GIS software and application development as well as consulting. For example, it is a marketing fact-of-life that the GIS software, ARC/INFO, dominates both the Thai and Australian markets. From this, it can be seen that there exists a high potential for cooperation between the Thai-Australian branches. For example, in terms of technology transfer, training, or making use of the relatively cheaper labor available in Thailand for projects requiring mass manual digitization. Such models of cooperation are not restricted to a particular brand name or company, but applies to all commercial cooperation. The objective is to promote business opportunities in GIS for Australian firms in the Thai market, and vice versa. Furthermore, there are several opportunities for Australian companies in GIS consulting, particularly in the lucrative urban and utility fields. Notable amongst these is the potential for facilities management at various state agencies of the Thai government.

Training, on a commercial basis, may also hold some potential for Thai-Australian cooperation. Australian GIS companies with experience in short-term training will find a large market in Thailand, perhaps in conjunction with Thai companies. Particular applications should be targeted, rather than broad-based general training about GIS so as not to compete or duplicate the university based training mentioned above.

Finally, there is a large potential for Thai- Australian cooperation in third party joint ventures. For example, the area of rural electrification is worth exploring. Thailand has achieved a very high rate of electrification in the last five years. It therefore seems appropriate as a good vehicle to develop third party joint ventures in countries neighboring Thailand. Thai-Australian cooperation in regional projects should bring benefits to both countries. All Southeast Asian countries can be considered as potential markets.

Institutional Arrangements

In order to further pursue Thai-Australian cooperation in the field of GIS, strong and dynamic linkages between Thai and Australian institutions should be arranged. A two-pronged approach is recommended. For government-to-government dialogue, the existing joint committee, under the direction of DITAC and MOSTE, should consider GIS as a prominent component of its activities. In particular, GIS should be regarded as an important tool for managing the environment. Through DITAC and MOSTE, a network of Thai and Australian GIS agencies should be established, based on their mutual needs and strengths. The objective is the promotion of Australian GIS interests in line with the Thai governmental and commercial needs.

It is also proposed that AIDAB funding be sought for promoting Thai-Australian cooperation on GIS. The total annual budget for Thailand under AIDAB is presently about A$24.5 million in grant and another A$14.5 million for supplementary. The mission believes in the value of applying GIS for natural resources and environmental management, and in the potential of applying Australian expertise to Thailand in this field. It is thus proposed that at least A$4 million project be established to facilitate GIS cooperation. On the Thai side, DTEC is the responsible agency for foreign technical assistance. Once this proposal is accepted, a project proposal will be formulated between DITAC and MOSTE. It is possible to commence such a project from early 1992 onwards.

Concurrently, business opportunities on GIS should be promoted through commercial channels. Under the Australian- Thailand Business Council, a committee on environment and GIS should be established. One of the main objectives of this committee is to promote business contacts between Australian and Thai firms on GIS through the arrangement of business missions, seminars, match-making conferences, etc. This will be promoted in parallel with the government-to-government efforts.

Appendix VII

NGIS Center Action Plan Details

The following tables represent the NGIS Center's Action Plan for its first five years. It includes task identification, scheduling, budgeting, as well as the humand and budgetary resources required to accomplish the tasks outlined.

A digitial file (in Microsoft Project format) in both Thai and English has been forwarded to MOSTE in order to assist them, as much as possible, in planning for the Center's implementation.

Task/Sub-task	Amount
NGIS TASKS	**58,927,748**
Purchase Initial Hardware & Software	**13,000,000**
Hardware & software maintainence	**6,500,000**
Plan system upgrades	Salaries only
Standardization work	**3,300,000**
Standardization (outside)	3,000,000
Maintain standards outside	**300,000**
Maintain NGIS staff	Salaries only
NGIS training	**1,344,000**
GIS training 1 (outside)	172,000
GIS training 2 (outside)	233,000
GIS training 3 (outside)	294,000
GIS training 4 (outside)	445,000
NGIS GIS training	200,000
Maintain spatial indexes	**1,600,000**
Contract out	1,600,000
NGIS maintain	Salaries only
NGIS GIS research & coordination	**9,000,000**
Contract out (4 projects)	8,000,000
NGIS staff project	1,000,000
NGIS staff development	**15,000,000**
Select NGIS candidates for training	
Train NGIS staff (MSc - PhD)	15,000,000
NGIS applications work	Salaries only
Outside development of NGIS BBS	**350,000**
Maintain NGIS BBS	**200,000**
Outside maintain NGIS BBS	200,000
NGIS maintain NGIS BBS	Salaries only
NGIS seminars	**2,000,000**
1st GIS seminar	400,000
2nd GIS seminar	400,000
3rd GIS seminar	400,000
4th GIS seminar	400,000
5th GIS seminar	400,000
International GIS seminar	**840,000**
Attend International GIS conference	120,000
Attend International GIS conference	120,000
Attend International GIS conference	600,000
NGIS library	**250,000**
Establish GIS library	50,000
Continue GIS library acquisitions	200,000
Routine work	**5,543,748**
NGIS staff salaries (partial)	2,582,316
NGIS staff salaries (full)	2,961,432

Action Plan Item	Amount
Hardware & Software	**19,500,000**
GIS hardware & software budget	13,000,000
Maintainence budget	6,500,000
Projects	**14,250,000**
Standardization project	3,000,000
Maintain index budget	300,000
Spatial index re-survey	1,600,000
GIS issue research project	9,000,000
BBS development team	350,000
Training	**15,750,000**
Misc training items	750,000
NGIS scholarship fund	15,000,000
Miscellaneous	**3,290,000**
Attend international GIS seminars (5)	840,000
Maintain NGIS BBS	200,000
Seminar BKK costs	2,000,000
Initial library purchases	250,000
Staff	**6,137,750**
NGIS Director salary	1,305,300
Systems analsyst	163,350
Outside trainers	594,000
Secretary	730,716
Coordinator	430,601
Assistant to Director	978,638
GIS programmer	109,445
GIS developer	547,976
Trainer	163,350
Digitizer	78,081
GIS researchers	545,589
Remote sensing	109,118
Economist	109,118
Photogrammetrist	109,118
GIS information officer	163,350

Action Plan Task	Estimtated Start	Estimated Finish	Required Resource
Purchase initial hardware & software	**1 May '91**	**28 Apr '92**	**RTG budget**
Hardware & software maintainence	**2 Oct '92**	**31 Dec '96**	**Maintainence budget**
Plan system upgrades	**1 Jul '96**	**23 Aug '96**	
Standardization work	**3 Apr '92**	**31 Dec '96**	
Standardization (outside)	3 Apr '92	1 Apr '93	Standardization project
Maintain standards outside	1 Jul '93	31 Dec '95	Maintain index budget
Maintain NGIS staff	1 Oct '95	31 Dec '96	
NGIS training	**1 Jul '92**	**9 Aug '96**	
GIS training 1 (outside)	1 Jul '92	11 Aug '92	Outside trainers,Misc training items
GIS training 2 (outside)	12 Aug '93	22 Sep '93	Outside trainers,Misc training items
GIS training 3 (outside)	1 Jul '94	11 Aug '94	Outside trainers,Misc training items
GIS training 4 (outside)	1 Jul '95	11 Aug '95	Outside trainersMisc training items
NGIS GIS training	1 Jul '96	9 Aug '96	Misc training items
Maintain spatial indexes	**1 Apr '92**	**31 Dec '96**	
Contract out	1 Apr '92	1 Oct '95	Spatial index re-survey
NGIS maintain	1 Oct '95	31 Dec '96	
GIS research & coordination	**1 Apr '92**	**3 Jul '96**	
Contract out (4 projects)	1 Apr '92	1 Oct '95	GIS issue research project
NGIS staff project	1 Jan '96	3 Jul '96	GIS issue research project
NGIS staff development	1 Jan '92	1 Sep '95	
Select NGIS training candidates	**1 Jan '92**	**1 Sep '92**	
Train NGIS staff (MSc PhD)	**1 Sep '92**	**1 Sep '95**	**NGIS scholarship fund**
NGIS applications work	**1 Oct '95**	**31 Dec '96**	
Outside development of NGIS BBS	**2 Jun '92**	**31 Dec '92**	**BBS development team**
Maintain NGIS BBS	**1 Feb '93**	**31 Dec '96**	
Outside maintain NGIS BBS	1 Feb '93	1 Oct '95	Maintain NGIS BBS
NGIS maintain NGIS BBS	1 Oct '95	31 Dec '96	
NGIS seminars	**1 Sep '92**	**1 Sep '96**	
1st GIS seminar	1 Sep '92	1 Sep '92	Seminar BKK costs
2nd GIS seminar	1 Sep '93	1 Sep '93	Seminar BKK costs
3rd GIS seminar	1 Sep '94	1 Sep '94	Seminar BKK costs
4th GIS seminar	1 Sep '95	1 Sep '95	Seminar BKK costs
5th GIS seminar	1 Sep '96	1 Sep '96	Seminar BKK costs
International GIS seminar	**20 May '92**	**20 May '96**	
Attend International GIS conference	20 May '92	20 May '92	Attend GIS seminar budget
Attend International GIS conference	20 May '94	20 May '94	Attend GIS seminar budget
Attend International GIS conference (5 staff)	20 May '96	20 May '96	Attend GIS seminar budget
NGIS library	**1 Sep '92**	**31 Dec '96**	
Establish GIS library	**1 Sep '92**	**1 Sep '92**	**Initial library purchases**
Continue GIS library acquisitions	1 Sep '92	31 Dec '96	Initial library purchases
Routine work	**1 Jan '92**	**31 Dec '96**	
NGIS staff (partial)	**1 Jan '92**	**1 Oct '95**	**NGIS Director, Secretary[2], Coordinator, Assistant to Director**
NGIS staff (full)	**1 Oct '95**	**31 Dec '96**	**NGIS Director, Secretary[3], Coordinator, Assistant to Director, Systems analsyst., etc.**

Appendix VIII

NGIS Center Hardware and Software Specifications

The following section details the suggested hardware and software that the National GIS Center is thought to need to successfully carry out its tasks.

อุปกรณ์ที่จะจัดหาในปี พ.ศ. ๒๕๓๔

อุปกรณ์ด้านฮาร์ดแวร์

ลำดับ	รายละเอียด	จำนวนชุด
๑	ระบบคอมพิวเตอร์ Engineering Workstations หลัก - ทำงานภายใต้ O/S ชนิด UNIX หรือเทียบเท่า - สามารถแสดงผลการทำงานในโหมดภาษาไทย - ทำงานโดยใช้เทคโนโลยี RISC - มีตัวช่วยคำนวณฟังก์ชันทางคณิตศาสตร์ - ทำงานที่ความเร็วอย่างน้อย ๑๕ MIPS - หน่วยความจำใช้งานอย่างน้อย ๑๒ Mb - หน่วยความจำความเร็วสูง (CACHE) ขนาดไม่น้อยกว่า ๖๔ Kb - อุปกรณ์แสดงผลภาพสี ขนาดไม่เล็กกว่า ๑๙ นิ้ว ชนิดความละเอียด อย่างน้อย ๑๐๒๔ x ๘๐๐ จุด - มีอุปกรณ์เชื่อมต่อแบบอนุกรม - ตู้ขับจานแม่เหล็กแบบแข็งความจุรวมไม่น้อยกว่า ๒.๒ Gb - ตู้ขับจานแม่เหล็กแบบอ่อนขนาดความจุ ๑.๔๔ Mb - ตู้ขับเทปแม่เหล็กความหนาแน่น ๑๕๐ Mb - มีอุปกรณ์เชื่อมต่อกับระบบเครือข่าย (Local Area Network Transceiver) แบบ Ethernet	๑
๒	ระบบคอมพิวเตอร์ Engineering Workstations - ทำงานภายใต้ O/S ชนิด UNIX หรือเทียบเท่า - สามารถแสดงผลการทำงานในโหมดภาษาไทย - ทำงานโดยใช้เทคโนโลยี RISC - มีตัวช่วยคำนวณฟังก์ชันทางคณิตศาสตร์ - ทำงานที่ความเร็วอย่างน้อย ๑๕ MIPS	๔

ลำดับ	รายละเอียด	จำนวนชุด
	- หน่วยความจำใช้งานอย่างน้อย ๘ Mb - หน่วยความจำความเร็วสูง (CACHE) ขนาดไม่น้อยกว่า ๖๔ Kb - อุปกรณ์แสดงผลภาพสี ขนาดไม่เล็กกว่า ๑๙ นิ้ว ชนิดความละเอียดอย่างน้อย ๑๐๒๔ x ๙๐๐ จุด - มีอุปกรณ์เชื่อมต่อแบบอนุกรม - ตู้ขับจานแม่เหล็กแบบแข็งความจุรวมไม่น้อยกว่า ๔๐๐ Mb - ตู้ขับจานแม่เหล็กแบบอ่อนขนาดความจุ ๑.๔๔ Mb - มีอุปกรณ์เชื่อมต่อกับระบบเครือข่าย (Local Area Network Transceiver) แบบ Ethernet	
๓	**ระบบไมโครคอมพิวเตอร์ ที่มีคุณสมบัติดังนี้** - ใช้หน่วยประมวลผลกลาง ๘๐๓๘๖ หรือเทียบเท่า - มีตัวช่วยคำนวณฟังก์ชันทางคณิตศาสตร์ ๘๐๓๘๗ - ทำงานที่ความเร็วอย่างน้อย ๒๐ MHz - หน่วยความจำใช้งานอย่างน้อย ๒ Mb - อุปกรณ์แสดงผลชนิด VGA และจอแสดงภาพสีชนิดความละเอียดสูง - มีอุปกรณ์เชื่อมต่อแบบอนุกรมและแบบขนานอย่างน้อย แบบละ ๒ port - ตู้ขับจานแม่เหล็กแบบแข็งความจุอย่างน้อย ๑๐๐ Mb - ตู้ขับจานแม่เหล็กแบบอ่อน ความจุสูงสุด ๑.๒ Mb ขนาด ๕.๒๕ นิ้ว อย่างน้อย ๑ ชุด - มีอุปกรณ์เชื่อมต่อกับระบบเครือข่าย (LAN) Ethernet	๕
๔	เครื่องพลอตแบบใช้ปากกาอย่างน้อย ๘ สี ขนาด A0 แบบกระดาษม้วน	๑
๕	เครื่อง Digitze ข้อมูล ขนาด A0 พร้อมอุปกรณ์ขาตั้ง ระบบ Hydraulic	๓
๖	เครื่อง Digitize ข้อมูล ขนาด A3	๕
๗	เครื่องพลอตแบบ Thermal Transfer Plotter ขนาด A4	๒

ลำดับ	รายละเอียด	จำนวนชุด
๘	เครื่องพิมพ์แบบ Laser ที่มี Postscript ขนาด A4	๑
๙	เครื่องพิมพ์แบบ INK JET COLOR ขนาด A4	๑
๑๐	เครื่องอ่านเทปแม่เหล็ก ขนาด ๑๐.๕ นิ้ว สำหรับระบบไมโครคอมพิวเตอร์	๑
๑๑	เครื่องจ่ายกระแสไฟฟ้าฉุกเฉิน (UPS) ขนาด ๓ KVA	๑
๑๒	เครื่องจ่ายกระแสไฟฟ้าฉุกเฉิน (UPS) ขนาด ๒ KVA	๑

อุปกรณ์ด้านซอล์ฟแวร์สำหรับ Engineering Workstation

ลำดับ	รายละเอียด	จำนวนชุด
๑	ซอฟท์แวร์ระบบสารสนเทศภูมิศาสตร์ที่มีความสามารถดังนี้ - มีฟังก์ชันพื้นฐานต่างๆของระบบสารสนเทศภูมิศาสตร์ ซึ่งสามารถเก็บ และแสดงผลภาษาไทยทั้งในโหมดกราฟฟิก และในฐานข้อมูล - มีฟังก์ชันสำหรับทำการ Overlay ข้อมูล - มีฟังก์ชันสำหรับการทำ Network - มีฟังก์ชันสำหรับ Spatial และ Text Database Query - มีฟังก์ชันสำหรับการทำ Triangulated Irregular Network - มีฟังก์ชันสำหรับการตรวจ แก้ และเพิ่มเติมข้อมูล - มีฟังก์ชันสำหรับการทำแผนที่ผลลัพธ์ - มีฟังก์ชันสำหรับทำการเปลี่ยนพิกัดข้อมูล - มีฟังก์ชัน Coordinate geometry สำหรับงานทางด้านค่าพิกัด และการสำรวจทำแผนที่	๕

อุปกรณ์ด้านซอล์ฟแวร์สำหรับระบบไมโครคอมพิวเตอร์

ลำดับ	รายละเอียด	จำนวนชุด
๑	ซอฟท์แวร์ระบบสารสนเทศภูมิศาสตร์ที่มีความสามารถดังนี้ - มีฟังก์ชันพื้นฐานต่างๆ ของระบบสารสนเทศภูมิศาสตร์ - มีฟังก์ชันสำหรับทำการ Overlay ข้อมูล - มีฟังก์ชันสำหรับการทำ Network - มีฟังก์ชันสำหรับ Spatial และ Text Database Query - มีฟังก์ชันสำหรับการทำ Triangulated Irregular Network - มีฟังก์ชันสำหรับการตรวจ แก้ และเพิ่มเติมข้อมูล - มีฟังก์ชันสำหรับการทำแผนที่ผลลัพธ์ - มีฟังก์ชันสำหรับทำการเปลี่ยนพิกัดข้อมูล	๕
๒	ซอฟท์แวร์ประมวลผลข้อมูลจากการสำรวจทางไกลดังนี้ - มีฟังก์ชันการทำงานพื้นฐานที่จำเป็นในการวิเคราะห์และประมวลผลข้อมูลจากการสำรวจระยะไกล ครบถ้วน - สามารถวิเคราะห์และแสดงผลข้อมูลการสำรวจระยะไกลบนจอภาพแบบ VGA ที่มีจอแสดงภาพสีความละเอียดสูงได้ - มีฟังก์ชันสำหรับการทำงานร่วมกับซอร์ฟแวร์ของระบบสารสนเทศภูมิศาสตร์ดังกล่าวข้างต้น	๕

Appendix IX

NGIS Center Library List

The following is a list of suggested texts, journals, trade magazines, etc., for the NGIS Center's library to begin acquistions. It is also suggested here that translations begin to made of these documents **as soon as possible**. Thai language translations will speed up the transfer of GIS technology more than anything else. It should therefore be made a high priority for the Center's library.

Texts

Accuracy of Spatial Databases, Goodchild, M., Gopal, S., (editors), 1989, Taylor and Francis, Bristol, PA, USA.

Applications of GIS Series, Marble, D., Peuquet, D., 1992, Taylor and Francis, Bristol, PA, USA.

Association for Geographic Information Yearbook (various years), AGI, Taylor and Francis, Bristol, PA, USA.

AUTO-CARTO, International Symposium on Computer-Assisted Cartography, American Society for Photogrammetry and Remote Sensing and the American Congress on Surveying and Mapping, 210 Little Falls St., Falls Church, VA 22046, USA.

Computer Graphics: A Programming Approach, Harrington, S., 1986, McGraw-Hill Book, Co. Singapore.

Computer-assisted cartography : principles and prospects, Monmonier, M., 1982, Prentice-Hall, Englewood Cliffs, NJ, USA.

Design With Nature, McHarg, I., 1969, Doubleday, New York.

ESRI Annual Users Conference Proceedings (various years), Environmental Systems Research Institute, Inc. 380 New York St, Redlands, CA 92373, USA.

Geographic and Land Information Systems for Practicing Surveyors, Onsrud, H., Cook, D., 1990, American Congress on Surveying and Mapping, Bethesda MD, USA.

Geographic Information Systems and Cartographic Modelling, Tomlin, D. 1990, Prentice Hall.

Geographic Information Systems: A Management Perspective , Aronoff, S., 1989, WDL Publications, Ottawa, Canada

Geographic Information Systems: An Introduction, Starr, J., Estes, J., 1990, Prentice-Hall, Englewood Cliffs, NJ 07632, USA.

GIS Applications in Natural Resources, 1991, GIS World, Fort Collins, CO, USA.

GIS Applications in Thailand Seminar Proceedings, 1989, TDRI

GIS Sourcebook (various years), GIS World, Fort Collins, CO, USA.

GIS/LIS Proceedings (various years), American Congress on Surveying and Mapping, Bethesda MD, USA.

GIS: Developments and Applications, 1991, Belhaven Press, London, Great Britain.

Integrated Information for Natural Resources Management, Hastings, P., Boonraksa, C., 1990, TDRI.

Integrated Models in Geography, Chorley, R., Hagget, P. (editors), 1969, University Paperback, Methuen London.

International Symposium on Spatial Data Handling Proceedings, International Geographical Union, Commission on Geographical Data Sensing and Processing, PO Box 571, Williamsville, N.Y. 14221, USA.

Interpreting Space: GIS and Archaeology, Allen, K., Green S., Zubrow, E., (editors) 1990, Taylor and Francis, Bristol, PA, USA.

Introductory Readings in Geographic Information Systems, Peuquet, D., Marble, D., (editors), 1990, Taylor and Francis, Bristol, PA, USA.

Land Information Management: An Introduction with Special Reference to Cadastral Problems of Third World Countries, Dale, P., McLaughlin, J., 1988, Oxford University Press.

Principles of Geographical Information Systems for Land Resources Assessment, P. A. Burrough, 1986, Clarendon Press, Oxford University Press, Walton St. Oxford OX26DP, Great Britain.

Prinicples of Interactive Computer Graphics, Newman, W., Sproul, R. 1984, McGraw-Hill Book, Co. Singapore.

Procedural Elements for Computer Graphics, Rogers, D.F., 1985, McGraw-Hill Book, Co. Singapore.

Spatial Analysis: A Reader in Statistical Geography, Berry, B., Marble, F. 1965, Prentice-Hall, Englewood Cliffs, NJ 07632, USA.

The Role of GIS in Development Planning, Marble, D., Sazanami, H., 1992, Taylor and Francis, Bristol, PA, USA.

Three Dimensional Applications of GIS, Raper, J., 1989, Taylor and Francis, Bristol, PA, USA.

Understanding GIS, Rhind, D., Mounsey, H., 1989, Taylor and Francis, Bristol, PA, USA.

Journals

International Journal of Geographical Information Systems, Coppock, J., Guptill, S. (editors), Taylor and Francis, Bristol, PA, USA.

International Journal of Remote Sensing, Cracknell, A., Taylor and Francis, Bristol, PA, USA.

Geographical Analysis: An International Journal of Theoritical Geography, Goodchild, M. (editor), Taylor and Francis, Bristol, PA, USA.

Trade Magazines

GIS World, Parker, H. (editor), Fort Collins, CO, USA.

Rajapark Building, 163 Asoke, Sukhumvit Road, Bangkok 10110 Thailand
Tel. 258-9012-7, 258-9027-9 Fax. 258-9046 Telex 20666 Rajapak TH