DESIGN OF A MULTINATIONAL GIS-BASED INFORMATION MANAGEMENT SYSTEM FOR ENVIRONMENTAL DECISION MAKING IN THE MEKONG REGION

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ABSTRACT

The Mekong River and its system of tributaries drain a vast fertile basin of fundamental importance to six nations - Cambodia, Lao PDR, Myanmar, Thailand, Vietnam and the Peoples Republic of China (especially Yunnan Province). These rivers are the arteries of the region, providing a vital source of water for agriculture, industry, drinking and transportation. Most of the countries are experiencing rapid development and industrialisation with incumbent social disruptions, as well as benefits. It is now recognised that the problems created by these pressures transcend national boundaries and can only be solved by cooperative multinational efforts.
Decision making on environmental measures, particularly those which require cooperation between sovereign nations, requires timely, appropriate and systematic environmental information. This information must be collected consistently, on a standard or comparable basis, **and must be made available** to all relevant decision makers in a cooperative manner. In recognition of these needs, the Asian Development Bank sponsored a Technical Assistance project which, among its objectives, commissioned the design of a multi-national GIS-based information management system to provide for a means of exchanging and sharing between the six countries the information essential to good decision making on trans-border issues. This paper reports on the design approach, and on the conceptual distributed GIS design that resulted.

1 BACKGROUND

The Mekong River and its system of tributaries drain a vast fertile basin (Approximately 1.3 Million Km^2) of fundamental importance to six nations - Cambodia, Lao PDR, Myanmar, Thailand, Vietnam and the Peoples Republic of China (especially Yunnan Province). These rivers are the arteries of the region, providing a vital source of water for agriculture, industry, drinking and transportation. The population supported by the basin is very high (perhaps 120 Million) and land use patterns are very complex. Agriculture includes paddy rice, tropical and sub-tropical fruit, plantations, cash crops, field crops and livestock. There is coastal and upland forestry, marine and freshwater fisheries. Most of the countries are experiencing rapid development and industrialisation with incumbent social disruptions, as well as benefits. (The above mentioned six countries are referred to by the Asian Development Bank (ADB) as the "Greater Mekong Subregion" or "GMS" and this terminology is used throughput this paper.)
It is now recognised that the problems created by these pressures (deforestation, soil degradation, loss of biodiversity, flooding, air and water pollution) transcend national boundaries and can only be solved by cooperative multinational efforts. One concrete demonstration of this is the recent signing of the Mekong Agreement which calls for signatories to cooperate in ensuring the sustainability of the resources in the Mekong Basin. This treaty and other national administrative changes reflect a growing awareness of the need to manage the environment of the Basin in a sustainable and integrated manner (both geographically and sectorally). Individual counties in the region have established environmental monitoring agencies and have enacted environmental legislation and related legal and administrative measures for compliance, or economic measures to encourage improved land use practices.
Decision making on such measures, particularly those which require cooperation between sovereign nations, requires timely, appropriate and systematic environmental information. This information must be collected consistently, on a standard or comparable basis, **and must be made available** to all relevant decision makers in a cooperative manner. Achieving this requires the use of modern information technology (IT) tools for data gathering, data management, data analysis, presentation, and communication.

In recognition of these needs, the Asian Development Bank (ADB) sponsored a Technical Assistance project which, among its objectives, commissioned the design of a multi-national GIS-based information management system to provide for a means of exchanging and sharing between the six countries the information essential to good decision making on trans-border issues. The Project was executed for the ADB (in conjunction with the United Nations Environment Programme (UNEP)) by a consortium led by the Canadian consulting firm Roche International. The project was known by the title Subregional Environmental Management and Information System (SEMIS).

2 DESIGN APPROACH

2.1 Design Factors

The natural ecosystems of the six riparian countries are intimately linked, and environmental issues do not respect national boundaries. It is therefore accepted that environmental issues must be considered on the basis of entire watersheds or ecosystems, and that actions in one country or administrative subdivision may affect its neighbours. This is true in any region of the world, but especially true in the GMS because of the common link of the Mekong River system. A large number of critical decisions will soon have to be made by the nations of the subregion.

Local and national decision makers need information to choose between development options and to set appropriate priorities; international funders such as the ADB and World Bank, need information for planning and setting subregional priorities. In addition, most of the riparian countries need to respond and report to international conventions and treaties to which they are party, such as the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species (CITES), and the Ramsar Convention (on wetlands).

Many reports, including the Mekong River Basin Diagnostic Study (MRC, 1996) and Sesser (1995), have noted that information in the subregion, although substantial, is fragmented, inconsistent and difficult to integrate. It is crucial, therefore, for all the interested partners (international agencies, the six riparian countries and their separate institutions) to be able to share and exchange data in an **efficient** and **timely** way.

To accomplish this it is necessary to have a consistent subregion wide **information system**, including associated standards and guidelines. Note that an information system is more than a "database". An **information system** is a structured set of processes (and associated people and equipment) for converting data into information, and for presenting it in forms which are useful for communication and decision making.

2.2 A Step-wise Design Approach

The design of a GIS based decision support system was based on the principle of information availability and sharing – that is, sought to provide to decision makers the capacity to assemble, integrate and exchange the environmental and resource information needed for decision making on the crucial issues facing the region. For that reason the design was approached as a series of logical steps as follows:

1. Identification of the key **environmental issues** requiring decisions
2. Identification of the **"core datasets"** required to support decision making on these issues
3. Adaptation or development of the **standards** necessary for the effective use and sharing of environmental data
4. Conceptual **system design** that met the functional needs of decision makers and was appropriate to the regional conditions

Because of the length restrictions applied to papers in this series, only the design phase is reported at any length.

2.3 Functional Design Challenges

As noted by UNEP (UNEP, 1995) it is important that the SEMIS system facilitates the availability and use of information for decision making in the subregion - hence must provide the **functions** which will support and assist in answering five fundamental questions for sustainable development:

1) What is happening? Where is it happening? (What are the environmental conditions and trends?)

2) Why is it happening? How is it happening? (What are the human and natural causes of these changes?)

3) Why are these changes significant? (What are the biophysical and socio-economic implications?)

4) What is our response? (What are the societal responses for protecting the environment?)

5) Is the response adequate?

The current level of capacity and technology in environmental information management and exchange in the six countries varies considerably, but the following summarises the common needs:

- tools to assist in the analysis of environmental data (such as GIS, image analysis, modelling software)
- training in the use and application of these tools for analysis, problem solving and high level decision making.
- tools to assist in information integration and exchange (such as telecommunications, satellite data exchange, databases for large datasets, data communication and exchange software)
- supporting materials for effective data integration (such as data standards, transfer formats, metadata formats)
- training in the methods of data integration (such as data management and exchange policies and procedures)
- methods and facilities to present integrated information to decision makers.

3 ENVIRONMENTAL ISSUES IN THE SUBREGION

No single framework is accepted as the ideal for organising or expressing "issues". For this project, a country-by-country analysis was undertaken through a consultation process with senior decision makers in all of the six countries. Although each country clearly had different needs and priorities, a group of issues stand out as common to most nations in the Subregion. With some generalisation, Figure 1 tabulates the identified issues of concern for each country. The first seven of these, common to at least 4 countries can be considered the key common environmental issues of the GMS, and formed the basis for determining the core datasets and system functionality.

Issue	Cambodia	China (Yunnan)	Laos	Myanmar	Thailand	Vietnam
1. Deforestation	■	■	■	■	■	■
2. Inland Water Quality	■	■		■	■	■
3. Land Degradation/Unsustainable Agriculture		■	■	■	■	■
4. Water Diversion	■		■		■	■
5. Urban Air Quality		■		■	■	■
6. Waste Management		■	■		■	■
7. Loss of Biodiversity	■	■	■	■		
Coastal Zone Degradation	■				■	■
Natural Hazards				■	■	■
Marine Water Quality	■		■			
Wetlands Degradation	■					
Acid Rain		■				
Water Transport			■			
Toxic Waste Transport			■			
Fisheries Management						■

Figure 1: Environmental Issues by Country

4 SELECTION AND DEFINITION OF THE CORE DATASETS

4.1 Approach

The core datasets are those most likely to be required to support decision making for the identified common environmental issues. In determining these datasets consideration was given not only to the data needed to assess the state of the medium or phenomenon involved, but also of the root causes (or driving forces), and the potential impacts (or consequences). Towards this end, each of the common Subregional issues was elaborated in terms of driving forces, impacts, typical questions/decisions requiring core datasets, and the implied data requirements.
This analysis was used to identify the scope and nature of the required data, and select those datasets considered to be "core".

1.2 Selection of the Core Dataset

It is important to note, that the complete set of all data needed to address all aspects of an issue would be huge indeed, and not practical to collect or manage. The Core Datasets should include only those data which are fundamental or basic to providing information on the current state of the issue and related driving forces. In selecting data for inclusion in the core dataset particular emphasis has been placed on data which will support decision making for a **number** of issues. Some data are fundamental to nearly any environmental issue. These include the basic topography, climate, soil, land cover (including forest, grasslands and non-vegetative cover), the constructed infrastructure, and the administrative subdivision. These form the foundation upon which environmental decisions must be based.

The resulting list of the SEMIS Core Datasets is as follows (Details in ADB, 1998a):

Infrastructure	*Soil Class*
Vegetation Cover	*Air Quality Measurements*
Demography	*Climate Zonation*
Administrative Boundaries	*Topography*
Land Use	*Geology*
Major Harvesting Activities	*Water Quality Measurements*

5 STANDARDS ADOPTED

5.1 Principles

Exchanging environmental information requires standards for data exchange formats, but even more essential are means to ensure that the data can be effectively integrated and used. This requires data coding and content standards – particularly for the classification of thematic information layers, such as landuse, vegetation, soil and so on. For this reason, considerable effort was expended to adopt and adapt data standards suitable for the purpose, based on best international practice, adapted for the conditions of the GMS. There is insufficient space in this short paper to elaborate on the standards adopted. These have been described in detail in ADB, 1998b.

6 CONCEPTUAL DATABASE DESIGN

6.1 Design Criteria

The following are the key criteria which have governed the development of the Conceptual Design of SEMIS:
Decentralisation: The SEMIS design must provide for a decentralised network of databases which can link and exchange data within and between countries, as and when required.
Hierarchical: A **hierarchical** system is required, in which detailed data will be kept nationally; integrated subregional data is managed by an agency in the subregion, with a potential for a higher level of integration held internationally.
Spatially Based: All data are to be geo-referenced, so that decision makers can determine **where** a problem is occurring, as well as its extent and intensity. This implies a need for GIS functionality.
Expandable/Flexible: Initially SEMIS addresses the needs to manage and exchange the Core Datasets. The design must also consider the need to easily add datasets in the future, and have flexibility to adjust to evolving needs.
Ease of Use and Maintenance: The SEMIS design must provide for facilities for easy access to and management of data. There must be functions for the maintenance of "metadata" and other forms of auxiliary information.

Appropriate Technology: The design must consider the current level of information technology in the countries of the GMS, and ensure the design can be implemented in a practical way, and locally maintained.
Compatibility with Existing Subregional Databases: The design must have no elements which force the abandonment of existing systems or data, and must take as much advantage as possible of data already collected.

6.2 Overview of the Conceptual Design

At the national level, it is expected that a number of different agencies will hold the component core datasets - for instance departments of Forestry, Agriculture, Fisheries, Environment, etc. The decision makers within the country will obtain needed information through sharing and exchanging, facilitated by a "hub", for instance in the national environmental agency. This "hub" may choose to hold only metadata, or may also be the custodian of one or more core datasets, but their main role is to facilitate the exchange of data using the SEMIS agreed data exchange standards. An important part of the design is that there should be **no duplication of data,** rather data is exchanged when needed using the appropriate standard. Figure 2 illustrates this concept. The national "hub" acts to obtain and exchange data with other riparian countries and international organisations using the standard exchange formats and keeps information about available core datasets in the subregion in the agreed standard metadata format. At the subregional level the "hub" would be an international agency such as UNEP or MRC, and will link to national hubs and to other relevant international agencies which might have useful data - again using the same standard exchange formats.
It should be noted that no exchanges are **required** to go through the hub. Once connections and interchange agreements are established, direct transfers are also possible, if desired.

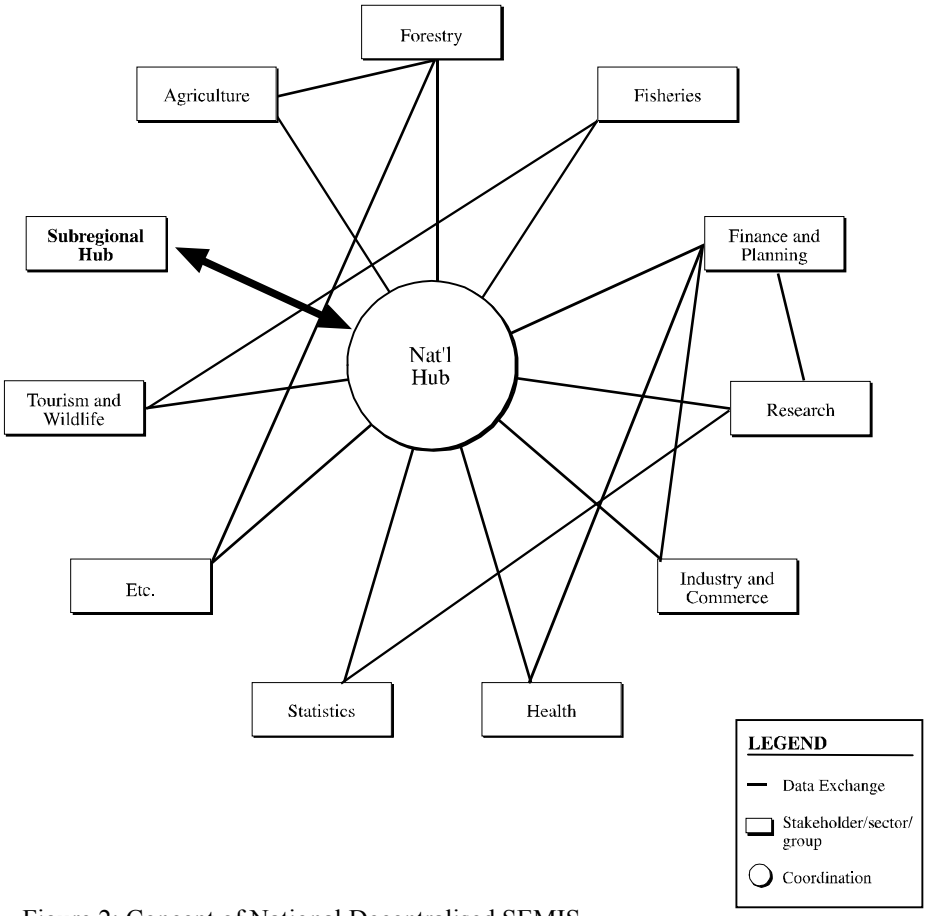

Figure 2: Concept of National Decentralised SEMIS

6.3 Overview Conceptual Data Model

SEMIS data consists of 4 data groups:
1. Core Datasets

the basic data required to support decision making concerning the common subregional issues.

2. Non-core Datasets

additional environmental datasets of potential value, but which may only be relevant to one country, local region, or a sub-set of projects. Such datasets may evolve into core datasets at a later date

3. Output Datasets

these datasets are **derived** from the core and non-core datasets and from additional project specific data through the use of the processing functions (such as GIS) of SEMIS.

4. Auxiliary Datasets

also called "metadata or "codata", this is data that helps to access, use and manage SEMIS. This includes information on current standards, quality of datasets, data catalogues, available expertise

The **core datasets** are the principal focus of this paper, and their relationships are presented in detail in the following Section. Figure 3 indicates the datasets included in each data group.

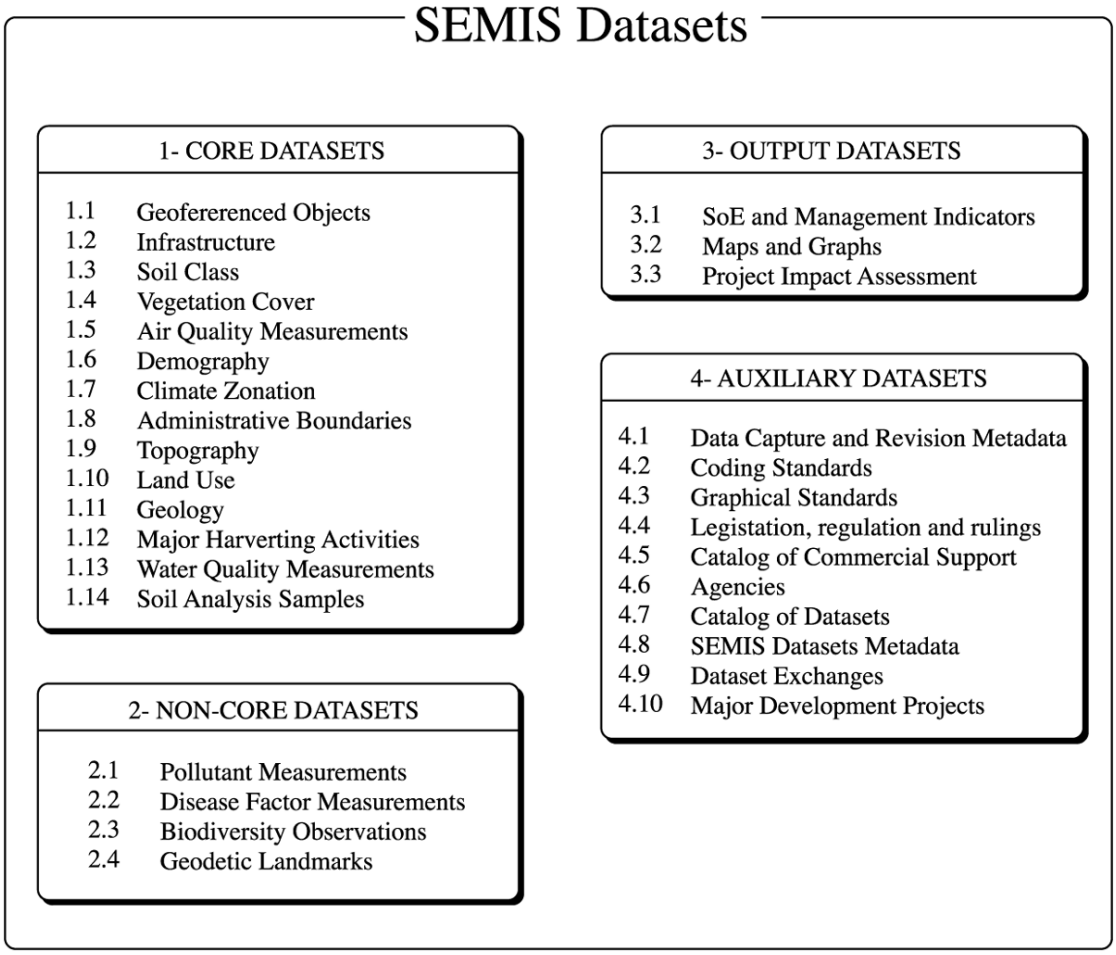

Figure 3: SEMIS Datasets

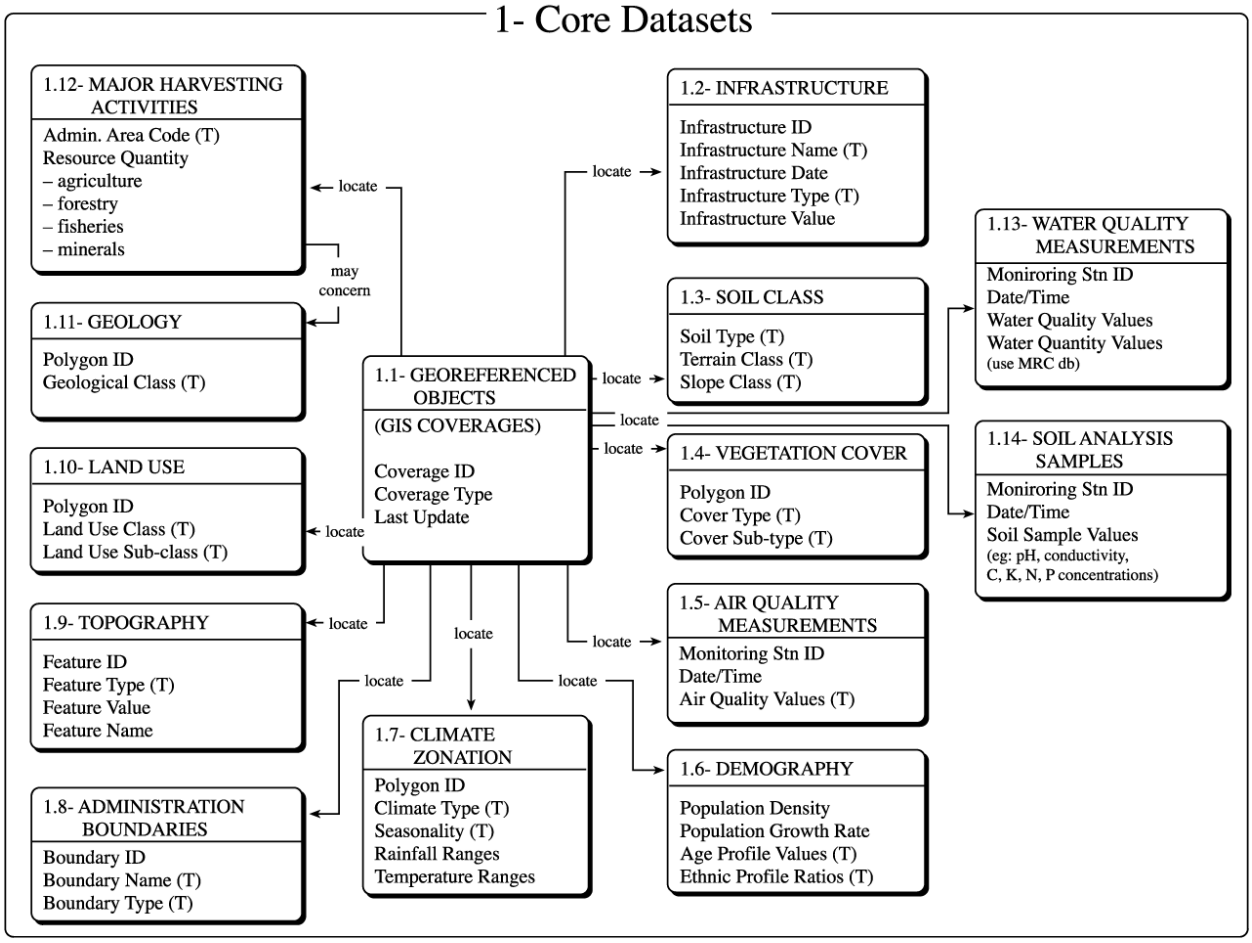

Figure 4: Conceptual Data Model – Core Datasets

6.4 Core Datasets Model

Figure 4 presents the conceptual data model for the 13 Core Datasets. Each box represents one logical entity, and within the box are noted the principal attributes of each entity. For diagrammatic purposes, these have been simplified, but are specified in detail in the Data Standards (ADB, 1998b).
The annotation "(T)" following an attribute indicates that a coding or classification standard was required, and has been defined in the Data Standards. The lines between the boxes indicate the connections or relationships between the logical entities. Some simplification has been made for visibility. For, example, both the Demography (1.6) and Major Harvesting Activities (1.12) would share the connection to the Administrative Boundaries (1.8), and this has not been shown. The necessary linkage of the Water Quality Measurements (1.14) to the Mekong River Commission database has also not been made explicit.

A 14th logical entity, **Georeferenced Objects**, has been added, and this is the core of the spatial database design. The Georeferenced Objects would normally be implemented by linking to a commercial GIS, such as Arc/INFO. The points, lines and polygons which make up the geographic component of these core dataset entities would be held in the Georeferenced Objects, as a set of spatial data layers or "coverages".

7 CONCLUSIONS

- The principal implications of the functional requirements of SEMIS to the physical implementation of the system are:
  - a full function GIS is required, with capability to manage large spatial coverage, and to link to non-spatial relational databases.
  - a relational database management system is required
  - statistical analysis and time-series analysis are required

- Given the **decentralised** concept of SEMIS, it would not be necessary for **each** participating agency to duplicate all the full capabilities. Initially it might be best to concentrate GIS processing in one or a few centres in each country to build a centre of expertise. Compatible database capabilities could be more widespread. Statistical analysis and time-series analysis capabilities are often very specialised to a particular discipline and so there could be specialised centres of expertise in these functions as appropriate - e.g. in trend analysis of water quality.
- The system functional design proposes in-country data exploitation facilities as well as trans-border data sharing facilities in order to meet the needs posed by assessments and decisions related to international projects.
- A distributed loosely coupled network of national and sub-national GIS installations communicating through the Internet can effectively meet the needs of decision makers in the Greater Mekong Subregion. All the needed components will soon be in place in the Subregion-region, through the activities of this Project and through other related projects.
- Such an open-ended design can allow countries with limited IT infrastructure to begin with simple low-technology systems, and still participate in information exchange and integration
- Pragmatic information content standards can be adopted and adapted from current practices of national and international agencies.
- The SEMIS design provides the **capacity** for the exchange and integration of spatially referenced environmental information to support wise decision making in the GMS, but cultural and political barriers may have to be overcome before free flowing exchange of data and cooperative planning becomes a reality.

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