Emergency Preparedness System for the Lower Mekong River Basin: A Conceptual Approach Using Earth Observation and Geomatics

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Abstract

With the aid of the Canadian Space Agency and the Canadian geospatial industry (Ærde, HCL, Strata 360), CARTEL is working in close collaboration with the Mekong River Commission (MRC) and the Cambodian Red Cross to establish a Flood Emergency Response System in Cambodia. Earth Observation (EO) and Geomatics generally insists on spatial distribution and the accessibility of the health centres, food warehouses, flood safe areas as well as the spatial distribution of the disease according to the changing factors of the physical environment and planning and the management of public health in order to improve quality of the decision-making process. The strategy is centered on the analysis of the needs for the managers of the Mekong River Commission and of the Cambodian Red Cross. It also focuses on the questions and data relating to the follow-up in space and time of the flood events and its effects on the local communities. This study takes into account the three dimensions of security: vulnerability, preparedness, response. The methodology includes the following stages: (1) analysis of the needs of the Mekong River Basin managers such as health, transportation, safe areas, infrastructures at risk, food security; (2) design of the diagram of the emergency response system including the identification and the conception of georeference data and spatial analysis functionalities; (3) design and development of a database and metadata; (4) development of vulnerability maps by using multi-date EO imagery (RADARSAT-1, aerial photography, high resolution optical imagery) combined with the historical and topographic data.

1 Introduction

In recent years, it has become a pressing issue for governments to improve human security in emergency response situations. Some of the recent initiatives using space technologies to assist in disaster management are the Disaster Emergency Logistic Telemedicine Advanced Satellites System developed with support of ESA, the International Charter on Space and Major Disasters signed by CNES, CONAE, CSA, ESA, ISRO, NOAA, and the UN, the Mozambique Flood Information System developed with the support of the German Aerospace Center (DLR), the Environmental Monitoring Information Network in Bangladesh under development by RADARSAT International (RSI), the GIS-Based Flood Information System (AWRA, 2003), the National Urban Search and Rescue Response System (FEMA, 2003), the Real-Time Emergency Management via Satellite (REMSAT, MDA, 2001), the UN International Strategy for Disaster Reduction, etc.

When natural disasters occur, such as storms or floods, population's relocalisation and its management constitute a complex problem for health and security. These disasters mainly strike unprivileged populations, who reside in high-risk areas, such as along the banks of rivers or in non- protected coastal zones. As an example, water treatment facilities are often destroyed by floods, which bring drinking water contamination by bacteria, viruses, parasites and toxic substances. Rice fields, fisheries and aquaculture infrastructures are also damaged, causing food insecurity. In 2000 in Cambodia, 3,500,000 people were affected by floods (347 deaths, 7,068 houses destroyed, 347,107 ha of rice fields damaged). But droughts, which can also occur in this area, are an equally important threat to human security and they can disrupt the food security in the area.

2 The Lower Mekong Basin

Located in SE Asia, the Mekong River is 4 800 km long, flowing north-south. It drains a large, multinational watershed of 795 000 km^2 shared by China, Myanmar, Laos, Thailand, Cambodia and Vietnam (figure 1). The Mekong River Commission (MRC) has been established in order to harmonize management, environmental issues and water use between the different countries involved. Subjected to a monsoon climate, with the rainy season occurring from May to November, the Mekong usually enters a flooding stage from July to December. The overall hydrology of the Mekong is relatively complex, especially in the lower part of its basin, located in Cambodia and Vietnam.

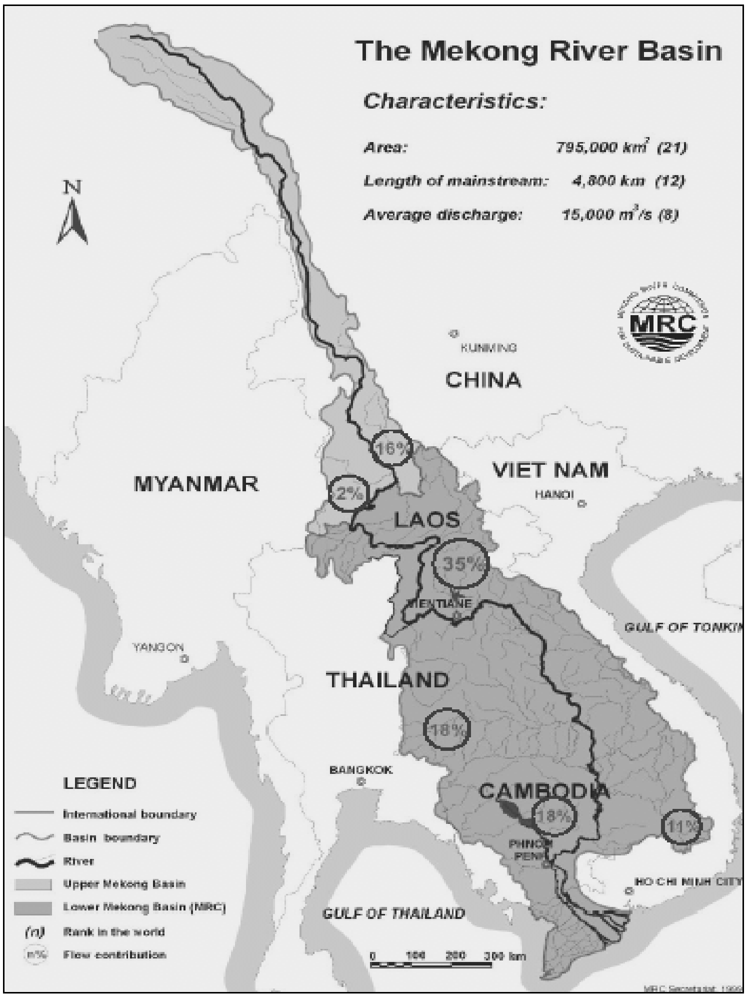

Fig. 1. Overview of the Mekong river basin. Percentages in circles refer to basin proportions in the different countries. (modified from Mekong River Commission)

The Cambodian Floodplain plays an important hydrological role in the regulation and dampening of the floodwave (Fujii et al., 2003). Especially, the great lake of Cambodia (Tonle Sap), which is a dead end tributary of the Mekong, fills and drains according to the floods and the tidal cycles in the delta, located in Vietnam.

The flooding process is part of regular life in the lower Mekong basin. It provides irrigation for crops, water for the fisheries and navigation facilities for the communication network. The water area therefore varies considerably as shown in figure 2. Over time, the population has adapted its way of life to these conditions and even benefits from it, taking advantage of the seasonal cycles of high and low water to develop its original and very productive agriculture and fisheries. However, exceptional floods and droughts seem to occur more frequently in recent years.

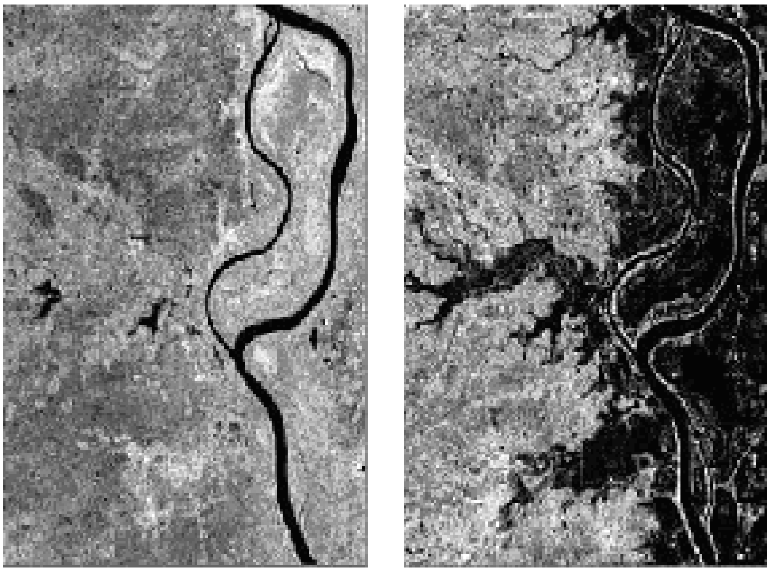

Fig. 2. A section of the Tonle Sap river in Cambodia during dry season (left) and flood season (right) as observed by RADARSAT-1. Water areas appear in black. (© CSA, courtesy of Hatfield Consultants Ltd.)

It is still difficult to explain their origin with a high certitude, but two causes are generally mentioned: the rapid deforestation due to illegal logging and agricultural expansion, which reduces the water flow retarding capacity in the basin, and the climate change which produces an increase of sea level, higher tides and more frequent typhoons.

3 Objectives of the Project

As many developing countries having suffered from natural disasters but also from long periods of war, Cambodia lacks a good infrastructure in updated maps, in geospatial information and in communications. The Cambodian Red Cross (CRC), which is the major national agency for emergency planning and intervention, is taking its rescue and mitigation decisions by relying on the experience of the people in the field and on the existing geographical data in the country. The former have a good knowledge of the local situation and have also an extended experience of living in emergency situations, but they usually lack the more general overview at regional or national levels, which may be required for planning interventions in the case of a large crisis. The existing geographical information is usually scattered, outdated and not organized in a flexible or standardized format. It is therefore difficult for the authorities to plan a structured approach in emergency preparedness and mitigation based on spatially distributed information.

The objectives of the present project are, therefore, to develop a model of an emergency response system based on geomatics, and to install it as a prototype at the MRC, more specifically inside its Flood Management and Mitigation Programme (FMMP).

4 Methodology

4.1 Evaluation of User Needs

The CRC and the FMMP of the MRC need an operational decision support system based on geographic information in order to be able to plan their operations for population rescue, food distribution, safe areas locations and health services.

After having worked in close cooperation with the CRC in order to identify its geospatial information needs, these needs can be summarized by a list of questions requiring answers of the "where?" type, requiring a geographic location answer. These questions and information needs can be divided in five subcategories:

- location of and access to health services
- location of and access to flood safe areas
- needs related to evacuation roads and waterways
- inventory and location of infrastructures at risk
- access to food security

The CRC also provided our team with the adequate information about the existing approaches, its past experience in emergency situations and some examples of local actions taken. We jointly decided to develop a prototype GIS based emergency response system for the district of Kândal, located close to Phnom Penh, for easier validation in the field.

4.2 Analysis of Similar Systems

The second step of the approach was to look at other systems existing elsewhere in the world. These systems vary in complexity, from relatively simple flood risk maps based on digital topography and past flood extensions observed by satellite to more complex systems relying on an integrated multi-risk management system. There are two Canadian examples of these cases: a) the 1997 Red River flood in Manitoba which used RADARSAT-1 data in a near real time mode for mapping flood extent and planning rescue and protection activities in the field (Bonn and Dixon, 2004) b) the REMSAT system, developed by MDA and Telesat with the support of CSA, ESA and the telecom industry (MDA 2001). This system has shown it efficiency during the severe forest fires that occurred in British Columbia, Canada in 2003.

The European Commission has also contributed to the development of similar initiatives under the EU-MEDIN program, where risk assessment, mitigation and geographic information are strongly integrated (Ghazi, 2003). The important choices that we had to make needed to take into account the capability of the end user to make the system work in an environment that had its technological limitations: frequent power failures, limited computing facilities, possible disruption of communications.

4.3 Development of the Conceptual Model

The conceptual model used in the system is based on the principles developed by Bénié (2003) for the health care aspects and presented in figure 3. It is basically a system that uses a series of feed-back loops for the decision making support system. It includes steps for validation and adjustments with the real world situation, and provides constantly updated information to the decision makers.

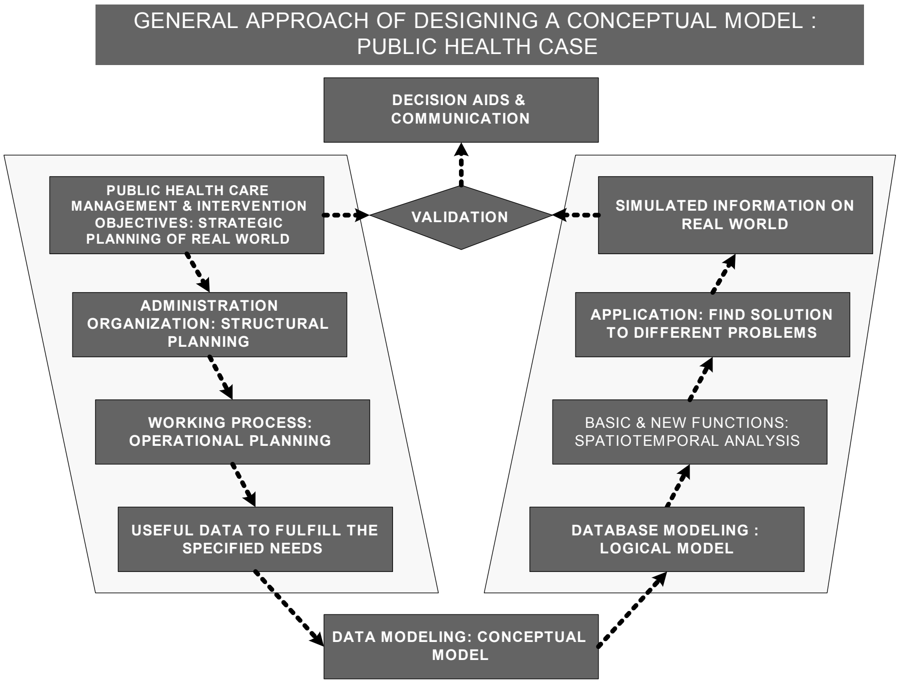

Fig. 3. Conceptual structure of a geographic information system for public health (Bénié & al., 2003)

This step of the conceptual model development is often overlooked in GIS developments, but it is a crucial one to ensure a smooth functioning of the whole system. The system should be able to answer smoothly and efficiently to a series of queries such as:

– Where are the nearest Health Centres from the Flood zones?
– Where is the nearest Health Centre from the village X?
– What is the Health Center capacity? The occupation rate?
– What is the shortest way from village X to Health Center X?
– What are the villages at less than X km from a Health Centre?
– What are the villages located in a possible cholera zone? Malaria zone?
– Does the hospital X possess an emergency kit?
– Where are the safe sites in case of floods?
– Where are the evacuation roads for village X?
– Etc.

4.4 Implementation of a Prototype

After this conceptual work, we have chosen to develop and implement a prototype of the system for two vulnerable communes located close to Phnom Penh Peam Oknha Ong & Kaoh Reah, district of Lveam Aem, Kandal Province, Cambodia) (figure 4). This will be the pilot area for the prototype to be implemented and tested by the CRC. This area is located in the vicinity of the junction between the Mekong and the Tonle Sap rivers. The CRC has already some inventories of food warehouses, rescue facilities and safe areas for this region, but they are not yet mapped and documented. Constitution of the prototype will incorporate this information as attributes in the GIS. Figure 5 shows an example of simulated information on food warehouses in Cambdodia.

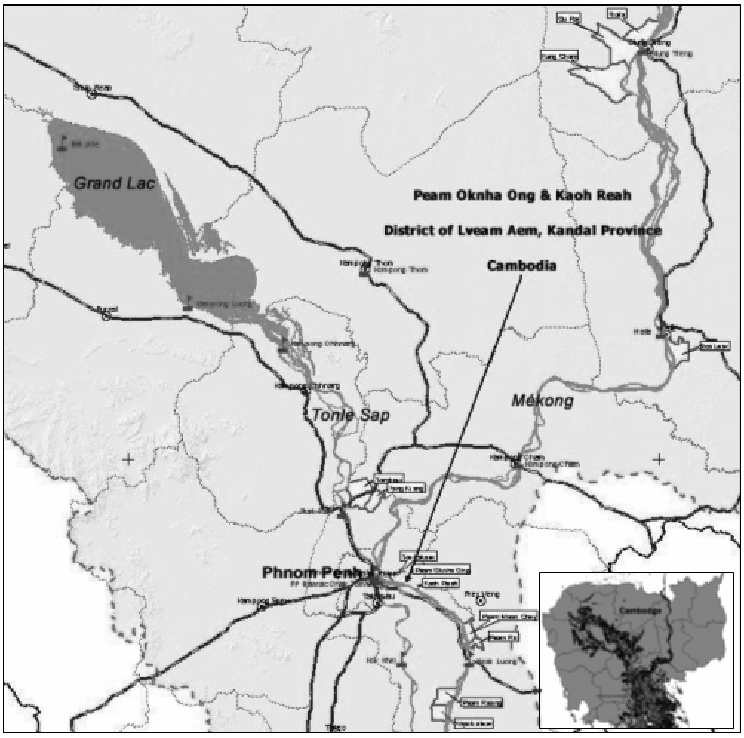

Fig. 4. Location of two vulnerable communes (pilot area), Kandal Province, SE of Phnom Penh (modified from Mekong River Commission and Cambodia Red Cross)

warehouses_cambodia.dbf

Wh_no	Province	District	Sub_dist	Village	Org	Build_alt	1floor_alt	2floor_alt	Coating	Food_type	Food_kg	Water_l	Km_nat_rd
23	Phnom Penh	1201	120108	Phum 8	WFP	4	3	0	Bricks	Rice	12000	3000	0,5
24	Kampong Cham	808	80807	Krang Mkak	WFP	10	3,2	6,2	Wood	Rice	50000	0	3
25	Kandal	810	81013	Khpob Kraom	CRC	6	4,2	0	Bricks	Rice	10000	2500	20
26	Kandal	811	81104	Ta Khmau	OXFAM	4	3	0	Wood	Wheat	20000	5000	4,3
27	Kandal	802	80201	Kandal Leu	WFP	5	3,7	0	Wood	Rice	5000	1200	3
28	Prey Veng	1403	140307	Kampong Trabaek	AAH	6	3,8	0	Bricks	Dry Fruits	2000	0	10
29	Kampong Cham	307	30109	Cheung Chhrok	WFP	3	4	0	Bricks	Dry Fish	3000	1300	2.3

Fig. 5. Simulated Geospatial Information table on food warehouses in the study area (Aubé, 2004)

This information is then completed with the geographic location and incorporated as attributes in the GIS, with links to the appropriate queries.

5 Preliminary Results

These results are at their very early stages and have not yet been validated in the field or by the end users, these steps being planned for the second half of 2005 and through 2006.

5.1 Conceptual Model Structure

The conceptual model is structured in classes (level 1), subclasses (levels 2 to 5) and entities (level 6). Figure 6 gives an approximation of this structure.

5.2 Attribute Tables

The attribute tables such as the one presented in figure 5 are linked to the entities and can be mapped or retrieved through queries resulting from spatial analysis. The type of questions to be asked to the system are quasi endless. Typically they can be spelled as: what is the shortest (or the safest) route from any place to the nearest safe zone, hospital or food warehouse.

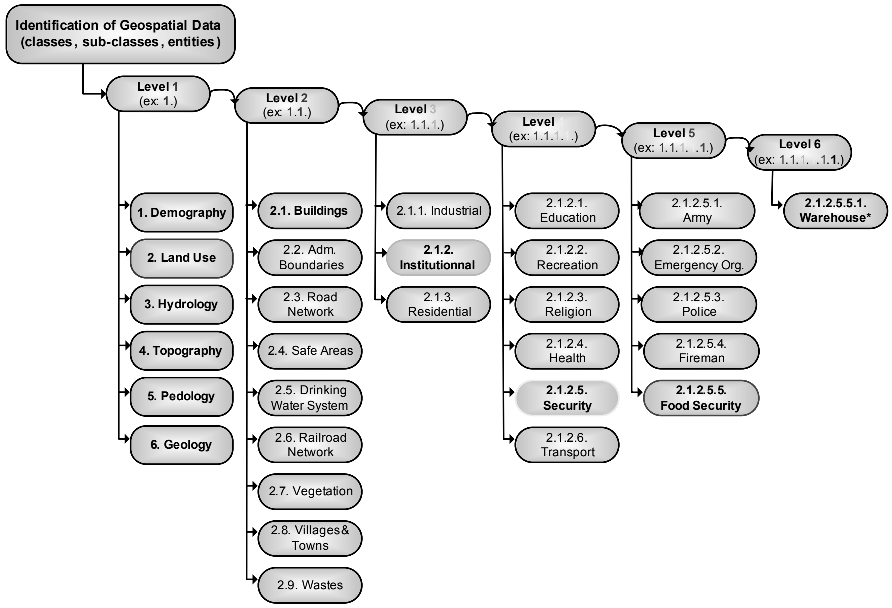

Fig. 6. Hierarchical structure of the conceptual data model (Aubé, 2004)

5.3 User Interface

The user interface is designed to be as friendly as possible, and in some aspects it looks like a web interface.

6 Conclusions

The development of the MERS (Mekong Emergency Response System) for the MRC and the CRC is intended at this stage to be a demonstration project to be experimented by the end users on a very local basis. If successful, it will be enlarged and integrated in the Flood Management and Mitigation Program of the MRC, with the CRC acting as the major end user. In its present stage, it is more a preparedness system than a response system, therefore the title of this paper. It has, however, the potential to evolve into a response system when it will be integrated in the FMMP. This may however require additional functionalities such as links with the flood forecasting systems and weather data, but its structure could allows this future flexibility.

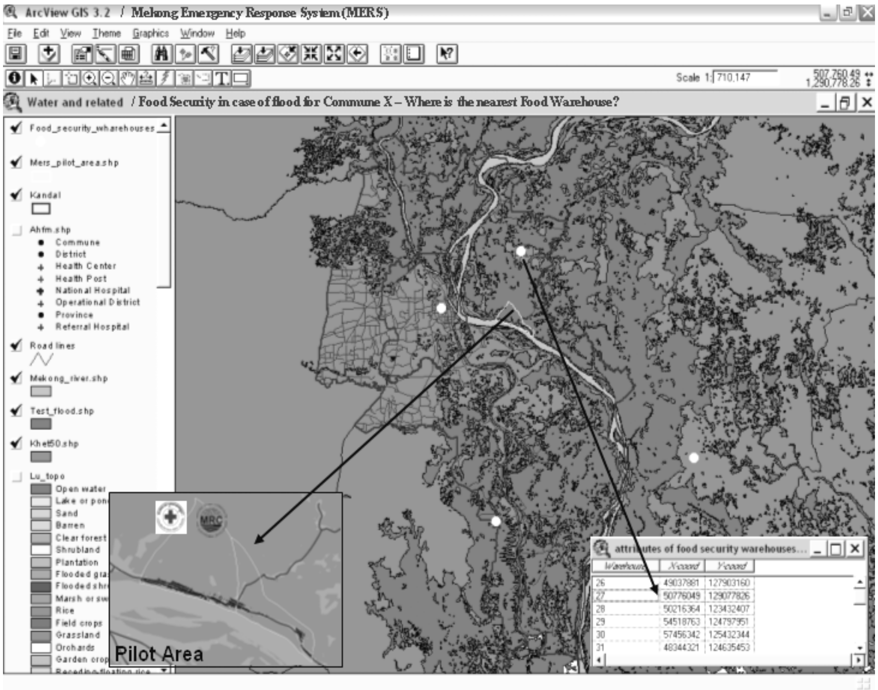

Fig. 7. Example of the MERS prototype user interface and possible outputs (Aubé, 2004)

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