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Preliminary Design and Feasibility of a Geographic Information System Component to the Highland Agricultural Development Project in Guatemala

DESFIL

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PRELIMINARY DESIGN and FEASIBILITY of a GEOGRAPHIC INFORMATION SYSTEM COMPONENT TO THE HIGHLAND AGRICULTURAL DEVELOPMENT PROJECT (HAD, Project No. 520-0274)

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ABBREVIATIONS

BANDESA	Banco Nacional de Desarrollo Agricola
BANGUAT	Banco de Guatemala
CATIE	Centro Agronomico Tropical de Investigacion y Ensenansa
CIPREDA	Centro Internacional de Preinversion para el Desarrollo Agricola
DESFIL	Development Strategies for Fragile Lands; an USAID/LAC & S&T/RD program
DIRYA	Direccion de Riego y Avenamiento
DGC	Direccion General de Caminos
DCMH	Direccion General de Minas e Hidrocarburos
DIGEBOS	Direccion General de Bosques y Vida Silvestre
DIGESA	Direccion General de Servicios Agricolas
DIGESEPE	Direccion General de Servicios Pecuarios
EARTHSAT	Earth Satellite Corporation
EOSAT	Earth Observation Satellite Company
GIS	Geographical Information System
GOG	Government of Guatemala
HAD	Highland Agricultural Development Project
ICTA	Instituto de Ciencia y Tecnologia Agricola
IGM	Instituto Geografico Militar
INAFOR	Instituto Nacional Forestal (presently DIGEBOS)
INDE	Instituto Nacional de Electrificacion
INDECA	Instituto Nacional de Comercializacion Agricola
INE	Instituto Nacional de Estadistica
INSIVUMEH	Instituto de Sismologia, Vulcanologia, Meteorologia e Hidrologia
INTA	Instituto Nacional de Transformacion Agricola
MAGA	Ministerio de Agricultura, Ganaderia y Alimentacion
MOSCAMED	Programa de la Mosca del Mediterraneo
MSS	Landsat's Multispectral Scanner
NGO	Non-Governmental Organization
OAS	Organization of American States
OCREN	Oficina de Control de Recursos de la Nacion
TM	Landsat's Thematic Mapper
UNEP	United Nations Environmental Programme
USAID	United States Agency for International Development
USPADA	Unidad Sectorial de Planificacion Agropecuaria y Alimentacion

1.0 SUMMARY

In September, 1988, Earth Satellite Corporation (EarthSat), a DESFIL subcontractor, provided assistance to USAID/Guatemala for a preliminary design of a Geographical Information System component to the Highland Agricultural Development Project (HAD, Project 520-0274). This report presents the findings, conclusions, and recommendations of that preliminary design. The study team conducted numerous interviews and reviews in Guatemala in order to identify and evaluate existing data supply and data gaps, information needs, institutions, and technologies. Time constraints made it impossible to view first hand all, or even a majority, of the data relevant to a GIS database, much of which is dispersed through numerous institutions and their regional facilities. To meet this constrain, the study team drew upon interviews with senior personnel in the various institutions, the published record of both information supply and information needs to meet program demands, and their collective personal experience.

1.1 INFORMATION DEMAND

- Guatemala shares with all Latin American countries a deteriorating natural resources base through the impact of deforestation and expanding agriculture, and their consequential soil erosion, particularly in the steeply sloped and economically impoverished Highland regions. Implementation of programs whose policies provide viable alternatives to the majority of inhabitants whose efforts to achieve subsistence are impacting the resources that provide such subsistence are urgently needed and the focus of USAID's agricultural assistance program in Guatemala.

- Sound policies require accurate and timely information. With multiple, often conflicting economic development needs and demands on use of the resource base, information must address the consequences of alternative strategies. Further, policies intended to promote the sustainable production of food through environmentally sound practices require information on natural resources--soils, water, vegetation and climate; and on the resource base's occupancy--its population, culture, infrastructure and growth.

- There is an equally important demand for information at the field level and within regional offices, but most geographical data is centralized and thus rarely utilized at regional or sub-levels.

- There is a growing desire among many of the institutions in the HAD Project to assemble and utilize spatial resource

databases. The idea of implementing a GIS has clearly created expectations among all of the MAGA institutions.

1.2 INFORMATION SUPPLY

- Considerable data and maps exist and are relevant, in some cases crucial, to a GIS database implementation.

- Geographical coverage varies by data type and institution, and much of the existing data is grossly incomplete in national coverage; for areas of primary interest to the HAD Project, data and maps are generally non-existent.

- Existing cartographic data are significantly out of date, and with few exceptions, there are no on-going efforts to update.

- Statistical data is commonly in a form that will require major effort to merely identify its location and form, and the potential lack of geographic attributes to statistical or sample data could limit its utility for GIS application.

- For data to be useful, it must be accessible and this is clearly not present for much of the existing data.

- Institutions do not have a tradition of sharing available data, even within a single Ministry, either horizontally or vertically within the organization. A decentralized organization without strong central coordination and management results in incomplete and incompatible data.

- Some essential cartographic data has rigidly controlled access for reasons of domestic security.

1.3 MANAGING INFORMATION--INSTITUTIONAL FINDINGS

- The amount of extant data available in MAGA's offices and institutions is immense, yet also unmanageable using present methodologies. The present situation generates tendencies which lower the quality of extant data: relevant data is rarely efficiently used, or standardized, so as to be transformed into useful information which can support necessary planning or timely decision-making, reflecting also common weaknesses in basic analytical capacities.

- Resource information be presented on maps have demonstrated great value in development project planning and implementation; indeed, seldom does a successful development project go forward without such maps. Among some of the interviewed MAGA institutions, however, there is no

tradition of using cartographic or spatial statistical data or analyses in any of their activities. This questions their present capacity to utilize GIS concepts, either manually or automated, in their programs without extensive training and technical assistance at all technical and user levels.

- Even at the highest levels of the GOG, there are presently efforts to develop databases and analytical capabilities to provide policy oriented information at the macro level. These efforts, principally by scattered individual initiatives, conceptually incorporate the concepts of a GIS, and at high costs in terms of time expended. Similar conceptual capabilities and interests exist primarily among those institutions who have a mapping or planning mandate and tradition.

- The continued training of technicians, professionals, and managers in the operational use and analytical capabilities of GIS's is essential to their adoption and effective use. The emphasis on GIS programs must be on the current coordination and information needs of operational programs, and particularly oriented to the HAD Project.

1.4 TECHNOLOGY SUPPLY

- Geographical Information System technology is an information handling science which uses computers to record and analyze data on a variety of themes with a common geographic reference, and the ability to effectively overlay, model, and manipulate these data to meet given analytical objectives.

- A GIS may be considered as a tool to convert basic data into useful information for management purposes. Conversion is effected through execution of specific, generic data processing functions. Maps, frequently the product of recasting basic data into an intelligible form, thus become information products rather than data sources.

- Development of user-friendly, higher storage capacity, low cost hardware and software systems, and the growth of GIS as a discipline, have expanded the capabilities and applications of this technology to planning, monitoring, evaluation and analysis to support decision making.

- GIS technology is widely available, and can dramatically increase the utility of existing data and broaden their use.

1.5 CONCLUSIONS

- After meeting with representatives of various GOG agencies, the study team concludes that within MAGA there are three institutions who may be considered for a GIS Facility, each with varying budgetary implications. These three institutions are DIGESA, DIGEBOS, and USPADA. Suggested criteria for institutional selection are presented.

- Implementation of a GIS component within the HAD Project will be a long-term venture and investment, and will require continuous monitoring rather than merely a one-time evaluation. Estimated budget requirements, including hardware, software, facilities, personnel, training and maintenance (but not including database preparation activities by participating institutions), may approach $1 million for HAD's LOP (approximately 4.5 percent of the projected USAID investment in the HAD Project). Of the estimated first year costs of approximately $375,000. hardware, software and maintenance account for 28 percent, and training and technical assistance for 33 percent.

- Implementation of a Geographical Information System component within the HAD Project is both needed and appropriate. The current state of PC-based GIS technologies enables the development community, through local institutions, to economically and efficiently utilize the array of available and required resource and socio-economic data in the context of planning and management decisions.

- A properly managed and implemented GIS, based on current technologies, will clearly contribute to strengthening the analytical, planning, monitoring and decision making processes of the Ministry of Agriculture. The study team believes that this sector is ready for a GIS implementation, although this does not imply an easy task; there are many identified difficulties which must be overcome before success is achieved.

- The HAD Project participants within the Ministry of Agriculture have the capacity and desire to incorporate these technologies in their operational programs. A GIS component to the HAD Project can contribute to the development process in project selection, planning, implementation, and evaluation.

- The direct benefits to be realized through a GIS implementation will begin with a needed revision of the existing database of Guatemala's natural and socio/economic resources. The updating of existing data, the fulfillment of major gaps in the present data, and the development of standardized and systematic methodologies for data

gathering, compilation, and analysis will contribute to provision of more timely and more accurate information to development planners and agricultural policy makers.

- A significant effort and cost of a GIS is in developing a useful and compatible databases which will permit, in the medium term, constructive integration and coordination of HAD Project activities.

- Adoption may involve more political and institutional issues, than technological problems, because GIS requires the accumulation of large amounts of data covering the activities of many institutions in a single place. That repository must therefore have the strongest of political and management support.

- Within the HAD Project, this need is well recognized by GOG participants. Duplication of efforts and problems with data access and compatibility motivate the broad interest in this technology. Experience has shown that while the needs and potential benefits are clear, the institutional mechanisms which will assure the successful adoption of this technology are far less so.

- GIS technology is being increasingly utilized as a means of dramatically increasing the utility of mapped or spatial data. The benefits of GIS technology are particularly great in development programs, such as the HAD Project, because of the need to manage large volumes of data required in the development process.

- USAID's implementation of a GIS as an important tool in the development of agricultural, natural resources, and environmental databases is appropriate, and can provide cost savings and increase program effectiveness.

- Even though much cartographic data requisite to the HAD Project as well as a GIS database exist, they are not easily accessible for government agencies' planning purposes. The validity for restriction requirements must be respected and internal control procedures must be implemented in order to facilitate their access and appropriate use.

1.6 RECOMMENDATIONS

- The hope and expectations of many with whom the study team met that GIS technology can and will make significant contributions to the HAD Project seems well founded. The technological potential exists, and institutional impediments to the adoption and assimilation of the technology are noted. The inference, however, that the

tools exist and that they need only be acquired and set to the task of developing the information required errs in several respects: technological solutions to specific information requirements cannot be generic. A GIS is appropriate, but it will be suitable only with developing the requisite databases and focusing on the specific administrative, political, and management needs of the HAD project and the implementing institution.

- A concerted, quality-oriented effort to conform a reliable and standardized database must begin immediately. This is required for the HAD Project regardless of whether or not the analytical tasks are addressed through a GIS.

- Beginning with a relatively small project, including facility, staff, database, and application objectives, will facilitate the implementation process by providing on-the-job training and experience, testing, and demonstration of high visibility applications that provide output examples early in the implementation phase.

- Regardless of the computer configuration or location of the GIS Facility, careful attention must be paid to three areas of importance to successful system use and to management's appreciation (and continued support) of the system: the facility must be properly set up and maintained; a continual budget for maintenance and for hardware and software upgrades must be planned for; and system users must be skilled and adequately trained, in both system operations and specific applications, to get the desired results from their system.

- The GIS Facility must provide full access to participating users, coordination among participating users, and clear guidelines, objectives, and standards for use, especially for development of the databases.

- Training must be local, must deal with local data, and must survive the initial period of enthusiasm over the new system. Training must include applications training on specific HAD Project needs, hardware system support training, and orientation for managers, decision makers, and project implementors so they may know the potential of the tools available to them through their staff and colleagues. Local capabilities exist for some of this training and should be utilize as appropriate.

- The GIS Facility staff should not concern itself with generation of primary cartographic data, but rather establish priorities and standards for its quality, content and format, and execute its entry into the database. Cartographic compilation and related resource analysis and

mapping tasks should be assigned to qualified professionals and technicians in existing institutions, particularly DIGEBOS and IGM's Geographical Studies Division.

- Where requisite base maps and thematic maps are out of date or otherwise inadequate, image base maps for project areas should be produced from high quality satellite imagery which may be subsequently interpreted and analyzed by local professionals.

2.0 INTRODUCTION

2.1 OBJECTIVE

The objective of this study is to assist USAID/Guatemala in the preliminary analysis of feasibility and design of a Geographic Information System (GIS) component to the Highlands Agricultural Development Project (HAD, Project 520-0274). The study has been prepared by Earth Satellite Corporation, a DESFIL sub-contractor.

The primary goal of a Geographic Information System is to take spatial data, including maps, areal statistics, etc. and transform it, via overlays and other analytical operations, into new information which can support planning, policy and decision making processes. Geographical Information Systems have their roots in the history of thematic cartography. Modern GIS's have evolved from the combination of increased computational capabilities, refined analytical techniques, and an interest in improved resource management and environmental responsibility.

The primary goal of the GIS component to the HAD Project is to implement a multi-purpose, integrated system that will serve the planning and analytical needs of a variety of users involved in the HAD Project in particular, and agricultural development and natural resource management, and monitoring, in general. In addition, the objectives include: reducing duplication of effort by maximizing coordination among various users from participating institutions in the HAD program and thereby maximizing economies; centralize common data in order to eliminate discrepancies and unnecessary effort involved in maintaining multiple copies of the same or similar information; increasing efficiency in daily operations; increasing management coordination and control; and providing information for decision support and policy formulation at program, institution and ministry levels.

A GIS may be considered as a tool to convert basic data into useful information for management purposes. The conversion is effected through execution of specific, generic data processing functions on the data. Maps, frequently products of basic data, are an interpretative medium for recasting basic data into an intelligible form. Maps produced in a GIS thus become information products rather than data sources.

To define the role of the GIS and its spatial data and information requirements, it was important for the study team to address some basic, fundamental questions with both the USAID program managers and the HAD Project implementors: Who is the

real user? How can the GIS technology support that user, and what is the institutional body of data that the technology must deal with? When is it prudent for the Project to adopt the technology, and when can users reasonably expect to have access to the technology--the system and its information products? How does GIS fit in with the broader objectives of both the HAD Project and the Ministry of Agriculture's information management objectives? How can spatial resource data and information be integrated through a GIS with other managed information?

Not all of these questions can presently be answered. Rather, they are presented, along with other observations and findings, to stimulate thought and provoke ideas and issues. For the process to evolve into meaningful assessments of needs, a clear distinction must be made between information, which is needed by a manager to make decisions, and basic data, which is gathered by whatever surveying or measuring process to feed the decision-making process.

A continuing activity throughout implementation and operations of a GIS in the HAD Project will concern how the definition of needs proceeds from an understanding of the routine resource management decisions that must be made. The information needs, therefore, will be the specific facts and conditions relevant to support the decisions to be made.

2.2 BACKGROUND

Background provided in the present scope of work, the HAD Project Paper, and related documents and discussions with USAID/ Guatemala, indicates that the HAD project wishes to establish a Geographic Information System designed to support the identification of high-priority watersheds for sustainable development activities, including soil, water and forestry management. While the GIS should be nationwide in scope and capability, demographic characteristics of Guatemala suggest that most of its anticipated uses, at least initially, will focus on steeply sloped, intensively used upland areas, and on humid tropical lowlands where colonization and land settlement are rapidly altering fragile tropical ecosystems.

It is desired that the GIS, in a program context, be useful to coordinate information and data presently collected and used by a number of Guatemalan agencies and institutions, both within the Ministry of Agriculture (MAGA), implementor of the HAD Project, and other agencies and ministries. The Direccion General de Caminos (DGC), for example, currently uses a computerized mapping system to target high-priority areas for construction of rural access roads, and has a large volume of GIS-related data not now readily accessible by other interested institutional users in Guatemala.

Similarly, the Instituto Geografico Militar (IGM) has considerable quantities of topographic and thematic cartographic information, in map product form, which if made available and accessible in a GIS, would significantly facilitate and expand their use and application to resource development and environmental management throughout Guatemala.

A number of Guatemalan institutions have expressed interest in GIS capabilities and analytical applications, and are now collecting data which conceptually are appropriate for a GIS database. These include, for example, DIGESA, DIGEBOS, INSIVUMEH, IGM, USPADA, and others, but these data are not centered in one institution or "centro informatica"; are not necessarily consistent in their collection, tabulation, analysis or definition; and are not generally available to either the public or other institutions.

In various GIS discussions preparatory to this study report, any application identified is dependent upon the existence, availability, and quality of requisite data resident in the GIS database, the creation of which will be a task much more formidable than implementation of the system itself.

Finally, the present study assumes that the GIS program should be designed and implemented to be:

--- National in coverage; a national database, however, will be developed over extended time as data are collected and analyzed for specific, priority project areas and the institutional capacities, including human resources, are developed.

--- Centered in a single Institution that is generally accessible to the public; geographic information must be managed by public agencies that have a long term stake in the process, not some ad hoc central group. One test of such an agency is the mandate that provides definitions, quality standards, and other characteristics for resource development planning, monitoring, evaluation and policy implementation.

--- Organized to acknowledge the independent mandates of the contributing agencies.

--- Staffed by a permanent group of trained Guatemalan managers, professionals and technicians.

--- Available in a usable and understandable form to all potential users; equity should be the primary principle that will ensure a fairer treatment of all those effected by the use of the data and information.

3.0 THE ROLE OF A GIS TO THE HAD PROJECT

Access to accurate and timely information is a cornerstone in any decision making process. In today's society with multiple, often conflicting economic development needs and demands on the use of a resource, it is mandatory that decision makers interface their information with a variety of planning models and analyses that can realistically simulate the consequences of the array of strategies available to them. Within the context of agricultural development, the principal need is for information which will support the production of food and fiber. This demand includes information on natural resources, soils, water, vegetation, climate; and on culture, infrastructure, population and growth.

In addition there is an increasing recognition that critical biological resources are threatened by uncontrolled or poorly conceived development, and that the long-term consequences of this process may irreversibly impact both local and global environments. Understanding and managing these resources requires regular information on their extent and condition. Effective development planning requires basic maps of the physical environment, including planimetric base maps, current and potential land use, demography, current and planned infrastructure, etc.

Geographical Information System (GIS) technology is a rapidly developing information handling science which uses computers to record and analyze data on a variety of themes with a common geographic reference, and the ability to effectively overlay, model, and manipulate these data to meet given analytical objectives. The value of the system is as a planning and decision-making tool which enables the scientist, planner, or decision-maker to consider, with the aid of the computer, combinations of data sets in project planning, implementation, and monitoring. For example, a GIS analysis may exclude from consideration for cultivation areas containing certain soils, on specified slopes.

The number of themes (i.e. geographic descriptions) included in the database may be increased without limit, though generally the number is between 5 and 15; each may have lengthy attributes. Additional categories may include: soils, topography, surface hydrology, land use, vegetation cover, population, transportation networks, geology, political boundaries, critical habitats, rainfall, etc. Many of these data exist in Guatemala in map or statistical form though their completeness of coverage and quality varies greatly.

However, to be used in a GIS, data must first be converted into a computer-compatible form. Usually, the process is an

electro-mechanical one called "digitizing." The conversion of analog data, maps, and statistics, to digital form is labor intensive, requiring a skilled technician several hours to several days per map. In a regional study area such as with the HAD Project, hundreds of maps may be involved.

GIS as an operational technology has only recently arrived; although initial developments began in the 1960's and several commercial systems were introduced in the 1970's, major hardware and software advances, and acceptance by a broad user base worldwide, has been most greatly realized in the past five years. Both the United Nations Environmental Programme (UNEP) and the World Bank, for example, have initiated significant programs in operationally applying GIS technology in the developing world.

3.1 Resource Information Management Needs

Most existing resource information is presented on maps. Mapped information is of great value in project planning and implementation, and seldom does a development project go forward without a map. These maps may vary from detailed surveys to simple sketch maps, and they may contain a wide variety of data. If this mapped information were generally available (and often it is not available beyond the offices of the originator), and compatible with other mapped or statistical data, many projects and many users could benefit from its existence. Compatibility assures that the resource scientist/engineer or development planner/manager may use different data sets simultaneously without making mechanical or mental adjustments for differences in scale or area of coverage.

GIS technology is being increasingly utilized as a means of dramatically increasing the utility of mapped or spatial data. The benefits of GIS technology are particularly great in development programs, such as the HAD Project, because of the need to manage the large volumes of data required in the development process. Within the HAD Project, this need is well recognized by GOG participants and donor managers alike. Duplication of efforts and problems with data access and compatibility motivate the broad interest in this technology. Experience has shown that while the needs and potential benefits are clear, the institutional mechanisms which will assure the successful adoption of this technology are far less so.

3.2 Supply of Geographical Information Systems Technology

Recent developments of user-friendly, higher storage capacity, low cost integrated image processing and GIS hardware and software systems, and the growth of GIS as a discipline, has expanded the potentials and applications of these technologies.

Because of the tremendous changes created by the development of powerful personal computers (PC's), there are a number of commercially available GIS packages for desk top workstations. These PC workstations can operate as "stand alone" systems that allow the individual to literally take a 24" x 36" digitizing tablet off the wall and quickly develop and manage the data sets for an intermediate-sized watershed. At the same time this PC workstation can be networked with remote computing capabilities to become a component in a regional system. While dozens of systems, both PC- and mini-computer based, are available, there are few, however, that have been proven in operational environments and which have demonstrated withstanding the rigors of installations far removed from customer services and software support.

The current capabilities of several PC-based GIS systems are impressive, particularly when viewed from the perspective that many of the capabilities were not even available on mainframe computers just a few years ago. The current state of GIS (as well as digital-format remote sensing) technologies enables the development community, both donors and implementors, to economically and efficiently utilize the array of available and required resource and socio-economic data in the context of planning and management decisions.

Indeed the hope and expectations of many with whom the study team met that the GIS technology can and will make significant contributions to the HAD Project seems well founded. The technological potential exists; that is clear. Institutional impediments to the adoption and assimilation of the technology is noted in subsequent discussions. The inference, however, that the tools exist and that they need only be acquired and set to the task of developing the information required errs in several respects: technological solutions to specific resource information requirements cannot be generic. A GIS is appropriate, but it will be suitable only with fine tuning to the specific administrative, political, and management needs of the HAD Project and the implementing institution.

3.3 HAD Project Applications

Based on interviews conducted with potential GIS users participating in the HAD Project, and review of the Project Paper and related documents, the study team believes that there are both numerous needs and applications of a GIS component within the HAD Project, and that the potential exists for even greater user applications than presently anticipated. It is recommended that an affirmative GIS implementation decision be taken, and include a careful and paced start in order to affect the greatest possibility of successful training and technology transfer for GIS operation, maintenance and use, and to develop an appropriate

and well structured database. As previously noted, it is most important that the database be fully compatible, flexible, and designed to allow both present and future managements to fully support the purposes for which the GIS is developed and its operations (i.e. planning, monitoring, decision-making support, prioritization, evaluation, etc.).

One of the greatest advantages of the GIS approach is the ability to identify and prioritize areas within a selected region based on uniform criteria. Further analyses, including modelling and simulation can evaluate results of defined assumptions, such as improvement of access roads, increased credits, changing cultivation practices, etc.

Some applications are listed to illustrate representative GIS capabilities and applications within the context of the HAD Project. The listing was prepared from interviews conducted with agencies participating in the HAD Project. Each example could be modified based on availability of existing data, national policies, regional policies, and the specific focus or programs of each participating agency. And, although some examples may be extremely complex analytically, their actual development will depend upon the available database.

- Select areas for developing small scale irrigation systems.
- Select priority areas for soil conservation and agroforestry practices.
- Define zones of frost risk to agricultural production in order to implement crop frost protection programs.
- Prioritize credit needs as well as delinquency.
- Identify limiting factors for agricultural production.
- Prioritize activities based on socioeconomic factors.
- Prioritize watersheds in order to define strategies for extension, taking into account various factors, e.g. irrigation or sanitary water supplies.

4.0 AVAILABLE DATA CHARACTERISTICS AND DATABASE REQUIREMENTS

4.1 REVIEW OF EXISTING DATA

A stated goal of the GIS component to the HAD Project is to coordinate and access information and data presently collected and used by various Guatemalan agencies and which is applicable to the GIS database requirements. A specific task of the present study proscribed a "review and inventory of data, information, databases, maps, computer programs, charts, imagery, and other data in those institutions now collecting and compiling GIS data," and a "review current means and methods for collecting data, the ways they are compiled, formatted, and prepared for use, and how often they are updated."

Identifying decisions to be addressed and questions to be answered is one of the most critical elements in a GIS planning and design process, and ultimately, along with the quality and extent of data, to the success of the project. Hence, as the study team gathered information on available data types and coverage, etc., it concurrently focused on anticipated applications of the GIS and hence requisite data requirements. Both processes were conducted through a series of interviews with various GOG agencies and institutions as well as document reviews.

The findings, in summary, are mixed as well as complex, both technically and institutionally. Considerable data and maps exist and are relevant, in some cases crucial, to the GIS database implementation. However:

--- Geographic coverage varies by data type and institution, and much of the existing data is grossly incomplete in national coverage; for areas of primary interest, the Western Highlands, data and maps are generally non-existent.

--- Existing cartographic data are significantly out of date, and with few exceptions, there are no on-going efforts to update. While ten to twenty year old geologic or topographic maps have not changed, land use and infrastructure, for example, must be relatively current to be useful in a GIS as an effective planning tool.

For data to be useful, it must be accessible and this is clearly not present for much of the existing data:

--- Statistical data is commonly in a form that will require major effort to merely identify its location and form, and the potential lack of geographic attributes to statistical or sample data which could limit its utility for GIS application.

--- Institutions do not have a tradition of sharing available data, even within a single Ministry, either horizontally or vertically within the organization. Within a single institution, a decentralized organization without strong central coordination and management results in incomplete and incompatible data. As one senior Ministry planner noted, data collected by four entities for the same parameters, and in the same region, were of such discrepancy as to be impossible to correlate, and thus questioning the validity of each.

--- Much of the most essential data, particularly cartographic, has rigidly controlled access for reasons of domestic security. Agencies and individuals who should beneficially use these data have not established the required internal controls or other requirements to access these data.

--- Among some institutions, there is no tradition of using cartographic and spatial statistical data or analyses in any of their activities. This questions their present capacity to utilize GIS concepts, either manually or automated, in their programs, and calls for extensive training and technical assistance at all technical and user levels.

The study team conducted numerous reviews and interviews, both within the Ministry of Agriculture (MAGA) and its HAD Project participants, and outside the Ministry. The primary agencies included USPADA, DIGESA, DIGEBOS, INSIVUMEH, DGC, IGM, and the Office of the Vice President, and USAID/Guatemala. In addition, through USPADA the study team had the opportunity for presentations and discussions of GIS concepts and applications, and remote sensing data collection and monitoring techniques relevant to the HAD Project, in a meeting attended by senior personnel from BANDESA, DIGESA, DIGEBOS, ICTA, OCREN, INDECA, DIRYA, CIPREDA, INE, MOSCAMED, and BANGUAT.

4.2 SPECIFIC DATA FINDINGS

Sources of existing data are summarized on Table 4.1, and the following briefly describes their characteristics, coverage, and source.

Aerial Photography: Aerial photography acquired between 1954 and 1987 , and available through IGM, is shown on Figures in Appendix B. It is noted that the most recent aerial photography (1987, Figure B-6), at 1:60,000 scale, does not cover the principal HAD Project area. All IGM archive photography is Black-&-White, and of good quality. IGM has the capability to acquire additional large and medium scale aerial photography as required.

Table 4.1: Sources of Existing Data Relevant to the GIS*

DATA TYPE	INSTITUTION 1	2	3	4	5	6	7	8	9
1. Aerial Photography	X	X				X		X	
2. Satellite Imagery	X								
3. Topographic Maps	X	X				X			
4. Forest/Ecology Maps/data	X	X				X		X	X
5. Geologic Maps/data	X	X		X					
6. Hydrologic Maps/data	X		X						X
7. Land Use/Cover Maps/data	X					X	X	X	
8. Transportation Maps/data	X	X							
9. Soils Maps/data	X				X	X	X	X	
10. Land Capability Maps	X					X	X	X	
11. Watershed Maps/data	X		X			X			X
12. Meteorology/Climatology			X						

Key to Institutions: 1. IGM 2. DGC 3. INSIVUMEH
4. DGMH 5. DIGESA 6. DIGEBOS
7. ICTA 8. INTA 9. INDE

* This table does not imply that the existing data sources provide adequate coverage within the primary HAD Project area, are up-to-date, etc. as discussed in the test and appendices.

In addition, DGC, DIGEBOS, and INTA reportedly archived selected aerial photographic coverage, generally acquired through private contractors. Aerial photography coverage archived by DIGEBOS is shown on Figure B-7.

A local aerial survey firm, "Aerofoto Centroamericana S.A.," has undetermined archive holdings, as well as capacity to acquire new photography on a contract basis.

Satellite Imagery: Limited quantities of Landsat MSS imagery are archived at IGM and have been used in past regional remote sensing studies. A listing of IGM's Landsat holdings is shown in Appendix C; these include both black & white and color photographic prints, at 1:250,000 or smaller scale, and do not include digitally enhanced images nor digital data.

Recent and current Landsat Thematic Mapper satellite images have been acquired for all of Guatemala, with continuing data acquisitions available on request to EOSAT (the commercial operator of Landsat). Both digital and photographic products may be procured.

Topographic Maps: Complete topographic map coverage exists for Guatemala, through IGM, at 1:250,000 scale (13 sheets, Appendix D, Figure D-1) and 1:50,000 scale (259 sheets, Figure D-2). As noted on Figure D-2, eighty percent of these sheets have restricted access.

Figure D-3 shows the date of photography used and publication date for each 1:50,000 topographic map sheet, as of June, 1987. While many sheets are old, a revision program to update cultural information is underway at a rate of 20 to 25 sheets per year.

These maps should provide the primary cartographic control base in the GIS program. While concern has been expressed regarding their accessability, the study team is optimistic that appropriate accommodations will facilitate their access for use in the HAD Project.

Slope maps may be prepared through analyses of the topographic maps using a slope nomogram; an example is shown in Figure D-4.

DGC and DIGEBOS are also primary users of topographic maps, including larger scales for local area engineering design activities. Photogrammetric capabilities are provided by others, principally IGM. Coverage and availability could not be presently determined.

Forest Cover and Ecologic Data: Forest cover, ecologic, etc. maps have bee produced by IGM (see Figure D-8) and DIGEBOS, and additional limited coverage may reportedly be available through DGC, INTA, and INDE.

In addition, other agencies and local NGO's collect various ecologically related data; an example is the OAS funded TRIFINIO Project office. Given the limited accessability of topographic maps, these data are generally not in map or spatial form (and hence of uncertain use to the GIS database).

There are no reported on-going forest cover mapping programs, although qualified but limited capabilities exist at DIGEBOS and IGM.

Geologic Data: IGM has carried out a geological mapping program in collaboration with several US universities since 1962. To date, 36 map sheets at 1:50,000 scale (Figure D-5), and two map sheets at 1:250,000 scale (Nos. ND15-7 and ND16-5), have been published, in addition to a national geologic map at 1:500,000 scale.

In addition, geologic resource information may reportedly be available through DGC and DGMH. The anticipated primary applications of the GIS component in the HAD Project do not presently require geologic data.

Hydrologic Data: Drainage systems and topography to define watershed boundaries may be extracted from IGM's 1:50,000 topographic maps. These have been prepared for several basins and sub-basins, and published at 1;250,000 and 1:100,000 scales by IGM and INSIVUMEH. Figure D-6 shows the present status of INSIVUMEH's hydrologic basin studies, which are prepared on a macro basis; sub-basin and micro level studies may be conducted by INSIVUMEH upon request and subject to data availability.

Land Use and Land Cover Data: IGM has published 17 land use and land cover maps sheets at 1:50,000 scale (Figure D-7). These maps contain information on annual crops, perennial crops, forests, urban areas, etc. In addition to limited coverage, some may be out of date for present GIS database considerations.

DIGEBOS, ICTA, and INDE have also generated land use/land cover maps and statistics in selected areas for specific program needs. Existing DIGEBOS coverage is shown on Figure D-8.

While capabilities (although presently limited) for producing current land use/land cover maps, as required for

the GIS database, are extant at DIGEBOS and IGM, there are presently no on-going mapping or updating projects at either institution.

Transportation/Infrastructure Data: Two sources can provide basic transportation/infrastructure maps. IGM's 1:50,000 topographic maps contain roads, etc., although these may be out of date on older sheets that have not been recently revised (see Figure D-3). Current as well as planned road construction data are available from DGC.

Soils and Land Capability Data: IGM has published 51 Land Capability map sheets at 1:50,000 scale (Figure D-8). These maps show agricultural soil productivity based on soil depth, texture, permeability, and structure using USDA's 7th Approximation methodology. Additional and similar maps have been prepared by INAFOR (now DIGEBOS); a listing of DIGEBOS thematic map data is included in Appendix D, following Figure D-9. It is noted that DIGEBOS's mapping programs are based on an integrated natural resources management approach, and the basic geographic units are by watersheds.

In addition, soils and land capability data are reportedly available through DIGESA, ICTA and INTA; their availability in cartographic form, areas of coverage, etc., could not be determined from the interviews conducted or available data sources.

Meteorology/Climatology: INSIVUMEH routinely collects, disseminates and archives synoptic meteorological data from a well distributed network of over 300 observation and recording stations. Twelve of these stations transmit 3 hourly readings by radio to INSIVUMEH's headquarters; these observations include minimum/maximum temperatures, relative humidity, dew point, precipitation, and wind direction and speed.

The Agrometeorology Section is currently working to develop agroclimatic information for specific areas, but lacking a cartographic base, has not yet attempted national coverage although this need is recognized. In addition, information is collected and analyzed for potential evapotranspiration, frost occurrence, precipitation, the start/stop of the rainy season, and selected crop water requirements. They coordinate closely with the Climatology Section which maintains a data bank of temperature, precipitation, and evapotranspiration data.

In recent months, the Agrometeorology Section has provided DIGESA retrospective meteorology reports for approximately 45 day periods. It is their objective to begin, within the next 4 to 6 months, providing information

for 10-day outlooks, through published agrometeorology bulletins and broadcast media. This project, "Sistema de Informacion y Avisos Agrometoreologicos", will include climatic and synoptic analyses and outlooks for precipitation, soil moisture, humidity, frost warnings and forest fires. While the program is not yet operational, and its funding is uncertain, some materials have been prepared for MAGA and distributed through DIGESA to field offices and extension personnel. The geographic focus is on the principal commercial agricultural zones in Guatemala.

Integrated Watershed Data: IGM occasionally undertakes special mapping projects at the request of other Ministries. Examples include hydrologic and meteorologic map folios recently prepared with INSIVUMEH, land capability and land use maps prepared for DIGESA, maps and studies undertaken for the Ministry of Development, and others.

The Geographical Studies Division at IGM has recently prepared two comprehensive sub-basin studies, integrating a variety of physical and environmental resource information into a series of 1:100,000 scale maps. The manuscripts clearly indicated a professional capability within a small group to prepare database materials applicable to a GIS program component to HAD Project.

DIGEBOS reported focusing their integrated natural resources studies on watershed basins and sub-basins. In addition, INDE's planning and management of hydroelectric facilities requires basin and sub-basin management. The extent and form of these resource data, and their availability, however, have not been determined.

INSIVUMEH's hydrological and groundwater data and studies are conducted and presented by watershed basins and sub-basins. Groundwater basin study coverage is shown on Figure D-9.

Demographic Data: Data on population characteristics and distribution are collected through census surveys and archived by INE. The last national population census was conducted in 1981. Inter-census samples are also periodically conducted. INE data are routinely used by USPADA and other agencies at various levels of aggregation. While these data are statistical in form, they are generally amenable to spatial analysis and database development at departmental and municipality levels.

Integrating the above findings indicates major gaps in data by both type and coverage, as well as date; much of the data are not current nor in process of updating. Much is statistical,

contained in numerous files through regional offices and rarely contained in a centralized database. USPADA is presently developing a database of statistical and economic data, and noted that while there is substantial data of relevance, they are generally not being properly or efficiently used, nor standardized, to provide necessary or timely decision-making support. USPADA also commented on problems they often face in obtaining reliable data, as well as any data---a problem shared by other agencies who have similar interests and capacities for processing data and analyzing information to support their planning and policy mandates.

Even at the highest levels of the GOG there are presently efforts to develop databases and policy oriented information which conceptually incorporates the concepts of a GIS. The study team was provided examples by the Office of the Vice President that show statistical data at Departmental levels presented in both tabular and cartographic forms, as shown in Appendix E.

4.3 INITIAL DATABASE REQUIREMENTS

The PIO/T identified four basic GIS application and analysis requirements as follows:

1. Identify high-priority small watersheds for development.

2. Identify high-potential soils.

3. Identify high-potential sites for the development of small-scale irrigation systems.

4. Identify high-potential sites for the construction of rural access roads.

Each application requires the reduction of many different layers of data into a new layer of information, usually in cartographic format, that can support the decision making process. The key feature of a GIS is the analysis of data to produce new information. This information can consist of simple overlays to complex simulations.

These GIS applications will require several basic overlay and boolean operations to generate the desired identification information, but are not overly complex for current GIS capabilities given the availability of requisite data resident in the GIS database. In addition, they are directly relevant to the HAD Project objectives and appropriate for initial facility capability development.

To achieve each of the above GIS applications and analyses, certain data requirements have been identified to illustrate both

database development requirements, and the types of basic data which must be interactively considered for each application objective. The data requirements are shown in Table 4.2.

As further GIS application requirements are defined or developed, it will be useful to develop a "need/source matrix" and to ask: What sort of GIS products are needed to support the objective and decision requirements? What data inputs are necessary to produce the GIS products? What is known about the data inputs (accuracy, method of collection, etc.)?

Table 4.2: Data Requirements for Primary GIS Applications

DATA	APPLICATION: (PIO/T) 1	2	3	4
Topographic Maps (1:50,000)				
Elevation zones	X	X	X	X
Slope zones	X	X	X	X
Roads & other infrastructure	X		X	X
Distance to market (km & time)	X		X	X
Climate and Hydrology				
Climatological data	X		X	
Hydrological data	X		X	
Terrain characteristics				
Soil types	X	X	X	
Soil depth	X	X	X	
Land Capability	X	X	X	
Land Use (actual)	X	X	X	
Social characteristics				
Population density	X		X	X
Nutritional levels	X		X	
Socio-Economic characteristics				
Technology level	X		X	
Production levels	X		X	X
Availability of Credit	X		X	
Per capita income	X		X	
Crop types	X		X	X

4.4 DATA GAPS AND RECOMMENDED SOLUTIONS

The importance of the database, both in content and structure, has been a recurrent theme throughout this report, from discussions of data availability to data requirements for given applications and analyses of interest. A common result of data adequacy reviews is the indication that additional data are required, and this is clearly evident in the present study. The project's staff will be forced to acquire data which no one has in order to produce information required by the HAD Project. Usually these data will be in analog form and must be digitized for GIS archival.

One thing that must be realized about creation of the initial digital databases is that they will generally not be created using newly collected data. For spatial data, remote sensing technology permits this to take place in several themes, but many themes of critical interest, particularly with statistical data sets, it will be necessary to rely heavily upon conversion of the contents of existing files and archives which have been created as a result of ground surveys and detailed aerial photography analyses carried out over many years and which the database developers will "inherit".

What is the state of this inheritance? Present preliminary findings indicate poor when it is examined closely. It is predicted that one will immediately be struck by massive variations in quality, timeliness and coverage even within the most basic data elements. Hence, initial implementation activities of database design and structure must address the definition of its contents and the validity of the data which is placed in the databases. This is necessary to not only avoid failure, but to also minimize inefficiencies as the databases expand.

From the various interviews and document reviews, the study team has identified several problems not only in the available database, but also with extant capabilities of the various agencies under MAGA and which it recommends must be addressed for successful GIS implementation within the HAD Project. A summary is presented in the following.

4.4.1 Data Availability

Maps: One of the most important layers of data in a GIS program as recommended are the topographic maps of the project areas. Even though these data exist countrywide, they are not easily accessible for government agencies' planning purposes. Most of the interviewed agencies reported unsuccessful efforts to obtain desired topographic maps, even when reportedly following defined request procedures. The problem appears to worsen when the petition

is for field use in the project areas.

It appears that some progress is being made to ease access to restricted IGM products. At the same time, the validity of restriction requirements must be respected and internal control procedures must be implemented in order to facilitate access to these requisite products by appropriate users.

Statistical: Statistical data currently gathered by various agencies is, theoretically, available; however, it is commonly not of uniform format, even within the same agency. The study team also found a lack of established channels or procedures to share data among agencies within MAGA. There is no tradition in this regard, and when it happens, too often the data travels only one way without generating the necessary feedback required for planning, information verification, etc.

Some effort is currently addressing the problem of data sharing among the MAGA agencies. The greatest apparent obstacle is a lack of confidence among agencies in the data that was gathered by others, a statement repeated several times at different agencies.

4.4.2 Data Acceptability

Maps: Besides difficult accessability of topographic maps, there are also concerns about other thematic maps regarding data validity for planning purposes due to either being out of date or simply nonexistent. Land use and infrastructure may be based on aerial photography that is 10 to 15 or more years old; in general, the greatest changes in land use and infrastructure have occurred in the last ten years which implies that this data must be updat l for use as a current planning tool.

In cases where land use, land cover, infrastructure, and other cartographic data are either incomplete or in need of updating, these data gaps may be filled, at least in part, through the use of high resolution Landsat Thematic Mapper imagery, analyzed by present capabilities in Guatemala. USAID can procure the requisite imagery materials and technical assistance via an IQC and a local team could be organized for analysis and mapping purposes in order to maximize national resources in both aspects of image analysis and training for additional capabilities.

Statistical: The issue of data acceptability gets rather complex in regards to statistical data due to the diversity of data types, amounts, and lack of uniformity or standards. To solve this problem, a careful analysis should be carried

out within each agency that has, or may potentially have, a statistical database, with the following criteria:

1. What is the purpose of the data (e.g. planning, monitoring, evaluation)?

2. What questions/problems is the agency to ask of the GIS related to the data input?

3. Are the data spatially related and what is the statistical significance for each spatial level (national, regional, departmental, watershed, municipal, community, etc.)?

4. Is the data amount appropriate or can it be reduced?

5. Are the data available to other institutions?

It is not presently recommended to implement surveys merely to fulfill statistical data requirement gaps, a process that would be expensive and time consuming, and probably would not provide the expected results. The process should start with the existing statistical data that may satisfactorily be used. In order to share resource information between agencies and organizational levels, there must be common data structures and common terminology to consistently and accurately communicate about basic data.

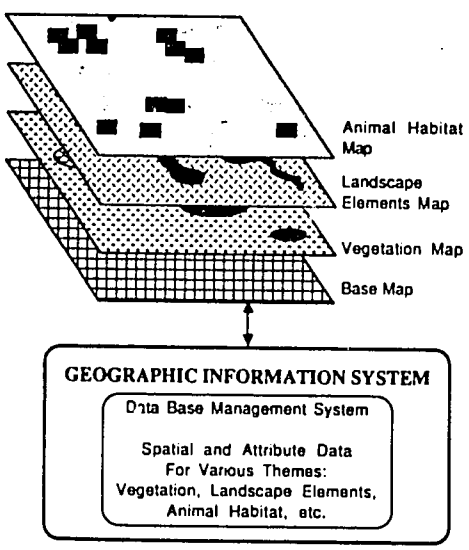
As participating agencies become acquainted with the GIS facilities, capabilities, and database requirements, new and repetitive surveys with more standardized processes and more explicit objectives than presently apparent may be designed and implemented.

5.0 RECOMMENDED GIS FACILITY REQUIREMENTS

5.1 CHARACTERISTICS OF GEOGRAPHICAL INFORMATION SYSTEMS

In many respects Geographic Information Systems are similar to automated information systems. This commonality is based on the following:

- Data collection;
- Transformation of the data into machine readable form;
- Editing and updating of the data files;
- Storage of the data;
- Computer analysis and manipulation of the data;
- Retrieval of entire files or selected portions of one or more files; and
- Generation of a variety of outputs, including maps, charts, and statistics.



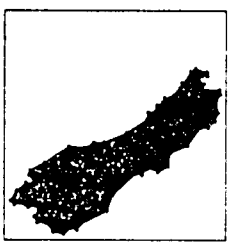
Many view GIS as a subsystem in an information management system. The most significant difference between a GIS and other information systems is in the spatial or geographic nature of the data handled by the GIS. The data must be georeferenced, that is, it is tied to locations on the surface of the earth, to create information with which managers, planners and scientists/engineers can interact.

Each GIs application requires the reduction of different "layers" of data into a new layer of information, usually in cartographic format, that can support the decision making process. The key feature of a GIS is the analysis of data to produce new information. This information can consist of simple overlays to complex simulations.

GIS software can be distinguished by the types of data structures and the type of data it is most efficient in processing. Systems are commonly distinguished by vector format versus raster format. Vector format GIS's are more cartographically oriented; examples can be found in engineering,

boundary analysis, and contour/isohyet generation. Raster format GIS's are commonly more analytically oriented, and much of the raster format research and development has been spinoffs from the digital image processing field. Most applications in this format have been in the natural resource planning and management field, often because of the strong dependence on remote sensing for database development. A recent variation on the raster format is the quadtree data structure which provides data management, storage, and processing efficiencies. In addition recent developments exist in raster/vector interfaces to standard interchange formats as well as to specific existing software systems within several commercial GIS's.

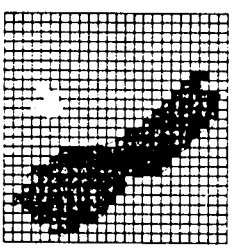
Vector Format



The basic units of the vector format are points and line segments used to represent geographic entities. A line is represented as a string of coordinate points; closed areas are defined as polygons, and represented by a set of lines that constitute their boundaries. The polygons define associated properties and provide the delineations for the spatial relationships. A polygon file, for example, may represent an area where a particular soil series or land use is located. Drainage features, power utilities, and transportation networks largely deal with streams and rivers, wires, and right-of-ways which are linear features best represented by points and lines. This format is common to most GIS's because it is used for capturing information on maps and drawings through digitizing.

The vector approach is suitable for representing networks, and while it can also be used in area analysis, it is inherently computationally complex and time consuming. Singly, it is not well suited to microcomputers for many analytical applications and thus is often interfaced with raster systems for analytical operations. Vector format GIS databases tend to be large. Overlay and other boolean operations are typically complex and time consuming, and many different formats make data exchange difficult among different vector systems. There are however, no constraints to overlaying of files of different resolutions.

Raster Format



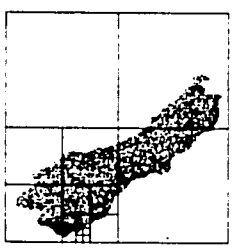
The basic unit of the raster format is a grid-like cell or pixel similar to a matrix to store information. Data is imputed either directly in the raster format (e.g. from digital satellite imagery), or in digitized vector format and converted to raster. The cell partitions the data plane (map) into these units of space in a uniform manner. Each unit of space can have a given set of associated properties.. Aggregating the cells representing the specific associated properties of interest provides the spatial relationships. As a

raster format example, all pasture land use may be represented by a certain cell value or color.

The raster format's grid cell usually does not capture the precision of the original vector; linear features, for example, are more coarse. There is a geometric increase in database size as resolution increases (i.e. a 1 sq. km. area at 100m resolution requires 100 cells; at 10m resolution it requires 10,000 cells). While many microcomputer based GISs adopt a raster approach, the amount of data this format can generate can potentially impose constraints on resolution, data storage, and processing speed. This, however, has been somewhat mitigated by use of 386-based microcomputers, expanded storage capacities up to 300mb, and off-line tape storage of data files.

In other aspects, raster format executes overlay and other boolean operations more simply and efficiently that vector systems, and forces the same resolution (co-registration of cells) for any analysis. Fewer format variations make data exchange easier among raster systems than vector systems.

<u>Quadtree Format</u> A variation of both vector and raster formats is known as the quadtree data structure for representing geographic information. A quadtree is a grid composed of cells which are subdivided individually until each is homogeneous. At boundaries of polygons, it may be possible to continue to subdivide almost indefinitely, and the level at which the process is terminated determines resolution and file size.



Quadtree data structures can approach the accuracy in resolution to any vector, as well as raster, data structure. The increase in database size as resolution increases is linear. Overlays and other boolean operations are computationally more complex than raster systems, but not as complex as vector systems, and there are no constraints to overlays of files of different resolution. The quadtree enables layers of data to be stored and manipulated at different levels of resolution and juxtaposed in overlays without requiring the translation of all data to the lowest common denominator cell. Quadtree is a more recent introduction to commercially available GIS's that vector or raster.

5.2 COMMERCIAL GIS DEVELOPMENT

Technological advances in computer hardware and software coupled with rising data demands for improved decision making have been the motivating forces in GIS technology development. The availability of accurate databases and data sources is commonly recognized as a limiting factor in the adoption and

expansion of GIS applications. Often suitable data do not exist and need to be generated, adding substantially to the cost of the system's implementation. The advent of the less expensive PC-based systems frequently places the cost of database development at more than that of the system's hardware, software, and training. This situation can also be expected in the case of the HAD Project.

Separately submitted with this report are vendor provided information packages containing descriptions, specifications, price lists, etc. for four commercially available in the USA PC-based Geographic Information Systems:

ERDAS--A raster based GIS.

The GIS module of ERDAS contains programs that include the classical concepts associated with GIS operations. The GIS module may "stand alone", or is fully integrated with ERDAS's digital image processing modules.

pc-ARC/INFO--A vector based GIS.

Adapted from ESRI's highly sophisticated ARC/INFO system, and modified to operate in a PC-environment with a series of software modules. One module, available through ERDAS is the ERDAS interface, allowing raster data to be converted to ARC files (raster to vector) and the vector data to be transformed into ERDAS raster files.

TERRA-PAK--A vector based GIS.

Also modified from a mainframe to operate in a PC environment with a series of software modules which utilize a proprietary relational database to store and manipulate attribute data, with interface with TerraMar's image processing modules.

SPANS--A raster based GIS.

TYDAC's GIS uses the quadtree design for data storage and processing. The system can also accept raster files from other GIS or image processing systems (i.e.ERDAS) and overlay vector graphics.

As a reference for interested readers, Appendix E contains a benchmark evaluation of PC-based image processing/GIS systems conducted by Earth Satellite Corporation for the US Army Corps of Engineers, Hydrologic Engineering Center, in 1987. The evaluation includes the ERDAS and TERRA-PAK systems, as well as the ERDAS/pcArcInfo link. The SPANS system was not included only because the referenced evaluation criteria included both image processing and GIS capabilities; SPANS provides only GIS functions, but accepts processed image files.

A Geographical Information System facility consists of both hardware and software components, as well as appropriate data,

facilities and qualified personnel. Depending on the specific GIS system, hardware components and minimal requirements will vary. Since the most critical issue in selecting a GIS is software function and performance criteria, most GIS software manufacturers support a variety of hardware configurations and provide either turn-key kits including both software and hardware, or detailed hardware specifications for customer provision in advance of software installation. In general, it is recommended that the first option, turn-key kits, be used; complete compatibility and functionality is assured by the GIS vendor and any potential cost-savings which may be perceived through separate hardware and software procurement is generally insignificant.

Additional GIS system components include maintenance, expendable supplies and materials, personnel and training, and database development, updating, and maintenance. Each are discussed in the following sections.

5.3 GIS HARDWARE COMPONENTS

A typical GIS hardware configuration consists of a computer (CPU) and periferals for data input, data display, and data output for hard copy products. Both mini-computers (e.g. DEC VAX and Micro VAXII series, Prime, Gould SCD, and Sun mini-computers) and micro-computers (e.g. IBM PC, Compaq, etc) are commonly the computing basis for GIS installations. The PC-Workstation GIS, based on an IBM PC/AT or Compaq, can be a stand-alone system for all data input, processing, and output functions. The user may utilize the full range of GIS capabilities on his/her desk (Figure 5.1).

Alternatively, as user needs expand, PC's may be networked to a mini-host(Figure 5.2). The PC acts as a terminal to the host CPU, actually running the host version of the software via an RS-232 link, or alternatively as in Intelligent Workstation, the PC and host computers can transfer and share files for varying degrees of processing and display. In either case, the PC is used for data display and routine input/output functions.

Dramatic increases in performance of personal computers over the last ten years has greatly expanded the range of applications to which they can be applied. Many tasks which were in the past restricted to mainframe computers can now be executed quite easily on an off-the-shelf personal computer, and more importantly the 80386 based super-micro computers. In terms of processor speed, addressable main memory and amount of on-line disk storage, today's super-PC rivals the mainframes of the not too distant past. Thus it is now practical to build a geographic information system, including an image processing system for database development, around personal computer technology.

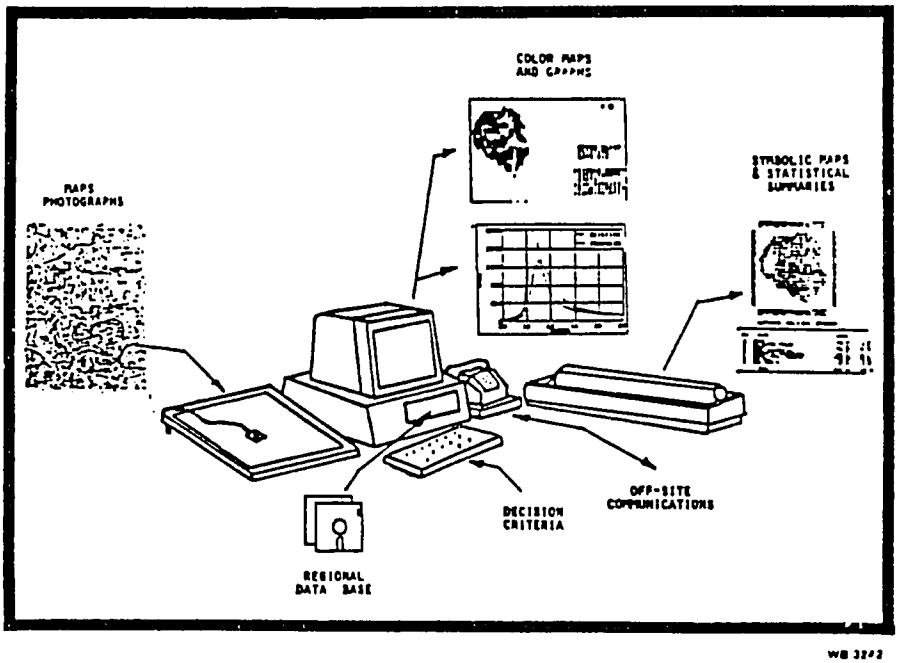


Figure 5.1: Microcomputer Work Station for Resource Analysis

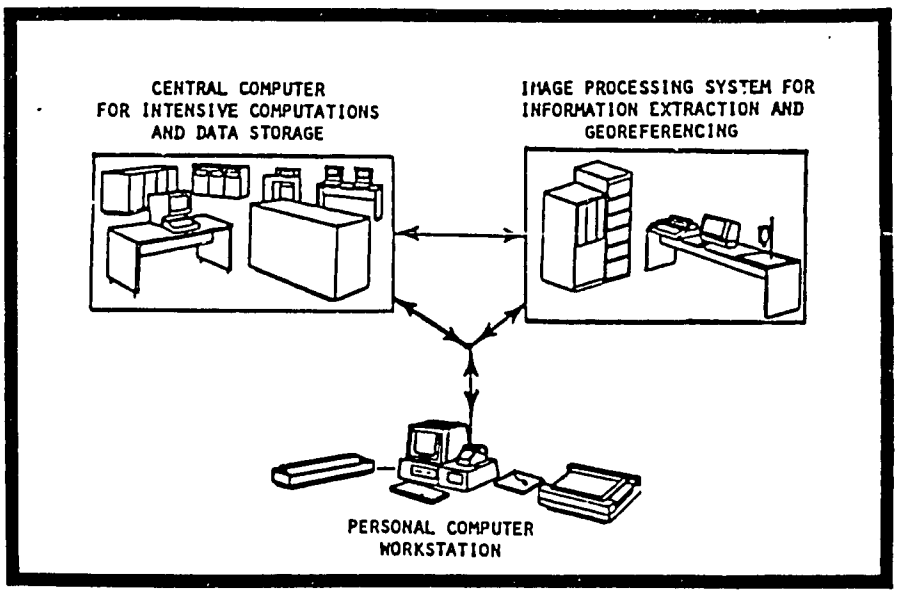


Figure 5.2: Network Structure for Remote Sensing/GIS Analyses

The 386-PC has increased the utility of various PC-based GIS and image processing systems currently on the market. ERDAS, pcARC/INFO, TerraPak, and SPANS all are among these. Processing power of the 386-PC allow these GIS systems to be used effectively for processing large databases and can greatly enhance the capability in spatial data management by providing a high powered interactive workstation.

In the present design, a PC-based GIS is recommended (Table 5.1). Input periferals include a digitizer for imputing maps, charts, drawings, etc., and a 9-inch tape drive for imputing previously encoded digital files, such as statistical data available on 9-inch tapes, or for imputing digital image data when the image processing functions are included with the GIS software, which is recommended. The tape drive may also be used for high-volume data storage and back-up if desired.

Other periferals include an RGB color monitor, and a hardcopy printer or plotter (raster systems use a color ink-jet or thermal transfer printer, while vector systems use mono- or color-pin plotter devices). Representative hardware specifications for these components are described in Table 5.1.

5.4 GIS Software Functions

Several manufacturers market PC-based GIS software packages, as well as integrated image processing software. Their functions and capabilities, while similar in basic applications and characteristics, also vary in data structure, performance, and expanded functions. Further, all major manufacturers have active and on-going software development programs and are continuously releasing improvements and changes in their respective systems.

Generic functional requirements recommended for a GIS within the HAD Project are summarized on Table 5.2.

Basic functions and capabilities are described for several systems contained in software overview documents included in vendor materials provided with the present report. Software is typically provided in a series of modules, each containing a series of application programs. For example, ERDAS is a user-friendly menu driven software system consisting of 12 modules, as shown on Figure 5.3.

As previously noted, a benchmark comparison of two commercially available PC-based image processing/GIS systems (ERDAS and Terramar, with additional descriptive comments for pcARC/INFO) was prepared in July 1987. The criteria used in this comparison, shown on Table 5.3, provide guidelines to additional or updated comparative evaluations. The findings of this comparison are included in Appendix E.

Table 5.1: Recommended GIS Hardware Components

Computer: Minimum CPU requirements for IBM PC/AT, Compaq 386, or 100% compatible systems

IBM PC/AT	Compaq 386
640 kb RAM	1.0 mb RAM
1.2 mb Floppy Disk Drive	1.2 mb Floppy Disk Drive
60 mb Hard Disk Drive	60 mb Hard Disk Drive
(300 mb recommended)	(300 mb recommended)
Serial/Parallel Adaptor	Serial/Parallel Adaptor
Color or mono display	Color or mono display
80287 Math co-processor	80287 Math co-processor
DOS 3.3 or higher	DOS 3.3 or higher

Color Display Monitor: (separate from above computer monitor) Mitsubishi or 100% compatible RGB Monitor

Options: (a) 512 x 512 x 32 bit Image Processor board with 13-inch or 19-inch RGB Monitor
(b) 1024 x 1024 x 32 bit Image Processor board with 13-inch or 19-inch RGB Monitor

Digitizer: Calcomp or GETCO Tablet with 16-button cursor and power supply.

Options: (a) 24" x 36" tabletop model
(b) 35" x 48" with floor stand

Hard Copy Printer: Tektronix or compatible Color Ink Jet Printer or Color Thermal Printer, with Starter Kit and 6 mos. supplies.

Options: (a) Color Ink Jet Printer
(b) Thermal Transfer Printer

Tape Drive: 9-inch tape drive may be used for data backup and/or storage, and is required for input of digital satellite image data.
Cypher 9" tape drive or equivalent and interface electronics.
Tape density options:(a) 1600bpi (b) 1600/6250bpi

Note: If only data storage is required, a 1/4" Tape Cartridge Device (60mb or more capacity) with interface electronics may be utilized.

Costs of GIS software varies by manufacturer, and depends on what modules/functions are included, and whether hardware is included with software (kits). Domestic U.S. Price Lists are included in the referenced vendor packages. Most vendors add 20 percent to the U.S. base price for international sales, plus shipping, taxes, duties, etc. as applicable.

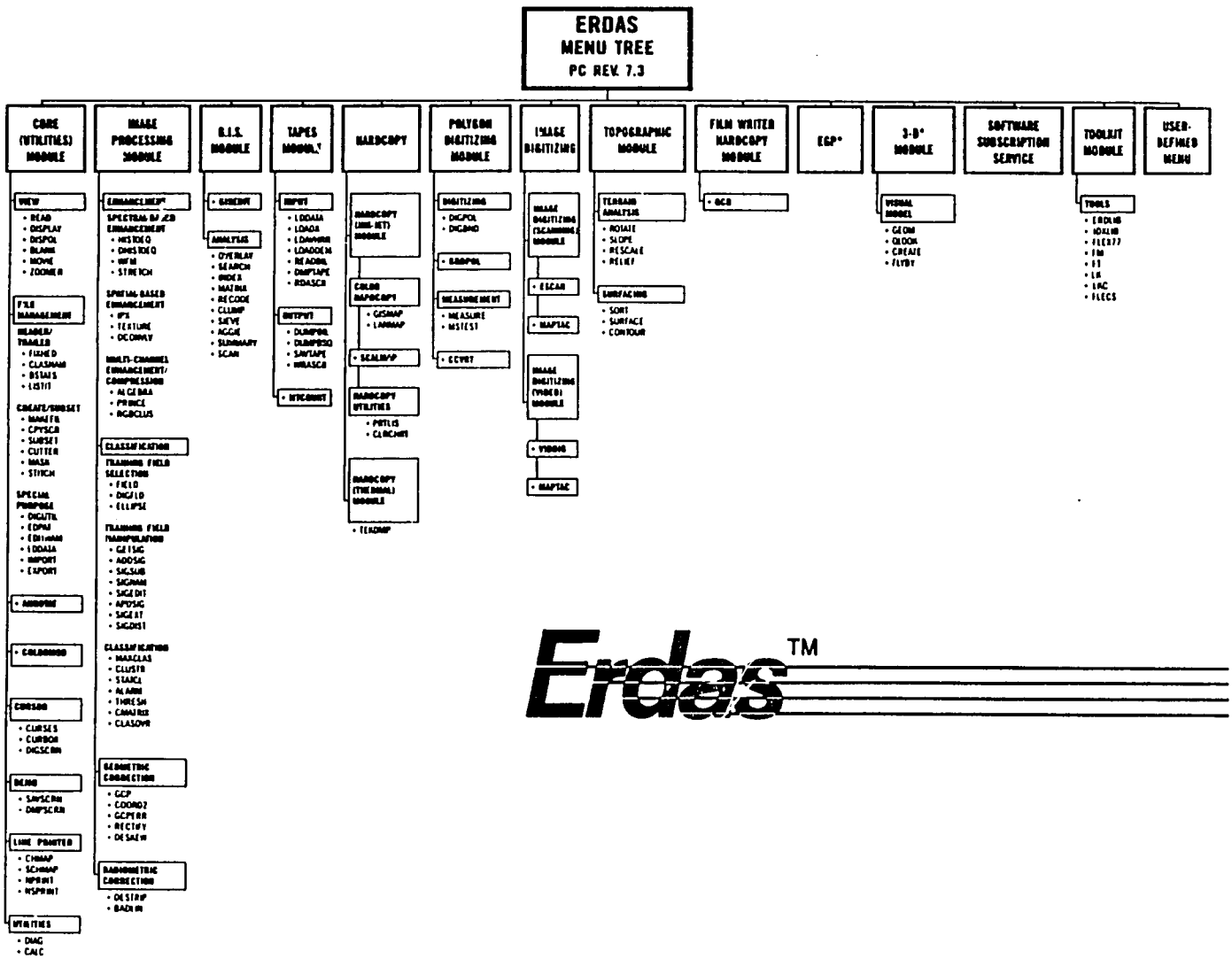
Table 5.2: RECOMMENDED MINIMAL FUNCTIONAL REQUIREMENTS OF A GIS FOR THE GUATEMALA HAD PROJECT

- Comprehensive GIS capabilities with an "off-the-shelf" PC;
- Develop and maintain multi-layered databases for an entire area of jurisdiction such as a Department or MAGA region;
- Define a sub-area of interest such as a watershed or municipality from a digitizing table or by keyboard entry, and:
- Obtain color displays and color hardcopy products that show the spatial distribution (depending on available database parameters) of:

Land use/land cover	Soil Type
Slope	Elevation zone
Agroclimatic attributes	Demographic attributes
Roads	Rivers and Streams

Other specific features or facility attributes

- Produce statistical tables that tabulate the relative quantities of classes within each data layer.
- Perform overlay and other boolean analyses that result in color display and printer maps that show the locations of user-defined conditions among classes in several data layers.
- Compute areas, lengths and distances, and zones.
- Maintain communications with supporting super micro, mini or mainframe computer to access mass storage devices or use f[illegible]r computational capabilities (may be off-line ini[illegible]y, but capable of accommodating future expansion [illegible] required).
- Modify the modelling module(s) of the overall system to accommodate different analytical or simulation packages or requirements.



* - PROGRAM

* - Custom Application Package (CAP)

TABLE 5.3 IMAGE PROCESSING/GIS SYSTEM COMPARISON CRITERIA

Hardware

1. 80386 based system
2. Co-processors
3. Optical disk

User Interface

1. Structure
2. Default answers
3. On-line help
4. Batch processing setup

Image Enhancement Functions

1. Ability to handle Landsat MSS, TM, and SPOT imagery
2. Ability to handle AVHRR imagery
3. Contrast stretch
4. Spatial filtering
5. Ratioing
6. Principal components/linear combinations
7. Intensity, Hue, Saturation

Image Classification Functions

1. Supervised and unsupervised classifications
2. Training for supervised classification
3. Processing speed benchmark: Baysian maximum likelihood

Georeferencing

1. Geometric corrections/rubber sheeting
2. Georeferencing of imagery to maps or GCPs
3. Georeferencing of multidate imagery

Polygon Digitizing

GIS Functions

1. Overlay
2. Zone generation
3. Attribute handling
4. Report generation
5. Optimal path routing
6. Line of sight computation
7. Post classification filtering to reduce polygons

IP/GIS Interface

1. Utilize GIS layers in classification process
2. Create GIS layer from classification

Hard Copy Generation: Ability to produce high quality map output

User Support

1. Telephone support
2 Software maintenance
3. Frequency and quality of software updates
4. User group
5. Software tool kit for user developed applications

5.5 GIS FACILITY STAFFING RECOMMENDATIONS

In addition to hardware, software, database and facility components, a GIS component to the HAD Project will require a competent and dedicated staff of professionals and technicians to maintain the GIS database and to provide analysis and applications services supportive of its planning, monitoring, and evaluation objectives within the HAD Project.

It is recommended that the GIS Facility staff need not be large or complex in organizational structure. Rather, a small, cohesive group who are well trained in all technical aspects and who have effective liaison (especially at technical levels) with participating institutions should be the initial staffing implementation. As the GIS activities and facilities expand to meet growing user needs and services, then the staff may also be appropriately expanded.

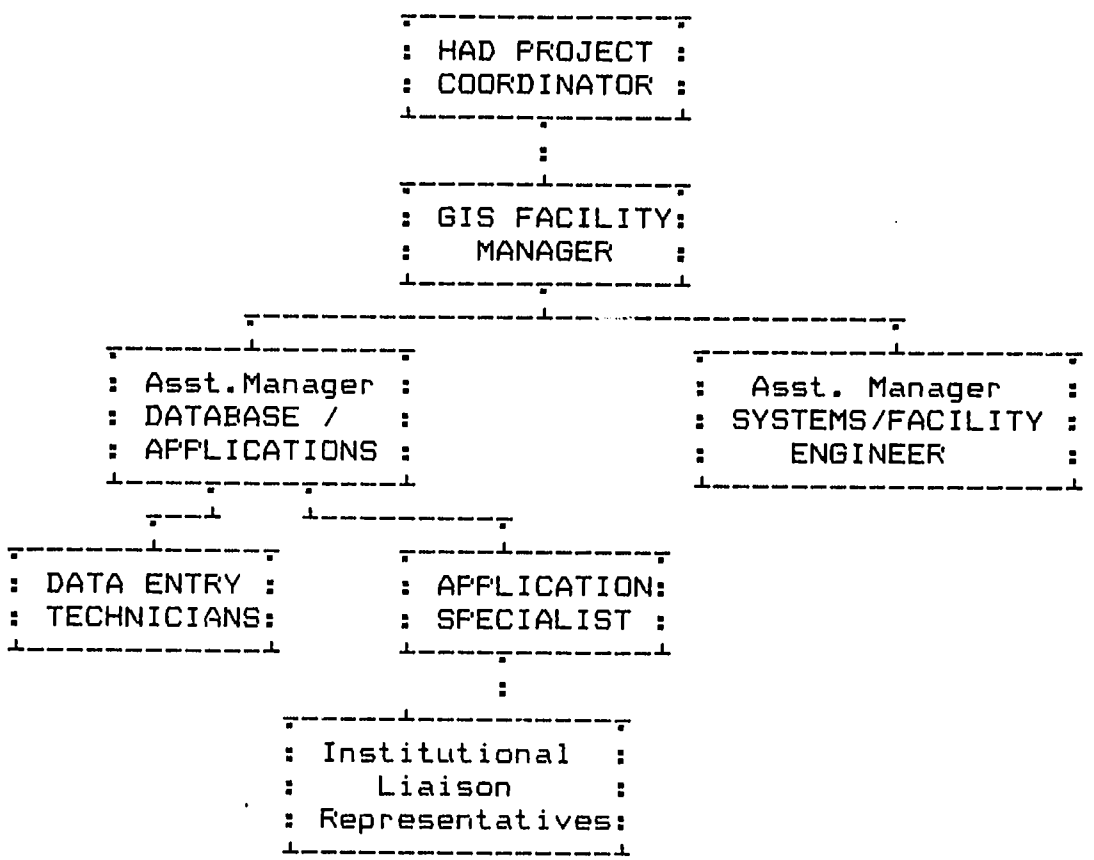
The recommended GIS Facility staffing, represented functionally in Figure 5.4, includes two basic levels for management and technical operations. A permanent core staff of approximately seven professionals and technicians will be supplemented by part-time technicians for database entry and maintenance, and part-time professionals from participating institutions. The latter group will be principally responsible for the management of the database for their respective institutions, including data procurement, generation, quality control, and preparation for database entry in conformance with GIS Facility guidelines and standards. Each staffing activity is briefly described in order to show the integration and interrelationships of a small and successful facility.

5.5.1 GIS Staff Functions

The GIS Facility Manager must have both relevant and strong technical skills and managerial capabilities. His/her successful ability to work closely with participating institution's management and to understand and coordinate technical aspects of the database, GIS processing, and analysis and application development, will be required, including direct involvement with all aspects of the facility's activities. The GIS Facility Manager should report directly to USAID's HAD Project Coordinator.

Assisting and reporting to the GIS Facility Manager are two Assistant Managers: (a) a Database/Applications Manager, and (b) a Facility Systems Engineer. The Database/Applications Manager should have broad responsibilities within the Facility and must have a solid background in a relevant applications discipline (e.g. agronomy, natural resources, geography, watershed management, etc.).

Figure 5.4: Recommended GIS Facility Staffing Plan



Supporting the Database/Applications (DB/A) manager are two units:

(a) Technicians responsible for database preparation, entry, and maintenance. A team of two database technicians, one with a cartographic background, and the other with a data entry / ADP background, is recommended. The team may be expanded during times of peak work load and/or multiple production shifts with similarly qualified technicians (the facility would be well served by such part-time staffing arranged through local university resources).

(b) Professional level GIS analysis/applications development specialist(s) who, along with the DB/A Manager, will develop and execute GIS analyses. The GIS Specialist must also work closely with both the database technicians and the Facility Systems Engineer. Like the DB/A Manager, the GIS Specialist should have strong applications discipline background; by coming

from different backgrounds, the unit will affect interdisciplinary objectives and strengthen its capacity to serve the multiple participating institutions. Initially one GIS Specialist is recommended in the core staff, to be supplemented with the part-time participation by equally qualified counterparts from the participating institutions.

The Facility Systems Engineer should be responsible for operation and maintenance of hardware and software, and provide technical support to the GIS application staff for applications and modeling development, user developed software enhancements, various software integration needs, etc. The Systems Engineer should be familiar with PC-based hardware and periferals, and have at least some programming capabilities. Extensive programming needs are not anticipated, and if required, may be acquired through part-time assistance (e.g. local university computer science students).

Also shown in the staffing plan is a Technical Assistance Advisor. Long-term Technical Assistance is recommended for the first two years to provide technical expertise to the GIS Facility Manger and staff, as well as program management and program application support. In addition to have an applied GIS/IP experience, the TA Advisor should also have a relevant application discipline background (e.g. geography, natural resources, watershed management, etc.).

5.5.2 Institutional Roles in GIS Staffing

Throughout the study team's discussion, we have repeatedly stressed the importance of the database design to the subsequent GIS operation. Imbedded in this issue is the question of who is responsible for carrying it out. The answer is found in the traditional complex of institutional roles associated with most institutional GIS's and with strong parallels in the specific HAD Project. These include:

1. Primary and secondary users of the GIS/database.

2. Data collection organizations.

3. The operator of the GIS/database system

4. The system sponsor.

Typically, and in the HAD Project, the primary user(s), operator, and sponsor are not found within the same organization. However, construction of the databases represents a new situation and the definition of the various institutional roles is far from clear.

It is the system sponsor, or the sponsor's consultants, who most commonly create the database design. Continued maintenance and development of the design are associated with the database administration functions assigned to the system operator, i.e. the GIS Facility. What institutions are to be associated with these roles in creation of the various databases? This must be addressed by all participants before viable design and development of the databases can begin.

Identification of the institutional components is the first step. The players must be identified, roles assigned and accepted, and there should be no confusion on the part of anyone as to where the responsibility lies for design, implementation and continued maintenance and operation of the GIS and its databases. Arising out is this clearly defined institutional structure, there must be a clear and detailed knowledge on the part of the Database/Applications manager and staff of the needs of all significant users of the databases. This will be successfully reflected by a logical structure defined for the spatial and statistical databases, comprehensive enough to support all user needs identified as being of a critical nature while maintaining adequate flexibility to meet future changes in these needs.

5.6 IMPLEMENTATION ISSUES

There is a growing desire on the part of many of the institutions participating in the HAD Project to assemble and utilize spatial databases (dealing, for example, with data elements such as soils, terrain, vegetation, climate, population, etc.). The idea of implementing a GIS component within the HAD Project has clearly created expectations among all of the MAGA institutions. As a result of the study team's meetings, a number of issues have surfaced and which should be addressed as part of a GIS implementation.

Implementation of a GIS component within the HAD Project will be a long-term venture and investment, and will require continuous monitoring rather than merely a one-time evaluation. However, as indicated, beginning with relatively small project(s) will facilitate the implementation process by providing on-the-job training and experience, testing, and demonstration of high visibility applications that provide output examples early in the implementation phase.

5.6.1 Organizational Issues and Institutional Relationships

Implementation should focus initially on institutional cooperation while also addressing technical issues. Implementation should also determine short-term and long-term custodial mandates, and assign responsibilities for each layer in the system to insure continual maintenance. Because the HAD Project is interdisciplinary and multi-institutional, an array of disciplines and professionals should be involved in the initial system development and planning stages. Since there will be only a single GIS Facility (at least initially), regardless of where it is physically located the "host" institution must accomplish: (a) access to participating users, (b) coordination among participating users, and (c) clear guidelines, objectives, and standards for use, especially for development of the databases.

During the first year of implementation, the GIS Facility will have several limitations that will improve as the processes matures. A learning curve exists in system development and use. Initial efforts and costs to collect, compile, and use data will be high until experience with the GIS has been gained.

Initial GIS Facility's operations will be multipurpose in order to accomplish training requisites, promote concepts, applications, and services among its primary users, design and construct databases, and maximize results in a short term.

The organizations engaged in creating the databases must overcome many substantial problems arising from physical and institutional factors. These include the volume of any spatial and statistical data which is to be handled on either a regional

or national basis, and the often incompatible or inconsistent definition of data elements. The developers must also respond to the fact that these databases, in order to retain any long-term viability, need to be structured in a fashion which will remain as responsive as possible to the varied and changing needs of a large and changing multi-user community. The solution to these database development problems should be realized through efficient, structured design of the databases, an approach which should involve short-term Technical Assistance. Such a structured approach is critical to successful database design and to subsequent GIS operation.

The GIS implementors should insure that the database is politically unbiased, and broadly accessible for both daily management and policy-making functions. The database must allow for efficient, comprehensive, and exhaustive analyses to insure fair and equitable treatment for all concerned.

Even though the intention is to implement a GIS at the national level, and the database design should reflect a national architecture. it is advisable to begin development and analyses on a more modest scale. This will facilitate training and experience, define the quantity and quality of data requirements for standardizing analyses, and demonstrate potential uses of the system to all participants. Some applications and analyses will be accomplished much faster than formerly, while other applications which were not possible will emerge, and unanticipated benefits will follow.

The process of identifying the decisions to be made and questions to be answered is one of the most critical elements to the ultimate success of the project. While the study team has begun this through various presentations and discussions, the process must continue in the planning and implementation process. This require the combined input of the program management staff as well as those providing the GIS service. The program staff must be able to communicate their needs (decisions to be made, questions to be answered, etc.) to the GIS specialists who, in turn, must determine which needs can be supported by products from the GIS.

5.6.2 INSTITUTIONAL CONSIDERATIONS

After interview and meeting with representatives of various GOG agencies, especially MAGA institutions, the study team concludes that within MAGA there are three institutions who may be considered for a GIS Facility implementation. This conclusion evolved from a preliminary review of each institution's activities and responsibilities in the agricultural sector as well as its responsibilities over the natural resources base of the country. These three MAGA institutions are DIGESA, DIGEBOS, and USPADA.

An additional factor considered by the study team was the institution's management expression of need for strengthening their respective planning, monitoring, evaluation and decision-making processes in order to provide an improved response to the beneficiaries of the HAD Project.

As may be expected, all three institutions have expressed strong interest for hosting the GIS Facility, and each has significant potential for substantive technical and/or managerial contributions for developing and implementing a GIS within the HAD Project.

While each institution manifests both strengths and weaknesses which will directly impact the type and level of support effort provided by the USAID mission to achieve program success, the duplicity of both need and interest by all presents the HAD Project both opportunity and dilemma. The opportunity is to affect inter-institutional coordination with a common objective, and to strengthen both intra- and inter-institutional relationships and coordination. The dilemma is where will the best interests of the HAD Project be served, both technically and managerially, by the contributions provided by the GIS component.

To assist HAD Program managers in both maximizing the opportunities of aggregated strengths and noted dilemma of multi-institutional needs and desires, the study team offers several criteria which consider a variety of important data, application, technical capabilities/needs and institutional issues. These suggested criteria are shown on Table 5.4.

Regardless of which institution "hosts" a GIS Facility within the HAD Project, or where the Facility is physically located, it is strongly recommended that the GIS Facility report directly to USAID's HAD Project Coordinator in order to affect the maximum possible inter-institutional coordination and participation and maintain a clear program focus within the context of the HAD Project and its geographic and resource information needs.

5.6.3 Training Needs

Two types of training needs, operational training and conceptual training, are recommended as required for full utilization of the GIS component within the HAD Project.

Operational training is initially provided by the GIS vendor and is basically oriented to provide the capacity and ability to interact with the software and hardware by those personnel directly responsible for the GIS operations and maintenance. The recommended approach to this vendor training is divided into two

Table 5.4: Suggested Criteria for GIS Institutional Selection

Database Management

1. Institution presently maintains relevant cartographic data.
2. Institution presently maintains relevant statistical data.
3. Institution has demonstrated access to available cartographic data.
4. Institution has demonstrated access to available statistical data.
5. Institution's data and information are inter-institutionally accessible.

User/Application Role

1. Institution has a defined role/responsibility in the HAD Project.
2. Institution realizes immediate GIS application needs as a primary information system user.
3. Institution has potential GIS application needs as a primary or secondary user.

Institutional Relationships (viewed externally)

1. Institution is viewed by others as a primary GIS information user.
2. Institution is viewed by others as an accessible data/information source.
3. Institution is viewed by others as a leading sector agency.
4. Institution has established inter-institutional program linkages.
5. Institution has inter institutional coordinating responsibilities (generally and/or for HAD Project).

Facility and Staff Capabilities

1. Suitable space/facilities for GIS equipment are available.
2. Qualified personnel are available (or potentially).
3. Institution can provide GIS program management and facility administrative support.
4. Institution has ADP experience and support
5. Institution's programs provide potential GIS utilization beyond HAD Project.

Technical Assistance Support Requirements

6. Institution would not require direct long-term USAID technical support.
7. Institution would not require direct long-term USAID management/administrative support.

sessions of one to two weeks each. The first session include the installation of the hardware and software, and is designed tointroduce and familiarize the technical operators with basic elements and functions of the software and hardware over a period of about two weeks in the local GIS Facility. A second phase of vendor provided training is then conducted approximately three to four months later, after the GIS operators have gained general familiarity and comfort with the basic GIS functions and operations, and have developed both considered questions as well as problems typical of initial daily experiences.

The second training session is considerably more intense, and is designed to provide answers to specific problems and to further capability and expertise in all aspects of the GIS and its operations and maintenance. This second training phase is often conducted in the vendor's facility for a small group of participants and where the full technical resources of the vendor are accessible as required to address specific issues or problems. This approach is routinely used, for example, by ERDAS, who, in addition, can arrange specialized training programs or workshops through its installation at CATIE.

Conceptual training is related to the analytical aspects and applications of the GIS. Due to its unique, project specific focus and character, it should be viewed as a continuous process through experiential use of the GIS and it products. Long-term Technical Assistance, supplemented by short-term Technical Assistance and locally based technical advisory services, is a recommended approach, in addition to participation by GIS Facility personnel in periodic short courses, seminars, workshops, symposia, and user-group meetings conducted through universities, professional organizations, vendors, etc., both domestically and internationally.

5.6.4 GIS Facility Implications

In order to sustain management's interest, an investment in anything has to produce positive results. Regardless of the particular computer configuration chosen for a GIS facility, careful attention should be paid to three areas of importance to successful system use and to management's (and sponsor's) appreciation (and continued support) of this technology.

a. The facility must be appropriately set up and maintained.
b. A continual budget for maintenance and for hardware and software upgrades must be planned for, and

c. System users must be skilled and adequately trained, in both system operations and specific applications, to get the desired results from their system.

This last item includes establishment of a continuing dialogue with the system vendor and with users of similar systems and applications to pertinent problems and advances in technology. Budgets for post-warranty hardware maintenance (service contracts and maintenance calls), software maintenance (upgrades), and operator maintenance (technical subscriptions, refresher courses, workshops, and associated travel funds) are equally as important as the initial system acquisition budget.

A facilities environment must be prepared properly and maintained. This includes sufficient clean and stable electric power important to sensitive electronics and memory, a sufficiently clean (reasonably dust free) environment--important to disk and tape drives and cooling fans. Site preparation and post-installation maintenance is a cost to be considered.

5.6.5 GIS Maintenance Issues

All GIS hardware components, including computers and periferal hardware, will require periodic maintenance and servicing. To the extent possible, the facility should arrange locally based maintenance and service contracts. Periodic, routine and preventative maintenance requirements should be the responsibility of the Facility Systems Engineer, including execution of simple, on-site, user maintenance requirements.

Software maintenance is best affected through annual subscriptions with software manufacturers for software modifications and updates as released. The cost is nominal compared to purchase of new software releases. In addition, an annual budget is recommended for purchase of new software appropriate to the facility's needs.

The database must also be maintained and updated. Although different than the requirements for hardware and software, database maintenance and updating is of utmost importance to the continuing operations of the GIS Facility. The specific types, frequency, and other characteristics of database maintenance and updating will be determined through data and information needs on an on-going basis. As indicated, these are suggested staff responsibilities for maintenance and updating of the database.

Finally, technical and professional staff skills must be maintained and updated, and this may be affected through a combination of activities, including on-the-job training and seminars, workshops and short courses organized locally as well as internationally (e.g. CATIE and US programs), and participation in annual User Group Meetings (such as those organized by ERDAS, ARC/INFO, and others). Short-term technical assistance on a regular and periodic basis also provides significant contribution to staff skill maintenance and updating.

6.0 GIS PROGRAM BUDGET ESTIMATES

Implementation of a GIS component in the HAD Project will be a long-term investment. In the preceeding sections the major cost components have been identified, including hardware, software, facilities, personnel, training and maintenance. Depending upon where the GIS Facility is located, these costs can vary significantly due to extant facilities and hardware, and the host institution's capabilities and technical support. Although the study team anticipates that implementation of a GIS Facility would most likely be hosted within DIGESA, it is realized that both DIGEBOS and USPADA offer alternative choices with concommitant budget implications.

The following describes the major budgetary requisites which USAID may anticipate following the preliminary design recommendations and assumptions presented in this study.

6.1 HARDWARE COMPONENT COSTS

The accompanying vendor packages include price lists for their respective hardware/software components, and vendors can provide detailed hardware specifications for purchaser's independent procurement if desired. The following lists principal hardware components and estimated costs (GSA Schedules may be applicable, but are not presently considered).

ITEM	DIGESA	DIGEBOS	USPADA
Computer, 386-PC, 300mb	$15,000.	$15,000.	$15,000.
Computer, 286-PC, 60mb	4,000.	4,000.	4,000.
Terminals to PC-286 (network)	1,400.	1,400.	700.
Tablet Digitizer	6,000.	6,000.	6,000.
RGB Monitor	2,900.	2,900.	2,900.
Line Printer, letter quality	600.	600.	n/a
Color Printer, Thermal	10,000.	10,000.	10,000.
9-inch Tape Drive	10,000.	10,000.	10,000.
1/4-inch Cartridge Drive	900.	900.	n/a
Misc. Spare Parts & Supplies	2,000.	2,000.	2,000.
Total Estimated Hardware	$60,900.	$60,900	$55,400.

6.2 SOFTWARE COST ESTIMATES

Software costs vary by vendor, functional modules, and optional inclusion of hardware components and their software interfaces. Using the ERDAS packages as a guide, less above hardware components, the following basic software functions are included in the cost budgets. "Other software" includes basic packages for word processing, spreedsheet, database, networking,

etc.

ITEM	DIGESA	DIGEBOS	USPADA
GIS software module, with core utilities	$15,000.	$15,000.	$15,000.
Polygon Digitizing, interface	5,000.	5,000.	5,000.
Tape Storage, interface	5,000.	5,000.	5,000.
Image Processing module	5,000.	5,000.	5,000.
Hardcopy module, interface	5,000.	5,000.	5,000.
Other software packages	4,000.	4,000.	2,000.
Total Estimated Software	$39,000.	$39,000.	$37,000.

6.3 Facility Preparation Costs

It is assumed that all candidate institutions can and will provide space for a GIS Facility, and that preparation costs will be similar among each institution. However, this should be further investigated; suitable space apppears to be presently available in the USPADA building, requiring less modification costs than what was observed at DIGEBOS. DIGESA also has suitable space, if allocated to this purpose. Site preparation costs include remodelling as required, furnishing, installation of phone, air conditioning, power supplies, etc., and related operating costs for the first year. Also included are annual office supplies/expendables, a project vehicle, and its annual operating expenses.

Site Preparations		$25,000.
Vehicle		15,000.
	subtotal	$40,000.
Utilities		3,000.
Office Supplies		5,000.
Vehicle operation		3,000.
	subtotal	$11,000.
	Total	$51,000.

6.3 FACILITY STAFFING COSTS

Salary costs for GIS Facility staffing as defined in Section 5.5 are estimated as follows (monthly Quetzales and annual Dollars). It is noted that staffing requirements vary based on extant capabilities resident at each institution and assummed availabile to the Facility. Part-time and institutional GIS coordinators are not included.

POSITION	Q/mo.	DIGESA	DIGEBOS	USPADA
Facility Manager	3600.	$16,000.	$16,000.	$16,000.
Fac/Systems Engineer	2500.	11.100.	11,100.	11,100.
DB/Applic Manager	2500.	11,100.	n/a	n/a
Data Entry Tech(s)	2000.	18,000.	9,000.	9,000.
Secretary/Admin.Asst.	1000.	4,500.	4,500.	4,500.
Total Estimates Salaries		$60,700.	$40,600.	$40,600.

In addition, Short-term Technical Assistance and qualified local consultant advisory services are recommended during the first two years of implementation. The estimated annual costs associated with technical assistance and advisory services are as follows:

Local consultant advisory services	$25,000.
Short-term Technical Assistance (5 mos./yr, $15K/mo.)	75,000.

6.4 MAINTENANCE COSTS

Hardware maintenance costs are estimated at 15 percent of the purchase cost, beginning after the warranty period (7.5% for the first year, 15% per year thereafter).

Annual software maintenance includes subscription upgrades from day one and new purchases beginning in year two.

In addition, an annual contingency budget is identified, beginning in year two. This budget includes funds for hardware upgrades/replacements, etc.

One of the major costs of implementing a GIS is establishing the database. Database coding and entry costs are included in the present estimates; data collection, compilation, and preparation for database entry, however, are not included, and are considered to be costs borne by HAD Project participants. Estimates for developing the requisite data are highly variable and depend upon not only the method of data collection but a variety of other factors such as the number of attributes, data complexity, scale and accuracy standards. Aerial photography and supporting ground surveys are used as a method of capturing most of the spatial (cartographic) data; therefore, costs for aerial photographs, interpretation, and field surveys should be included in the data preparation estimates. Landsat imagery is a cost-effective alternative to aerial photography for a number of requisite themes.

6.5 TRAINING COSTS

Training costs which are not otherwise included in the Technical Assistance and Advisory services includes vendor's installation training, vendor's advanced training, and short courses, symposia, workshops, etc. (including travel and per diem). These costs are equally applicable to each institution.

6.6 ESTIMATED BUDGET SUMMARIES AND LOP PROJECTIONS

The above budget estimates, with institutional variation, are summarized in tables (Table 6.1A: DIGESA; Table 6.1B: DIGEBOS; Table 6.1C: USPADA) showing first year, continuing annual, and LOP estimates. An escalator of five percent begins in year two.

TABLE 6.1A: ESTIMATED GIS FACILITY BUDGET FOR DIGESA

ITEM		$1,000/year 1	2	3	4	5	LOP
1.	Hardware	60.9	2.1	2.2	2.3	2.4	69.9
2.	Software	39.0	2.0	2.1	2.2	2.3	47.6
3.	Facility Prep.	40.0					40.0
4.	Utilities/Supplies	11.0	11.5	12.1	12.7	13.4	60.7
5.	Staff Salaries	60.7	63.7	66.9	70.3	73.8	335.4
6.	Tech. Assistance	100.0	105.0				205.0
7.	Training: Install.	8.0					8.0
	Advanced	6.0					6.0
	Other	10.0	10.5	11.0	11.6	12.2	55.3
8.	Mainten.:Hardware	4.6	9.1	9.6	10.0	10.5	43.8
	Software	2.0	3.0	3.2	3.3	3.5	15.0
	subtotal	342.2	206.9	107.1	112.4	118.1	886.7
9.	Misc./Contg.(10%)	34.2	20.7	10.7	11.2	11.8	88.6
	Total (DIGESA)	376.4	227.6	117.8	123.6	129.9	975.3

TABLE 6.1B: ESTIMATED GIS FACILITY BUDGET FOR DIGEBOS

ITEM		1	2	3	4	5	LOP
1.	Hardware	60.9	2.1	2.2	2.3	2.4	69.9
2.	Software	39.0	2.0	2.1	2.2	2.3	47.6
3.	Facility Prep.	40.0					40.0
4.	Utilities/Supplies	11.0	11.5	12.1	12.7	13.4	60.7
5.	Staff Salaries	40.6	42.6	44.7	47.0	49.4	224.3
6.	Tech. Assistance	100.0	105.0				205.0
7.	Training: Install.	8.0					8.0
	Advanced	6.0					6.0
	Other	10.0	10.5	11.0	11.6	12.2	55.3
8.	Mainten.:Hardware	4.6	9.1	9.6	10.0	10.5	43.8
	Software	2.0	3.0	3.2	3.3	3.5	15.0
	subtotal	322.1	185.8	84.9	89.1	93.7	775.6
9.	Misc./Contg.(10%)	32.2	18.6	8.5	8.9	9.4	77.6
	Total (DIGEBOS)	354.3	204.4	93.4	98.0	103.1	853.2

TABLE 6.1C: ESTIMATED GIS FACILITY BUDGET FOR USPADA

ITEM		1	2	3	4	5	LOP
1.	Hardware	55.4	2.1	2.2	2.3	2.4	64.4
2.	Software	37.0	2.0	2.1	2.2	2.3	47.6
3.	Facility Prep.	40.0					40.0
4.	Utilities/Supplies	11.0	11.5	12.1	12.7	13.4	60.7
5.	Staff Salaries	40.6	42.6	44.7	47.0	49.4	224.3
6.	Tech. Assistance	100.0	105.0				205.0
7.	Training: Install.	8.0					8.0
	Advanced	6.0					6.0
	Other	10.0	10.5	11.0	11.6	12.2	55.3
8.	Mainten.:Hardware	4.2	4.4	4.6	4.9	5.1	23.2
	Software	2.0	3.0	3.2	3.3	3.5	15.0
	subtotal	314.2	181.1	79.9	84.0	88.3	753.5
9.	Misc./Contg.(10%)	31.4	18.1	8.0	8.4	8.8	75.6
	Total (USPADA)	345.6	199.2	87.9	92.4	97.1	829.1

APPENDIX A

LIST OF CONTACTS

USAID/Guatemala	
Mr. Gordon Straub	Chief, Office of Rural Development
Mr. Brian Rudert	ORD
Ing. Mario Aragon R.	ORD
Ing. Edgar Pineda	ORD
Mr. Gary Smith	ORD/USDA
Mr. Tom Ivers	ORD
DIGESA	
Ing. Agr. Max O. Molina	Subdirector General en Funciones
Lic. Saul A Lima Leiva	Coordinador Unidad de Proyectos--UCPC
DIGIBOS	
Ing. Antonio Nisthal	Director General
Lic. Eduardo Cuevas	Subdirector General
Ing. Manuel Aragon	Jefe, Recursos Renovables
Ing. Rudy Cabrera	Jefe, Seccion Cuencas Hidrograficas
USPADA	
Ing. Fernando Vargas	Coordinador General
Ing. Byron Ponce S.	Jefe Centro de Computo
Ing. Roberto Caceres	Cooperacion Internacional
INSIVUMEH	
Ing. Estuardo Velasquez	Director General
Ing. J. Francisco Boshell	Asesor PNUD/OMM Agroclimatologia
Ing. Sergio Hernandez	Jefe Seccion de Hidrologia
Ing. Jorge L Sanchez Garcia	Jefe Seccion de Agrometeorologia
Ing. Rolando Aragon C.	Jefe Seccion de Aguas Subterraneos
Ing. Carlos Cobos	Jefe, Centro de Computo
VICEPRESIDENCIA DE LA REPUBLICA	
Lic. Salvador del Valle M.	Secretario General de la Vicepresidencia
Lic. Armando Maldonado D.	Subsecretario General de la Vicepresidencia

IGM

Cnl. Jorge Mario Morales M.	Director, IGM
Mr. Marcus Anderson	IAGS/DMA Project Chief
Ing. Jose Manual Sanchez	Depto. Estudios Geograficos: Suelos
Ing. Otto Illescas	Depto. Estudios Geograficos: Ecologia
Ing. Aleida Perez	Depto. Estudios Geograficos: Sensores Remotos

DGC

Ing. Miguel Gusman	Jefe, Computo, Caminos Rurales
Mr. Jimmy San Martin	Asesor Principal USAID

DIRYA

Ing. Cesar E. Cisneros A.	Coordinador del Programa Nacional de Riego

LANDIVAR UNIVERSITY

Ing. Carlos Lemmerhofer