GEOGRAPHIC INFORMATION SYSTEM (GIS) DEVELOPMENT AND IMPLEMENTATION GUIDELINE FOR NATURAL RESOURCE MANAGEMENT

By

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GEOGRAPHIC INFORMATION SYSTEM (GIS)

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GUIDELINE FOR NATURAL

RESOURCE MANAGEMENT

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PREFACE

This study was devised to identify natural resource management applications which could benefit from a geographic information system (GIS) and the possible steps that could be taken to develop such a system. This study concentrates on a system to be designed specifically for the applications identified by the interview and survey portion of the study. The case study area used was the Philmont Scout Ranch near Cimarron, New Mexico. It was the goal of this study to identify what planning tasks could benefit from a properly equipped GIS and what types of information, hardware and software would best suit specific applications. This paper can and should be utilized by natural resource management professionals, to prepare themselves for dealing with vendors and GIS software companies when shopping for a system.

I would like to thank all of the staff at Philmont for their assistance and information, in particular Mr. David Bates for his assistance with the questionnaire and video. Each of my committee members certainly must be thanked for their support and guidance. A special thanks to Dr. Lowell Caneday for the guidance and support he provided, without which this work might never have been completed. I would also like to thank Dr. Chris Cashel for stepping in late in this project and aiding it's completion. A very sincere thanks goes to my family for their cooperation and support, my step-father D.J. Walker for the use of his office and computer and helping to proof read this text, my mother Connie Walker for proof reading and moral support and, last, but certainly not least my wife, Shelly, for the encouragement to finish this project.

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CHAPTER I

INTRODUCTION

With a growing population, an increasing concern for the environment and an increase in the participation levels of outdoor recreation, it has become increasingly important to properly manage natural resources (Jenson 1985). To do this, one must deal with a large and diverse amount of information such as: vegetative cover, topography, surface water features, trail information, campsite locations, fire protection/fire danger information, evacuation routing, and anything that could potentially impact the resource or the user of the resource. If managers are to meet the recreational demand for primitive areas, an efficient means of integrating this information is required.

To accomplish such an undertaking, the information must be ordered or referenced by a common denominator. The factor that each of the information requirements has in common is a specific spatial location. The resources utilized for outdoor recreation are generally spatial; lakes, rivers, wilderness areas with trails and campsites can all be referenced by their spatial or geographic location. The function of an information system is to improve the ability to make decisions. It is the chain of operations that takes a user from planning the observation and collection of data, to storage and analysis of data, to the use of the derived information in some decision making process (Calkins and Tomlinson 1977). A geographic information system (GIS) is an information system designed to work with data referenced by spatial or geographic coordinates (Star and Estes 1990). A GIS can be manual or automated. A manual GIS would consist of maps, reports and data summary sheets, while an automated GIS utilizes the computer environment and specific software packages designed to manipulate information found in maps, reports and data summary sheets (Star and Estes 1990). With this information in mind, it is clear that any outdoor recreation planner who utilizes geographically referenced information (information contained in maps, reports and data summary sheets) would benefit by having an automated GIS.

GIS is useful for multi-purpose areas, intensively managed areas and large natural resource areas because of its ability to handle massive amounts of information. As demand for use increases in primitive areas, management informational needs will also increase. The amount and diversity of complex information required for natural resource management is so great that managers and decision makers need a tool for handling information effectively and accurately. Informational needs might consist of topography, surface water, vegetative cover, special features such as campsites or activity areas, or any combination of these or similar items. Within a GIS, information is stored in layers. Each type of information is in its own layer; topography layer, surface water layer, etc. A GIS is capable of data storage, as well as a variety of analytical and statistical calculations. These calculations are often required for management purposes (Herrington and Koten 1988), such as calculating distance from one point to another, determining what points are within certain distances from given identifiable areas, calculating how much resource area (square miles) is present and differentiating between land areas, water surface area or acreage covered by water as well as giving acreage or area measurement breakdowns of different types of land cover.

These analytical and statistical features allow a planner to derive new information from existing information layers. For example, a planner may want to add campsites without overcrowding existing areas. A GIS with the required information could be queried as to possible locations for campsites that meet certain requirements such as: locations with areas of 150-200 square feet, slope less than .033, distance to existing campsites greater than 500 yards and distance to an established trail less than 25 yards. This query would result in a geographical representation of all locations that meet the stated criteria.

Star and Estes (1990) indicate that the initial development of a GIS is not only of utmost importance for the system's effectiveness, but also a procedure that calls for clear and precise planning. Case studies from Star and Estes (1990) indicate that necessary developmental procedures are not clearly outlined. Resource managers are not familiar enough with GIS capabilities and data needs to properly design a system database or select appropriate GIS software packages. Issues of minimum mapping unit and data storage for efficient resource management decisions are cited as difficulties in the selection of GIS software and system design (Star and Estes 1990).

Need for the Study

Natural resource managers lack a guideline for assessing their GIS needs and for assisting in GIS design and implementation decisions. This was demonstrated by Guptill (1989) as he stated that managers are often placed at a disadvantage when faced with problems that could be solved by GIS.

The Philmont Scout Ranch (PSR) has been described as an intensively managed wilderness area, in that it is managed to maintain its primitive characteristics (Clawson 1968). It seems contradictory to refer to a wilderness as being intensively managed. However, with the demand and policy issues that revolve around wilderness areas, it has become necessary to manage all natural resources in some manner. If people are to continue to enjoy the natural environment, that environment and its use must be managed for preservation and conservation of the resource. This is accomplished through careful planning and monitoring of natural resource uses, such as outdoor recreation activities. The Philmont Scout Ranch management goals are to allow each visitor a wilderness-like experience within a primitive area, while maintaining the resource for future generations. The need for such diverse planning and management is the reason Philmont was chosen as a case study site for this project. Some possible GIS applications to meet Philmont's management goals would be itinerary planning, emergency response planning, grazing rotation planning, siting of campsites and trails, maintenance planning for trails, campsites and other facilities.

Purpose of the Study

The purpose of this study is to set forth a guideline for GIS development, define informational needs required for natural resource management decisions and explore GIS applications which could assist a natural resource manager at the Philmont Scout Ranch in the decision making process. All facilities, services, activities and day-to-day ranch operations must be carefully planned and orchestrated to provide the type of visitor experience expected at such a facility.

Study Objectives

The objectives included in this study were to:

1. Identify the resource management departments at the Philmont Scout Ranch.
2. Identify the geographically referenced information that is currently being used for management decisions by each identified department.
3. Identify any other information that could be beneficial for management decisions if incorporated into a GIS.
4. Identify current management needs that could be fulfilled by a GIS.
5. Make provisions in the system design to accommodate future management needs.
6. Outline a procedure for selecting the most appropriate GIS software for the agency's current and future needs.
7. Make provisions for the agency's data entry, implementation and product generation.

The Study Site

The study area for this project was the Philmont Scout Ranch in Cimarron, New Mexico. The following information about Philmont was provided by Mr. David Bates and other Philmont employees representing each department that expressed interest in utilizing GIS.

Philmont is a multi-use outdoor recreation area which is intensively managed to maintain a balance between heavy visitor use and preservation of the natural resource. With an area of nearly 214 square miles, the Philmont Scout Ranch is the largest private camping facility in the world. It serves approximately 18,000 visitors each year from throughout the United States and abroad. The visitors enjoy a near wilderness experience, participating in a backpacking trip into the primitive areas of Philmont. Twenty-eight staffed camps provide the visitor with a variety of programs from horseback riding, to mountain climbing or panning for gold in a mountain stream, to shooting black powder rifles. The backpacking trips cover 50-120 miles through primitive mountain terrain. The trips are planned in advance and a strict itinerary is adhered to for safety and logistical reasons.

Philmont consists of nearly 214 square miles of resource area with 300 miles of trails, 200 plus miles of fence enclosing 65 pastures which are home to numerous livestock including a herd of 350 cattle, 200 horses, 150 burros, and 150 bison. Philmont is also home to a vast array of game animals which are maintained by annual game harvest and management methods. There are 250 acres of farm land rotated among 700 irrigable acres. There are 150-200 miles of roads which are maintained to allow access to areas involved in farming and ranching as well as in cases of emergency assistance to campers or backcountry staff. Other facilities include a trading post at the basecamp and four (4) backcountry trading posts, dining hall, employee store, employee housing, backcountry buildings and improvements, a tent city with some 450 tents for incoming and outgoing campers and many campfire and chapel locations.

All facilities, services, activities and day-to-day ranch operations must be carefully planned and orchestrated to provide the type of visitor experience expected at such a facility. The need for such diverse planning and management is the reason Philmont was chosen as a case study site for this project.

Philmont is somewhat unique in both its management needs and its visitor service oriented goals. While Philmont is a true natural resource to be treasured and preserved, it is also a spectacular showplace where thousands of visitors each year are treated to a personal wilderness experience. These factors make Philmont unique to the point that planning and management of both the natural resource and the visitor activities are critical to efficient operation of such a facility.

Methodology

A phone interview with the program director served to identify the management goals of the individual departments, as well as determine general information about Philmont's management requirements. A detailed questionnaire was then sent to Philmont and distributed to all departments with natural resource management responsibilities. The information generated by the questionnaire served as a cornerstone for defining system requirements. Hardware and software decisions should be based on the identified needs of the departments. This study yielded a guideline for GIS development for natural resource managers. It also yielded suggestions regarding system design requirements and system applications for the Philmont Scout Ranch.

Limitations of the Study

This study only investigated the resource management departments at the Philmont Scout Ranch. Natural resource management needs at other facilities and/or agencies will be somewhat different due to differing management goals and objectives.

This study also deals with rapidly changing technologies in GIS and computer systems. This study is based on information gathered in 1990 and 1991. Computer and GIS technologies discussed in this work may be somewhat different than those available at a more current date.

This study was limited to a phone interview and survey process of only the department heads and key personnel of interested departments at Philmont. Personal interviews were not available and no site visits were made during this research.

CHAPTER II

LITERATURE REVIEW

Basic GIS Concepts

A geographic information system (GIS) is an information system designed to work with data referenced by spatial or geographic coordinates (Star and Estes 1990). The function of an information system is to improve the ability to make decisions. It is the chain of operations that takes a user from planning the observation and collection of data, to storage and analysis of data, to the use of the derived information in some decision making process (Calkins and Tomlinson 1977). With these concepts in mind it can be perceived that a map is an information system, and that a GIS can either be manual or automated. A manual GIS would consist of maps, reports and data summary sheets, while an automated GIS would utilize the environment of a computer and specific software packages designed to manipulate information found in maps, reports and data summary sheets (Star and Estes 1990).

In order to accomplish this manipulation the data must be arranged in some usable format, such as data layers. These data layers exist within the computer and are used to make decisions based on the information contained within the layers. There are two data structures used to store information in a GIS, raster and vector.

Raster data structures utilize a cellular organization of spatial data. In raster format a value is developed and presented for a cell in an array over space. An example would be vegetative cover.

If an area of land is to be represented in raster data structure the space or area of interest is divided into grids thus producing cells that correspond to a spatial location. The vegetative cover of each cell is recorded as having a specific value that reflects a certain type of vegetative cover. For example a grid cell representing a spatial location covered with trees could be represented by a solid black color while a cell representing a spatial location covered with grass could be represented by a light grey color. Values of each cell may be set by the system user to represent as much detail and variation in vegetative cover as the system will allow. If a user desired to differentiate between species of trees, it could be done by setting the cell values to represent that distinction. This type of data structure is very well suited to handle large land areas and utilize less storage space within a system.

Vector data structures utilize coordinate points, in the form of points, lines or polygons to depict spatial information. This structure deals with the elemental points whose locations are known to arbitrary precision.

To contrast vector structure to raster structure using an example of a body of water, the raster depiction of the water would give a somewhat reduced resolution of the boundaries of water and land because a cell can only have one value, that of either the water or the land. On the other hand a vector structure can depict the precise location of the point where the two features meet.

While the vector approach gives more precise information it also requires a great deal more storage space within the system. For example to store a vector image representing a feature larger than a single point, many coordinates must be stored. The more points along a line or polygon that are stored allows for a more precise or detailed representation of that feature. While a raster depiction of the same image will yield less clarity it will require only the value of the cell or cells that make-up the feature.

The issue of raster versus vector data storage may be debated many times with the same end result: each has its distinct advantages and disadvantages. The applications involved, the amount of storage space available and degree of resolution needed will decide which structure is warranted. For the purposes of natural resource management a raster structure may be sufficient, however with the evolution of GIS software to the point of being able to deal with both structures, it is best to utilize both within a single system. This reduces decisions and provides the advantages of each structure.

Antenucci (1991) discusses another point in the debate of raster versus vector, that of data entry. Data entry is many times the most costly step in system design, however there are methods of rapid entry of data. The use of automated scanners to electronically read mapped or photographed information is the most probable method for this study. Scanners are capable of converting information into a raster data structure which is compatible with many types of GIS software. Furthermore, many software packages are able to handle raster and vector data structures. In this case large amounts of information can be converted and stored in raster format and a vector overlay of more precise information allows a user the best of both data structures (Antenucci 1991).

Another feature of a GIS is the relational database, or the attribute information which pertains to the spatial information stored in the data layers of the system. On a paper map as an example, there are a variety of symbols and words that describe the spatial information presented. The relational database for a GIS is like the printed or symbolized information on a paper map.

There are a variety of methods for relational database structure. These deal with how the information is stored and how it is linked to the spatial information that it describes. This is a matter that is best dealt with in the data management portion of system design. The type of relational database that is present within a system will have an effect on system access, speed of information retrieval and data entry and upkeep.

There are five elements of a GIS that are of great importance to consider during the planning stages. They are presented by Star and Estes (1990) as being the functional elements of a GIS. They are data acquisition, preprocessing, data management, manipulation and analysis, and product generation.

GIS Applications in Resource Management

A variety of state and federal resource management agencies are employing GIS. In Maryland, the Department of Natural Resources uses GIS to manage its wetland resource areas (Carr 1989). GIS is being used as an analytical tool to determine the habitat effectiveness for elk populations in the state of Oregon (Eby and Bright 1985). In Ohio, a GIS is being used to store, analyze and manipulate data needed for the implementation of the master plan for the Berlin Lake, Ohio Reservoir Project. Elements included are operation, maintenance, development and management of the United States Army Corps of Engineers Multi-Purpose Reservoir Project (Edwardo et al 1985).

GIS has been used as a fire management planning tool in the San Jacinto Ranger District of the San Bernardino National Forest. The system used was a 3-dimensional representation of the relationship between topographic relief and fire behavior. The integration of these factors have provided managers with the ability to query the system as to the likelihood of fires in different areas. It has also provided the option of using GIS to determine the outcome of various fire management techniques during fire emergencies, thus reducing the time for developing a fire fighting plan (Salazar and Power 1988).

Another 3-D GIS is being used to manage the Yangming Shan National Park in Taiwan. The system is used for change detection, trail design and maintenance, as well as general support for administrative decisions (Wu et al. 1989). The applications of GIS vary from measuring erosion susceptibility (Graetz et al. 1986) to the development of statewide alternative energy surveys (Oliver 1989). Shih (1988) used GIS and satellite data as a means of classifying land-use.

GIS compatibility with other management tools adds functionality to a management system. This allows a manager to link more than one management device and create a more specialized and effective tool for resource management. It is possible to integrate GIS and Soil Conservation Service (SCS) storm runoff volume and peak timing model (Berry and Sailor 1987). This compatibility is also useful in the data entry procedure. Due to the nature of satellite digital information tapes, data may be entered into the system using automated equipment (Lillesand and Kiefer 1987). The integration of certain modeling techniques with a GIS yields an automated method for estimating habitat quality (Lyon et al. 1987). Osborne and Stoogenke (1989) integrated a forest growth model and a GIS to enable them to determine forest profitability over time.

GIS technology is being implemented by a great many natural resource management agencies. The United States National Park Service (NPS) has been using GIS for many years on a small scale. However, since 1987 they have experienced explosive growth in the use of GIS. The use has become so widespread that a Geographic Information Systems Division (GISD) has been established (Waggoner 1991).

The United States Environmental Protection Agency (EPA) has shown varied uses for GIS; air pollution monitoring, monitoring of the Resource Conservation and Recovery Act (RCRA), modeling of scenarios for environmental decision making and habitat identification (Porter 1990, #1). The EPA has also begun a project known as the Environmental Monitoring and Assessment Program (EMAP). It is a long term program designed to monitor status and trends in the condition of U.S. ecological resources (Norton and Slonecker 1991). The EMAP project will use GIS technology to characterize ecological resources and assess environmental problems.

GIS has also become useful to the Army Corps of Engineers. The Office of Environmental Policy has addressed immediate GIS concerns in Corps field offices and a GIS task force has been assigned to the Waterways Experiment Station at Vicksburg, Mississippi. The station has CAD (Computer Aided Drafting) equipment and the task force is dedicated to identifying software advancements that may be needed and to promote information exchange among users (Porter 1990, #2).

Region 6 of the U. S. Forest Service is using GIS in an effort to quantify all vegetation in the region's national forests and parks and to determine how much of that vegetation is old growth (Teply and Green 1991). The South Carolina Water Resources Commission (SCWRC) is conducting a research and demonstration project to develop a GIS for natural resource applications and to examine alternative approaches to managing and regulating the environment. The goal of this project is to unite the two objectives and investigate the use of GIS as a tool for resource management and decision making (Hale et al. 1991).

The EMAP project, as well as many other large scale resource monitoring projects, demands a great deal of information to complete base maps and data layers. That is why most projects of this size frequently use remotely sensed information. The EMAP project compiles data by utilizing multistage remote sensing, storing and analyzing that information in a GIS database along with a variety of existing spatial data sets (Norton and Slonecker 1991). Remote sensing offers many alternatives to mapping vegetation and land-cover. Large-scale aerial photography and satellite digital data have been used for collection of wetland data for the Par Pond on the Savannah River Site in South Carolina (Jenson et al. 1991).

A Wisconsin tourism region made up of a consortium of counties in the northwestern corner of the state alleviated the high cost of data base creation by using U.S. Bureau of the Census's Topologically Integrated Geographic Encoding and Referencing (TIGER) files. Commercial software was used to convert the TIGER files into a usable format for the relatively inexpensive software they had chosen for their system (Foust and Botts 1991).

The initial development of the GIS is the most important step in creating the most effective system for its intended use. Dangermond (1989) outlined a process that can be followed when developing a system for a client. The needs of the user are the most important aspects of the process. Current and future needs should be considered (Sonnen 1987). There are also basic structural differences of GIS technology that must be considered (Star and Estes 1990). "Computerized geographic information systems (GIS) are emerging as the spatial data handling tools of choice for solving complex geographical problems. However, few guidelines exist for assisting potential users in identifying suitable hardware and software" (Guptill 1989 p. 1583). Guptill (1989) also stated that the lack of guidelines for GIS development places many would-be users at a disadvantage when faced with problems that could be dealt with by a GIS. Many uses for GIS are emerging in diverse areas of interest, however two themes for development are true for all applications: 1) how to begin, and 2) what steps should be taken.

The city of Pittsburgh Department of City Planning has determined that the first critical step for them was a needs analysis (Wells 1991). Wells (1991) further stated that with all the confusing claims by vendors and the numerous GIS packages available, an organization interested in GIS must be well prepared and understand their needs in order to choose the most effective software package for their use.

Wilderness and Primitive Lands

The Wilderness Preservation Act of 1964 describes wilderness as "an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." The Wilderness Act set aside specific areas which are to be preserved as pristine. Timber harvest is prohibited and no roads are allowed (Tietenberg 1988). The act also states that, except for emergencies, no temporary roads, no use of motor vehicles, motorized equipment or motorboats, no landing of aircraft, no form of mechanical transportation, and no structure or installation shall be within any wilderness area (Jensen 1985). Wilderness areas are open to hiking and in some cases, horseback riding, primitive camping, and similar pursuits (Jensen 1985). Wilderness areas are public land and are managed by the U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service or, U.S. Bureau of Land Management.

A primitive area is a U.S. Forest Service (USFS) designation for an area within a U.S. National Forest set aside for preservation in its natural condition with no alteration or development beyond fire prevention measures. Natural resource management goals for wilderness and primitive areas are similar in that the intent is to preserve the natural characteristics of the resource while allowing its use or visitation by man.

Philmont Scout Ranch

The Philmont Scout Ranch, located near Cimarron, New Mexico, consists of nearly 137,000 acres. It is the largest privately owned camping facility in the world (Wikle and Bryant 1991). A large part of the ranch was a gift to the Boy Scouts of America from oilman Waite Phillips, who had used the ranch as a hunting area (Clawson 1968). While the ranch would not qualify as a wilderness area under the Wilderness Act of 1964 or a USFS Primitive Area, Clawson

(1968) indicates that the scouts consider the ranch a wilderness and make a conscious effort to maintain its primitive and natural character.

The ranch is visited by 17,000-20,000 people every summer. Over 600 seasonal employees staff the ranch and its many program areas. This staffing level and visitor use are the primary reasons that Philmont has been termed "an intensively-managed Wilderness" (Clawson 1968, p. 21). It is the high volume of use and the management goals to maintain Philmonts primitive and natural characteristics that require this natural resource to be intensively managed.

CHAPTER III

MATERIALS AND METHODS

Instrument

The instrument and methodology on which this study was based was an interview and questionnaire process of the administrative department heads who have resource management responsibilities. Initial contact with Philmont personnel was made in September of 1990 to present this project to the Philmont management. A preliminary request for departmental information was made in November of 1990 and requested information was received in December of 1990. This information was used to determine which Philmont departments would be involved in the study and which department heads would be contacted. Phone interviews were conducted during December of 1990. The information obtained from the initial contact, request for departmental information and from the phone interviews were used to develop the GIS Needs Survey. The survey was developed to determine the geographically referenced information that is currently used, as well as to determine if any additional geographically referenced information would be useful in making management decisions. Questionnaires were distributed to the program, ranch and maintenance departments in March of 1991. The questionnaire was made up of both rank order choice questions and open ended list or opinion questions. A copy of the GIS Needs Survey is included in the Appendix of this text.

Procedure

After initial contact and the request for departmental information, a phone interview with the program director served to identify the management goals of the individual departments. This was done to identify the types of geographically referenced information that each department would most likely utilize in their management decisions. Based on responses from Philmont personnel in the initial information gathering process, it was decided that basic GIS education would assist the Philmont staff in completing the GIS Needs Survey. A videotape was used to help Philmont managers understand how a GIS could benefit their resource management efforts. A detailed questionnaire was then sent to each department, from which the required information layers can be determined. The management goals of each department were considered and pertinent information to achieve those goals should be included in the system. Attention should be given to the development of a system that would most effectively meet the needs of the managers and planners. Hardware and software decisions should be based on the identified needs of the departments. The products of this study are suggestions regarding system requirements and system applications that would be useful for managers and planners for the development and implementation of a GIS.

CHAPTER IV

FINDINGS

Information was gathered from department heads and key personnel of Philmont departments who are responsible for natural resource management at the ranch. Information gathered from the interview process as well as from the GIS Needs Survey are presented here with discussion about specific GIS applications and system requirements.

An initial phone interview with the program director resulted in a determination that some basic GIS education for Philmont staff would be required. Which was accomplished by sending a video cassette tape dealing with GIS applications in the National Park Service. The tape discussed various applications as well as basic GIS concepts, which were presented in chapter two of this text, in order to familiarize the reader with GIS requirements.

The video tape was used for this study to show the departments and potential users what they might expect from a GIS and to provide basic GIS education. This was done to give the users a better idea of what kinds of information would be needed for the system and what kinds applications they would have for a GIS. The education phase was implemented when it was determined that the staff was very interested in GIS, but had little understanding of what was involved in the development, or use of such a system. This step proved beneficial for enhancing the quality of information received from the questionnaire. Most departments were able to understand what information would be useful and what would not be needed for their particular operation. The questionnaire was also useful in determining the management objectives, the data sources and, the GIS applications that each department would have.

Departmental Overview

From the interview it was determined that three Philmont departments had interest in and applications for a GIS. These departments consist of the programming, ranching, and maintenance departments. Each of these departments have a wide range of needs and uses for a GIS. Organizational needs, goals and responsibilities are important considerations for system development.

Program Department. This department is concerned with the visitor use of the ranch. GIS uses for this department would be a vast array of applications. Such uses could be to develop and display maps of backcountry camps or to determine and display a variety of possible routes from one camp to the next. A desire to produce customized maps of special interest areas was also expressed. Any of a great number of questions about itineraries could be answered and graphically displayed with a properly designed GIS. Map production output plays a large part in what this department wants from a GIS, therefore this must be included in a plan for the development of the system and the arrangement of hardware and peripheral equipment.

Ranch Department. This department is responsible for the management of the natural resource itself; wildlife and, farming and ranching operations. Therefore the main information interest is in the areal features; trees, vegetation, soil type, slope, flood zones etc. These are the items that are frequently used in their day to day operation. Therefore these are the types of information layers that most concern the ranching staff. Many linear features were also identified as being essential to ranching operation. Identified GIS applications were the display of road locations, vegetation type or ground cover, the making of maps with specific topics; pasture use, stocking rates etc.

Maintenance Department. Due to their responsibility for facility upkeep and maintenance this department was primarily interested in location based information, buildings, utility lines and permanent improvements. They also use some attribute information about the linear or point features, such as depth/height, voltage/flow pressure and maintenance rotation. GIS applications include display of buildings for maintenance, display of fire routes, display of utility lines and display of structure design. This department also expressed interest in GIS applications for inventory purposes.

Questionnaire Results

The questionnaire served many purposes, of which the most important was identification of information layers are needed for this system. This was achieved by asking if certain linear, areal and point features would be essential, very useful, useful or not applicable. These categories were defined: essential being information that is essential to the operation of the department; very useful being information that is used or could be used for daily, weekly or monthly decision-making; useful being information with limited utility for decision-making or information that is used infrequently; not applicable being information that is not used by that department. The GIS Needs Survey is included in the Appendix. Survey results are summarized in the following tables.

TABLE I

LINEAR SPATIAL DATA: IMPORTANCE COMPARISON BY DEPARTMENT.

DATA LAYER	ESSENTIAL	VERY USEFUL	USEFUL	NOT APPLICABLE
Property Boundary	P,R	M		
Ranch Internal Boundary	R	P,M		
Wilderness Boundary	P			R,M
Trails	P		R	M
X-Country Ski Trails			P	R,M
Perennial Streams	R	P		M
Intermittent Streams	R	P		M
Fire Access Routes	R,M	P		
Contour Lines	P,R		M	
Electric Lines	M	P,R		
Water Lines	M	R	P	
Sewer Lines	M		R	P
Gas Lines	R,M			P
Cattle Fences	R		P	M
Fire Evacuation Routes	R	P	M	
Crew Itinerary Routes	P		R,M	
U.S. Routes	R	P	M	
State Routes	R	P	M	
Improved Roads	R	P	M	
Unimproved Roads	R	P	M	
Fire Breaks	R	P	M	
Horse Trails	R	P	M	

R, Designates the Ranch Department
P, Designates the Program Department
M, Designates the Maintenance Department

TABLE II

LINEAR ATTRIBUTE DATA: IMPORTANCE
COMPARISON BY DEPARTMENT.

DATA LAYER	ESSENTIAL	VERY USEFUL	USEFUL	NOT APPLI-CABLE
TRAILS				
Elevation Change		P	R	M
Maintenance Rotation		P	R,M	
ELECTRIC LINES				
Voltage	M		P	R
Underground/Overhead	M	P		R
Depth/Height	M		P	R
WATER LINES				
Flow Pressure	M	R	P	
Depth	M	R	P	
SEWER LINES				
Diameter	M		R	P
Depth	M		R	P
GAS LINES				
Diameter	R,M			P
Depth	R,M			P
CATTLE FENCES				
Maintenance Rotation				R,P,M

R, Designates the Ranch Department
P, Designates the Program Department
M, Designates the Maintenance Department

TABLE III

POINT SPATIAL DATA: IMPORTANCE COMPARISON BY DEPARTMENT.

DATA LAYER	ESSENTIAL	VERY USEFUL	USEFUL	NOT APPLICABLE
Parking Areas		R,P,M		
Trail Signs	P		R	M
Springs	R,P	M		
Trail Bridges		P	M,R	
Camps	P		M,R	
Building Locations	M,P		R	
Stock Tanks	R		M,P	
Other Permanent Improvements		R,P,M		
Fire Station Location		R	P	M
Programs		P	M,R	
Road Gates	R	P	M	
Cattle Gates	R		M	P
Water Wells	M,P	R		
Bench Marks	R		M,P	
Mountain Tops	P	R	M	
Commissaries		P	R	
Storm Drains	M,R	M		P
Garbage Dump	M,R			P
Mine Shaft Openings	M,R	P		
Pit Toilets	M,P		R	

R, Designates the Ranch Department
P, Designates the Program Department
M, Designates the Maintenance Department

TABLE IV

POINT ATTRIBUTE DATA: IMPORTANCE COMPARISON BY DEPARTMENT.

DATA LAYER	ESSENTIAL	VERY USEFUL	USEFUL	NOT APPLICABLE
CAMPS				
# of Staff		P	M,R	
# of Campsites	P		M,R	
BUILDING LOCATION				
Type of Structure	M	P	R	
Maintenance Rotation	M	P	R	
STOCK TANKS				
Volume	R		M,P	
PROGRAMS				
# of Participants		P	R,M	
Program Times		P	R,M	
ROAD GATES				
Access Controlled	R	P	M	
CATTLE GATES				
Access Controlled	R		M	P
WATER WELLS				
Maintenance Rotation	M	R,P		
BENCH MARKS				
Elevation	R		M,P	
MOUNTAIN TOPS				
Elevation	P	R	M	
PIT TOILETS				
Maintenance Rotation	M	P	R	

R, Designates the Ranch Department
P, Designates the Program Department
M, Designates the Maintenance Department

TABLE V

AREAL SPATIAL DATA: IMPORTANCE COMPARISON BY DEPARTMENT.

DATA LAYER	ESSENTIAL	VERY USEFUL	USEFUL	NOT APPLI-CABLE
Tree Species	R	P		M
Watershed Areas	R			P,M
Land Cover	R	P		M
Soil Types	R	P		M
Flood Zones	R	P		M
Slope Orientation	R	P		M
Lakes	R,P		M	
Subsurface Geology		R	P	M
Slope (angle)	R	P		M

R, Designates the Ranch Department
P, Designates the Program Department
M, Designates the Maintenance Department

These data layers provide information required for applications in all departments, however, the importance varies from one department to the next. The variance must be closely scrutinized when deciding what information layers are chosen for inclusion in the system.

The program department is interested in spatial and attribute information, that is the location of features and information about those features, such as where certain features are located in relationship to other features. For example; where trails are located in reference to campsites and program areas. A major application of interest to this department is visitor itinerary planning. Factors involved in this application include trail location, contour information, campsite location, program site locations and distance between these features.

To accomplish itinerary planning, all of these information layers are used to determine possible hiking routes from campsite to campsite or from campsite to program area. Routes may be selected based on distance and difficulty by overlaying trail location information and contour information. By doing this the degree of difficulty, length or any combination of variables may be chosen.

While spatial information is all that is required for such a simple application, attribute data would benefit the decision making process and increase the planning capabilities. As in the previous example, locations of trails, campsites and, program areas do not give attribute information such as trail condition, maintenance rotation, program times or, number of participants. By adding attribute information a more effective decision could be made. An itinerary planning decision could be made as to what program areas a visitor crew could reach by the program starting time and schedule an acceptable number of visitor participants for any given program. It is this type of planning capability that is required to meet the goal of the Philmont program department to provide each visitor with a wilderness like experience.

The ranch department utilizes both spatial and attribute data. It differs from the program department by indicating that areal data as well as linear and point data is of importance to their function. This departments interest in the areal features is expected as they are the natural features such as; tree species, watershed areas, land cover, soil type, etc. These features hold more importance to the ranch department than they do for the program or maintenance departments, because they are more in line with the management objectives of the ranch operation. Although areal features are important so to are linear feature such as: cattle fences, roads, streams, contour lines, various Philmont boundaries, fire access routes and, fire breaks. Applications such as: calculating stocking rates for pastures, calculating pasture area, inventory of pastures by name, generating custom maps for vegetation type, ground cover or road locations and, estimating fuel loads relating to vegetative types. These applications, like those of the program department, require overlays of many layers of information.

The maintenance department indicated more emphasis on attribute data than did the other departments. This follows well with their desired applications and their objectives. They are concerned with the upkeep and maintenance of Philmont facilities, therefore they are interested in conditions or descriptions of features as well as locations. The maintenance department listed applications such as: maintenance rotations for buildings and facilities, inventory of facilities and utility lines and, display of scheduled improvements. These applications call for spatial data for utility lines, buildings and, facilities such as: storm drains, garbage dumps, mine shaft openings and, pit toilets. These applications also call for attribute data corresponding to the spatial features such as depth, height, voltage, flow pressure and, diameter of utility lines; or maintenance rotation for buildings and facilities. While this department indicated the least amount of applications for a GIS, they did list one of the most common uses for a system, inventory. This is a common and significant use for a GIS in regard to facility maintenance or management. In order to make decisions about facility maintenance and planning, an accurate account of facilities and equipment present is essential.

By utilizing the information presented in tables I-V management departments at Philmont can accomplish the applications for which the system is designed. However, for system design information layers must be reviewed based on actual need. That is all data layers listed in the GIS Needs Survey will not be included in final system design. Only that information required for user applications or that information that is deemed justifiable based on its' potential benefit to the system and its' relative cost of input. In other words, information such as, subsurface geology is not essential to any department and it is a high input cost data layer, therefore, it should not be included in the system. On the other hand, information such as number of staff at a campsite is not essential to any department but it is a low input cost item, therefore it would be appropriate to enter this data into the system. Furthermore, information to be entered into the system does not have to be considered essential by a department. If the information is very useful to more than one department and if the cost of data input is low, then that information may be chosen to be included in the system.

All potential data layers must be considered in such a manner before final system data layers are determined. This review of potential data layers may not be feasible until after other steps of system design are complete or at least underway. For example, the cost of data input may not be known until after data acquisition has begun. Some data that is very useful may be difficult to gather or input into the system, this would increase the cost of system development. It is possible to do a preliminary selection of data layers based on the GIS Needs Survey. This preliminary selection will allow for data acquisition to begin. A final selection of data layers will be based on judgement of the relative cost of data and the relative worth of that data to overall system performance.

A preliminary selection of data layers required for the Philmont system, based on the GIS Needs Survey, is presented in Table VI and Table VII. A further consideration regarding data selection, is what information must be entered and what can be derived from overlays of other data layers. These tables also indicate what data must be entered and what may be derived from other data layers.

TABLE VI

SPATIAL DATA RECOMMENDATIONS
AND INPUT REQUIREMENTS.

DATA LAYER	ENTERED	DERIVED
Property Boundary	X	
Ranch Internal Boundary	X	
Wilderness Boundary	X	
Trails	X	
Perennial Streams	X	
Intermittent Streams	X	
Fire Access Routes	X	
Contour Lines	X	
Electric Lines	X	
Water Lines	X	
Sewer Lines	X	
Gas Lines	X	
Cattle Fences	X	
Fire Evacuation Routes	X	
Crew Itinerary Routes	X	
U.S. Routes	X	
State Routes	X	
Improved Roads	X	
Unimproved Roads	X	
Fire Breaks	X	
Horse Trails	X	
Tree Species	X	
Watershed Areas		X
Land Cover	X	
Soil Types	X	
Flood Zones		X
Slope Orientation / Angle		X
Lakes	X	

TABLE VI (Continued)

DATA LAYER	ENTERED	DERIVED
Parking Areas	X	
Trail Signs	X	
Springs	X	
Trail Bridges		X
Camps	X	
Building Locations	X	
Stock Tanks	X	
Other Permanent Improve-ments	X	
Programs	X	
Road Gates		X
Cattle Gates	X	
Water Wells	X	
Bench Marks	X	
Mountain Tops		X
Commissaries	X	
Storm Drains	X	
Garbage Dumps	X	
Mine Shaft Openings	X	
Pit Toilets	X	

TABLE VII

ATTRIBUTE DATA RECOMMENDATIONS
AND INPUT REQUIREMENTS.

SPATIAL DATA FEATURE ATTRIBUTE DATA	ENTERED	DERIVED
TRAILS		
Elevation Change		X
Maintenance Rotation	X	
ELECTRIC LINES		
Voltage	X	
Underground/overhead	X	
Depth/Height	X	
WATER LINES		
Flow Pressure	X	
Depth	X	
SEWER LINES		
Diameter	X	
Depth	X	
GAS LINES		
Diameter	X	
Depth	X	
CAMPS		
# of Staff	X	
# of Campsites	X	
BUILDING LOCATION		
Type of Structure	X	
Maintenance Rotation	X	
STOCK TANKS		
Volume	X	
PROGRAMS		
# of Participants	X	
Program Times	X	

TABLE VII (Continued)

SPATIAL DATA FEATURE ATTRIBUTE DATA	ENTERED	DERIVED
ROAD GATES		
Access Controlled	X	
CATTLE GATES		
Access Controlled	X	
WATER WELLS		
Maintenance Rotation	X	
BENCH MARKS		
Elevation		X
MOUNTAIN TOPS		
Elevation		X
PIT TOILETS		
Maintenance Rotation	X	

This distinction is important in system design because it directly affects the cost of system development. Data layers that are selected for use in the system must be resident in that system for them to be utilized. The method by which they are entered is important, as it effects the cost of data input and in turn the cost of the system. Any data layers that can be derived from other layers reduces overall system cost. For example the spatial data information about flood zones may be derived from contour (elevation) information. All areas that meet certain elevation criteria, for flood zones (100 years, 500 years, etc.), would be considered area in a flood zone. This information does not need to be manually entered into the system, thus reducing input time and cost. Other information such as: watershed areas, slope, road gates, trail bridges, mountain tops and, elevation of specific features can be derived from data layers that are manually entered into the system. This ability of a GIS allows for future expansion of data layers as system query results are stored as new data layers.

Data Sources. Data sources listed by the Philmont staff consist of: the SCS Conservation Plan and Multiple Use Plan, the Colfax County Soils Survey, aerial photos, the Limited Fuel Load Survey, the State Engineer Water Permits, the SCS Basin Outlook Reports, USGS maps of Philmont and, Philmont facility blueprints.

System Design Requirements

The data acquisition element could include the needs survey, from which the data or information that is desired for a GIS is determined. While the informational needs will vary from one organization to another, the use of a survey to obtain those needs will not change. When the needed information is determined, the actual acquisition or gathering of the data may begin. This will involve a variety of procedures depending greatly on the type of data to be collected. In the case of Philmont, utilization of data that has already been collected, existing maps, aerial photos and reports, shall be essential in keeping system costs to a minimum. This would be done primarily due to the high cost of generating new data from field observations or remotely sensed images. Automated scanning equipment may be used to alleviate data entry costs as well.

Data acquisition for Philmont will consist of gathering all maps, photographs and blueprints of facilities needed to meet the informational needs expressed by individual departments. For example; the program department expressed interest in using the system for crew itinerary planning, for this application all pertinent information, such as trail, contour, elevation, campsite and commissary information must be acquired. This information is then preprocessed and entered into the system. Data sources are important in that the quality and accuracy of system output is totally dependent upon the quality and accuracy of system input. All departments listed a variety of sources of geographic information that are currently used, primarily the USGS map of Philmont, which is in three sections at a scale of 1:24000. Updates of a Philmont map at a scale of 1:4000 should also be utilized. These maps have current revisions dated March 1991. Soil Conservation Survey maps and reports were listed as a major source of information along with various blueprints and Philmont plans. Aerial photos, county soil surveys, multiple use plans and State Engineer Water Permits were also among the list of source materials.

The preprocessing element involves two key aspects, data format conversion, and identification of object location on original data in a systematic manner. This is often the most costly in both time and money. However, it is also where shortcuts could prove to be even more costly. The finished system will be only as good as the information entered into the system at this point in development. The example of the program department's need for itinerary planning may be applied to preprocessing. The identified information layers and data required for these layers are converted to the proper format from the original source. This involves extracting the needed information from maps, photographs and printed records, then storing the information in the computer database. Information is stored in relation to the geographic location for which it corresponds, be it a point, line or polygon. Properly constructed data layers are very important to final system performance. In order to accomplish this, the intended applications must be understood and all required information needed to complete an application must be present in the system. A manager must ask what types of questions will the system need to answer, and provide the system all the information layers needed to answer the questions. Therefore, if the need for complex analytical capabilities is determined, then sufficient data for these operations must be present in the data layers.

The Philmont system should not be required to make any such complex calculations. This system should remain as simple as possible to promote a higher degree of user satisfaction. One function suggested for this system is the ability to handle both raster and vector data. This element has a great deal to do with the most effective selection of data layers as well as checking the accuracy of data sources. Departments must strive to minimize data layer duplication. It is for this reason that a detailed GIS needs survey be completed, and all persons involved take an active role in selection and development of the information layers to be used in the system.

The data management element involves the creation of and access to the database. Database management systems are the software that allows users to work with the data within a system. It should provide a method for defining the contents of the database, entering new information, updating existing information, queries about the contents of the database and modifications to the database. This should be dealt with when deciding what type of software best suits the environment for which it will be used. Database management functions make the information available to the user (Star and Estes 1990). It operates as a safeguard or security system for the GIS. It is meant to separate the user from data storage functions. This allows for data entry, update and retrieval to be done only when authority for such action is approved, while allowing the everyday use of the system.

The database will consist of attribute data which corresponds to spatial information in the data layers. The earlier discussion of spatial data structures, raster vs. vector, is sufficient to determine what structure is best suited for the intended applications. As previously stated, much of the commercially available GIS software is capable of utilizing both structures. For Philmont's applications it would be advantageous for the system to be capable of using both raster and vector data structures. This allows a user the advantages of both structures. As with spatial data structures, a detailed understanding of the relational database structure is not required for system development. However, a basic knowledge of the effects of the data structure on the operation of the system are important. The data structures, both spatial and relational will allow the user to access logical information needed to accomplish specific applications (Star and Estes 1991). The arrangement of the information, how it is stored within the system, will affect the speed of information retrieval as well as information update. It will also affect the amount of space needed to store information within the system. Raster structure allows for large amounts of spatial information to be stored using minimal storage space, while vector structure requires more storage capacity. Data management and structure of the databases within a system are closely linked to system configuration and shall be further discussed in that portion of the text.

The element of data management is addressed at the vendor level when deciding on what type of GIS software to purchase. The needs of the user and number of users accessing the system must be considered when database management decisions are made. System update, information input and system security are important aspects of database management and should be considered carefully when making software choices.

The manipulation and analysis element is a system user concern which should be considered from the beginning steps of system development. This is the portion of the system that allows the user to derive new information from existing data layers. This is useful to consider in development stages so that time is not spent entering data layers which could have been derived from other layers. With this in mind it is possible to trim the cost of the initial data entry or preprocessing step of development. This step also has impact on the decision of software for the system. Increased user demands and system applications may be called for at some time in the future. It is this concern and foresight that will enable a manager to chose a system design and software that has the adaptability to remain a useful management tool.

Product generation is the final system element, mentioned by Star and Estes (1990). This aspect will greatly enhance the usefulness of the system. This element will determine what types of information and in what forms that information will be generated as output from the system. Whether it is statistical reports, maps, or other forms of output, it must be decided upon prior to software/hardware purchase and system implementation. An example would be that of the program department application of itinerary planning, it would be of great importance for the system to have the ability to output information in map format. This type of output must be considered during development stages when considering system software and hardware. Detailed mapping capabilities must be present in the system if this application is to be accomplished. The hardware for map production must also be present for this application.

In addition to these elements, a manager must address agency or facility specific GIS development concerns, such as system hardware, software, and configuration. System hardware and software concerns are dealt with by understanding the number of users, number of user stations, and the application requirements of those users with regards to system interaction and product generation. Data storage and software specifications are concerns for hardware considerations. These decisions must be planned early in the preparation process, however, final hardware choices are dependent on applications and software requirements. Each software vendor will specify what hardware is needed for desired applications and individual software packages. For example a software package that is incapable of map production would not require sophisticated output equipment like a plotter. On the other hand a software package that requires 50 megabytes of storage could not be run on a PC with two floppy disk drives. These concerns may sound trivial, but it is best to be aware that not all software can be run on all hardware. This is a concern that should be dealt with when vendor information is being considered.

System configuration must be addressed when developing a multi-user system. System access issues must also be addressed. This deals with the topic of database management that was previously discussed. Information update must be done on a routine basis to allow for an accurate depiction of real world information. For example trails will change due to maintenance and natural occurrences, such as erosion or rockslides. The trail information must be kept up-to-date if accurate information is to be generated by the system. In order to maintain system security, database alteration should only be possible at one location by authorized database management personnel. This concern is best dealt with during hardware configuration.

Many different configurations are possible. Configurations will vary from agency to agency, due to the variation in user needs and system applications. At this early stage in system development for Philmont no definite configurations can be made, due to the dependence which lies upon software. However, a discussion of configurations used in other natural resource management agencies is applicable and will give some insight into possible choices for configuration.

The South Carolina Water Resources Commission (SCWRC) system configuration consists of a VAXstation 3500 and a VAX8350 minicomputer. However, the 8350 is also used for other agency programming, modeling and statistical analysis, which causes system degradation during peak use times. This agency plans to upgrade to a VAX 4000 server and DECterminal workstations, which will allow increased use and productivity during peak use times (Hale et al 1991).

The Pittsburgh Department of City Planning also utilizes a workstation configuration for their system (Wells 1991).

The New Zealand Department of Survey and Land Information (DOSLI) is a very large agency with a great many users. They solicited for bids worldwide from software and hardware vendors for their system components. After careful evaluation they decided upon a VAXstation and DECstation configuration which includes 54 VAXstation 2000 and DECstation 2100, 3100, and 5000 data capture workstations using DECNet Lan software to network each office. Due to the size of their agency, number of users and required applications they incorporate 27 digitizers and 13 plotters between 27 district offices (Crowe 1991). Another large agency utilizing the workstation approach to system configuration is the Australian Department of Lands, Division of Information (Varthas 1990).

These examples show the variety of software and hardware vendors that provide services to GIS users. The relevance to the Philmont system is that each agency, at its own level of involvement, is using GIS for similar applications as were expressed by Philmont staff. It might therefore be determined that a similar configuration could be used at Philmont. A central serving unit with user capabilities might be placed in the department with the greatest use for the system, the program department, and workstations in all other departments linked by software that will allow each department access to the system. Hardware required for data input and output, digitizer and plotter, might be best suited for the program department as well, with each department having its own printer for report generation and data output. System maintenance and upkeep could be done at the central location by the database manager. This will allow for a higher degree of control over information alteration by the database manager, while allowing individual users the freedom to access needed information on a daily basis. It also alleviates the user from the responsibility of system maintenance.

The hardware configuration of the system can take many shapes, each of which has its advantages concerning the data management, manipulation and, analytical functions of the system. One configuration would be separate computer systems in each department with each having full responsibility for data entry, manipulation and system maintenance. This would be the most costly and most time consuming method of configuration.

A more effective method would be that of the work-station previously mentioned in this section. The program department expressed interest in using the system in crew itinerary planning and monitoring. This task shall require more frequent data manipulation and product generation. It is for this reason that the previously mentioned configuration might be advantageous to relieve the cost of the systems peripheral equipment, such as digitizers and plotters that would be required for the production of detailed maps with custom information. Since the ranch and maintenance departments will also desire such output, but on a much less frequent basis, they will be able to accomplish this through the linkage of the workstations to the central unit. This configuration would also allow for a more accurate and manageable means of system update. It is also highly likely that a database manager be employed to update the system and accomplish more complex functions of the system. It would be more cost effective to have one individual who would be devoted to maintaining the system and be highly trained in its function and use. This will greatly enhance the quality of information that may be derived from the system.

The database manager would be responsible not only for system operations, but also for initial training of other users as well as trouble shooting for less experienced users. The workstation approach to system configuration will allow the individual departments greater access to the system during peak use periods. This is an important factor to consider during system design as was evidenced by Crowe (1991). If only one stand alone system were used it could be tied up much of the time doing system upkeep and specific applications for one department. Multiple access to the system is a concern when choosing system hardware, a central serving unit must be capable of handling multiple users.

CHAPTER V

Conclusion and Recommendations

Study Summary

The study yielded suggestions and basic information to be utilized by a decision maker in the process of GIS design and implementation. This text discusses the concerns that must be addressed for GIS development as well as methods by which a manager could determine system design requirements. The study also yielded the clear need for general GIS education of potential users. From the interviews and surveys of Philmont staff, it was clear that, while the interest in this technology was high, the knowledge of it was very low.

The purpose of this study was to develop a guideline for the development of a GIS for natural resource managers. In doing this many elements were discussed and concerns for system design were expressed. It was not the purpose of this study to design a complete system for natural resource managers. This study could be utilized as a model for GIS requirement determinations for natural resource managers. The steps taken in this study are the same as would be required for any natural resource management agency.

The following steps were necessary to complete the assessment of implementation requirements.

Step one:

Determine what departments could best utilize the capabilities of a GIS.

Step two:

Educate the potential users about the basic concepts of GIS and potential applications specific to their needs.

Step three:

Determine natural resource management goals and objectives for each specified department.

Step four:

Conduct GIS needs survey of potential users.

Step five:

Identify system requirements based on information gathered in previous steps.

Conclusion

Final decisions about system design should be based on information obtained from this process. The data layers for the system should be chosen from the information gathered by the GIS needs survey. This should be accomplished by meeting with all potential users for a discussion about specific management tasks that could realize a benefit from the system which warrants inclusion in the system. In other words, determine specific system design requirements based on the information gathered in the GIS Needs Survey and the knowledge of system requirements gained from GIS Education. They must then determine exactly what information the computer will need in order to accomplish the tasks that are needed. This is done by thoroughly examining what information is needed to solve a given problem. They must then decide what source information is available and what additional sources are needed. In system design everyone involved must strive to minimize duplication of information layers. It is for this reason that a series of meetings between the potential users of each department be conducted to decide what layers each department needs and organize the data acquisition and data entry. It is very possible that one department may require data layers that can be derived from another department's data layers. Cooperation is essential at the beginning stages as well as throughout the implementation and life of a system. Each department can share and benefit from the trading of information within the framework of a GIS.

Final decisions regarding system requirements and design are beyond the scope of this study. As an outside party, it would not be possible for this study to make conclusive system requirement decisions. These decisions must be based on cost benefit analysis of implementing such a system. However, with the system specifications derived from this guideline, a manager is no longer placed at a disadvantage. The manager knows what decisions could be enhanced by a GIS and what considerations are relevant to his/her GIS application needs. The real product of this study is a process by which a resource manager can become aware of specific GIS possibilities within his/her organization and what types of decisions must be made to begin system design and implementation. The process of this study does not and could not make definitive decisions, however if a resource manager were to take this study and the information derived from it, then sound knowledge based decisions could be made.

Recommendations

This project yielded specific recommendations for system design at Philmont. In the text of this paper many hardware configurations were discussed. Upon completion of the interview and survey process it is recommended that the Philmont system be easy to implement, easy to use, have map production output capabilities, and be flexible for future expansion.

The major recommendation of this study is the implementation of the following steps by Philmont personnel.

Step one:

Determine what departments could best utilize the capabilities of a GIS.

<u>Step two:</u>

Educate the potential users about the basic concepts of GIS and potential applications specific to their needs.

<u>Step three:</u>

Determine natural resource management goals and objectives for each specified department.

<u>Step four:</u>

Conduct GIS needs survey of potential users.

<u>Step five:</u>

Identify system requirements based on information gathered in previous steps.

A general recommendation of this study is to develop a PC based GIS system. There are many capable PC based GIS software packages on the market. It is recommended that a software package that is versatile, easy to use, compatible with popular database software, and able to run on an IBM-compatible microcomputer be chosen. A 386 IBM-compatible or greater with 200 megabyte hard drive would be sufficient, if it is dedicated as a GIS use only system. A color printer or plotter would be ideal for map production, but a laserjet printer would be capable of limited map production. A digitizing table would be needed for data entry and updating of information. Initially the software could be run on one computer located most likely in the department expressing the greater interest and most diverse applications, the program department. Here all initial data entry would take place. Either of two approaches to system configuration would then be appropriate: 1) stand alone systems resident in each of the three departments, or 2) a Local Area Network (LAN) system with a central serving unit and PC workstations at each department.

Data entered into the initial system could be accessed through the LAN or loaded onto the stand alone PCs. Ideally a system manager, a person dedicated to system operation and up-keep, would be the primary operator. This person should be someone experienced with GIS and knowledgeable of Philmont activities and natural resource management principles. Upon developing a system to the point of either system configuration, the system manager could train other Philmont staff in the departments that will use the system.

Another, somewhat less costly approach would be to have only one system resident in the program department. With the system in place and performing Program department applications during peak visitor periods and Ranch and Maintenance applications during other periods. This configuration would allow for a more detailed study of system use by the Philmont departments. If the frequency of use is great enough in all departments then the system can easily be expanded. This expansion could take shape in one of the many possible configurations and the decisions could be based on the frequency of system use required by any individual department.

The greatest cost, in both time and money, will be in data acquisition and input. Once this is completed the system can be expanded in any of the configurations mentioned with minimal cost. Initial data entry should be done at one system location to allow for greater quality control of information input.

Recommendations regarding information layers required for the Philmont system are presented in Table VI and Table VII. While nearly all information included in the GIS needs survey was useful to one or more department, the information listed in these tables is a preliminary selection of required data. A final decision will be made after data acquisition, which must be done by Philmont staff during actual system implementation.

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APPENDIX

GIS Needs Survey

GIS Needs Questionnaire
Philmont Scout Ranch

Name: Dave Bates Title: Director of Program

Department: Program Size of Staff: 6 year round 550 seasonal

Please indicate the geographic information used by your department by placing a check in the appropriate column. Information that describes geographic data is called "attribute" information and is indicated by a "-" sign.

PLEASE ADD TO THESE CATEGORIES AS YOU SEE APPROPRIATE!!!

Use the following criteria for evaluating the usefulness of the information:

essential: information that is essential to the operation of the department.

very useful: information that is used or could be used for daily, weekly or monthly decision-making; information that is highly desirable.

useful: information with limited utility for your decision-making; information that is used infrequently.

not applicable: information not used by my department.

LINEAR FEATURES

	essential	very useful	useful	not applicable
property boundary	(✓)	( )	( )	( )
ranch internal boundaries? Nairn Place?	( )	(✓)	( )	( )
wilderness area boundary Valle Vidal & Barker Wildlife Area & Cimarron Canyon	(✓)	( )	( )	( )
trails	(✓)	( )	( )	( )
- elevation change	( )	(✓)	( )	( )
- maintenance rotation	( )	(✓)	( )	( )
X-country skiing trails	( )	( )	(✓)	( )
perennial streams	( )	(✓)	( )	( )
intermittent streams	( )	(✓)	( )	( )
fire access routes	( )	(✓)	( )	( )
contour lines	(✓)	( )	( )	( )
electric lines	( )	(✓)	( )	( )
- voltage	( )	( )	(✓)	( )
- underground or overhead	( )	(✓)	( )	( )
- depth	( )	( )	(✓)	( )
water lines	( )	( )	(✓)	( )
- flow pressure	( )	( )	(✓)	( )
- depth	( )	( )	(✓)	( )

GIS Needs Questionnaire
Philmont Scout Ranch

	essential	very useful	useful	not applicable
sewer lines	( )	( )	( )	(✓)
- diameter	( )	( )	( )	(✓)
- depth	( )	( )	( )	(✓)
gas lines	( )	( )	( )	(✓)
- diameter	( )	( )	( )	(✓)
- depth	( )	( )	( )	(✓)
cattle fences	( )	( )	(✓)	( )
- maintenance rotation	( )	( )	( )	(✓)
fire evacuation routes	( )	(✓)	( )	( )
crew itinerary routes	(✓)	( )	( )	( )
U.S. routes	( )	(✓)	( )	( )
state routes	( )	(✓)	( )	( )
improved roads	( )	(✓)	( )	( )
unimproved roads	( )	(✓)	( )	( )
fire breaks	( )	(✓)	( )	( )
horse trails	( )	(✓)	( )	( )

AREAL FEATURES

	essential	very useful	useful	not applicable
tree species	( )	(✓)	( )	( )
watershed areas	( )	( )	( )	( )
land cover (vegetation)	( )	(✓)	( )	( )
soil types	( )	(✓)	( )	( )
- permeable/impermeable	( )	(✓)	( )	( )
flood zones	( )	(✓)	( )	( )
slope orientation (direction)	( )	(✓)	( )	( )
lakes	(✓)	( )	( )	( )
subsurface geology	( )	( )	(✓)	( )
slope (angle)	( )	(✓)	( )	( )

GIS Needs Questionnaire
Philmont Scout Ranch

POINT FEATURES

	essential	very useful	useful	not applicable
parking areas	( )	(✓)	( )	( )
trail sign locations	(✓)	( )	( )	( )
springs	(✓)	( )	( )	( )
trail bridges	( )	(✓)	( )	( )
camps	(✓)	( )	( )	( )
- no. of staff	( )	(✓)	( )	( )
- no. of campsites	(✓)	( )	( )	( )
location of buildings	(✓)	( )	( )	( )
- type of structure	( )	(✓)	( )	( )
- maintenance rotation	( )	(✓)	( )	( )
stock tanks	( )	( )	(✓)	( )
- volume	( )	( )	(✓)	( )
other permanent improvements	( )	(✓)	( )	( )
location of fire stations	( )	( )	(✓)	( )
programs	( )	(✓)	( )	( )
- number of participants	( )	(✓)	( )	( )
- program times	( )	(✓)	( )	( )
road gates	( )	(✓)	( )	( )
- access controlled?	( )	(✓)	( )	( )
cattle gates	( )	( )	( )	(✓)
- access controlled?	( )	( )	( )	(✓)
water wells	(✓)	( )	( )	( )
- maintenance rotation	( )	(✓)	( )	( )
bench marks	( )	( )	(✓)	( )
- height	( )	( )	(✓)	( )
mountain tops	(✓)	( )	( )	( )
- height	(✓)	( )	( )	( )
commissaries	( )	(✓)	( )	( )
storm drains	( )	( )	( )	(✓)
garbage dump We no longer have any - its all hauled to Taos	( )	( )	( )	(✓)
mine shaft openings	( )	(✓)	( )	( )
pit toilets	(✓)	( )	( )	( )
- maintenance rotation	( )	(✓)	( )	( )

GIS Needs Questionnaire
Philmont Scout Ranch

Geographic Information Systems have a wide range of capabilities that may be very useful to the decision-making needs of your department. Once the data are entered into a computer format, an almost limitless number of questions can be posed. Examples of some GIS operations are listed below:

1) create custom maps with selected information

example: display a map with fencelines, unimproved roads and gates only
-or-
display all buildings on this year's maintenance schedule
-or-
display all waterlines with diameters greater than one inch

2) creating map overlays that display the intersection of various types of information

example: show me all trails crossing meadows

3) determining buffer zones around points or lines

example: display all streams or lakes within 100 meters of a pit toilet

4) measure areas or distances

example: display the shortest route between point A and point B
-or-
measure the acreage of all grazing land within one mile of Ponil

Please list GIS operations that might be beneficial to decision-making in your department (use additional sheets if necessary).

1) ____________See attached________________________________

____

2) ____

____

3) ____

____

4) ____

____

5) ____

____

6) ____

____

GIS Needs Questionnaire
Philmont Scout Ranch

Please list all geographic information currently used to support decision-making in your department. Include maps, plans, drawings, photographs, etc... and their source, scale and date (if available).

Item	scale	source	date

Any other comments or remarks about the GIS needs of your department or this project would be appreciated:

It looks like GIS has many applications at Philmont As we get into the program I'm sure other applications will become apparent

VITA

Michal V. Butler

Candidate for the Degree of

Master of Science

Thesis: GEOGRAPHIC INFORMATION SYSTEM (GIS) DEVELOPMENT AND IMPLEMENTATION GUIDELINE FOR NATURAL RESOURCE MANAGEMENT

Major Field: Environmental Science

Biographical:

Personal Data: Born in Kiowa, Kansas, October 15, 1966, the son of W. Louis and Connie S. Butler.

Education: Graduated from Burlington Public School, Burlington, Oklahoma, in May 1984; attended Northwestern Oklahoma State University in Alva, Oklahoma from August 1984 until May 1986, transferred to Oklahoma State University in August 1986, received Bachelor of Science Degree in Recreation Administration and Management from Oklahoma State University in December 1989, completed requirements for Master of Science degree at Oklahoma State University in May, 1994.

Professional Experience: Environmental Laboratory Technician, Environmental Engineering Consultants, Stillwater, Oklahoma, April, 1990, to December 1990.

Environmental Specialist, Accurate, Inc. Stillwater, Oklahoma, December, 1990 to October, 1992.

NEPA Compliance Coordinator, Martin Marietta Energy Systems, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio, October, 1992 to October, 1993.

Environmental Engineer I, Martin Marietta Utility Services, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio, October, 1993 to Present.