

THE PERCEPTION OF GIS TECHNOLOGY AND ITS IMPLICATIONS FOR
SUCCESSFUL GIS IMPLEMENTATION FOR ENVIRONMENTAL AND
NATURAL RESOURCE APPLICATIONS: A CASE STUDY OF
FEDERAL AND STATE AGENCIES
IN NORTHWEST OREGON

by

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Geographic information systems (GIS) enable the management and analysis of spatial data in ways previously impossible. However, the technology has developed faster than the institutional framework necessary to support it: due to their unrealistic expectations involving the costs, capabilities and limitations of GIS, agencies may lose time, money and effort. This thesis explores the barriers to effective GIS use, based on literature review and interviews with GIS managers representing fifteen environmental agencies in Oregon. Significant problem areas involve expectations, staffing, software capabilities and database development. These barriers may result from inaccurate perceptions and may lead to frustration or even

abandonment of the technology. The key to effective GIS use is changing these perceptions and the underlying institutional behaviors. The potential of GIS as a tool for decision-making depends on the degree to which agencies can change without losing sight of the moral issues involved in environmental management.

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CHAPTER I

THESIS OBJECTIVES, GOALS, AND METHODOLOGY

Introduction

An emerging technology called geographic information systems (GIS) enables one the opportunity to observe the process of the implementation of a new technology, and to evaluate its success. This new technology has developed due to many factors, including: advances in computer technology, heightened environmental concerns, the need for more timely and accurate land information for natural resource management and other kinds of land use decisions, and other political, social, and economic factors. GIS is a complex and continually developing technology which has a broad range of applications from forestry to transportation planning to national defense systems, in addition to many inter-disciplinary uses. It has changed the acquisition, processing, storage, and analysis of spatial data. That is, data that is in a map form, representing actual land areas with geographic coordinates and descriptive attributes. More specifically, GIS has changed the way natural resource management and environmental planning is viewed and performed, as well as, affecting other areas of GIS application. It has enabled managers and planners to answer new kinds of questions, in addition to, performing tasks that were done previously by manual methods both faster and more efficiently. Many agencies, universities, private companies, and others, have acquired this technology, are in the stages of acquiring it, or desire to acquire it.

Geographic information systems are not a new concept. Spatial data overlays have been performed manually for years for the land use planning process. It is only in the past twenty years that digital methods have arisen to handle spatial data more efficiently and effectively. With the advent of new, faster, more efficient computer technology, computer mapping emerged, including database management systems, computer-aided drafting (CAD), and computerized cartography. All of these computer technologies are used to handle and process spatial data and land information, yet GIS technology has many capabilities that distinguish it from these related computer systems. Not only does GIS technology enable natural resource managers to perform many old tasks faster and help GIS users work more productively, it also allows managers to perform new kinds of analyses of spatial data and create computer models of management scenarios as an aid in natural resource and land use decisions. These capabilities make GIS unique. GIS has the potential to be an effective and powerful tool in making better decisions.

Like many new technologies, problems are inherent to GIS implementation. User experiences in implementing GIS technology effectively, with minimal cost or hardship, do not always end in success. Many issues and barriers arise in GIS applications for natural resource management, environmental planning, land use planning, and its other applications, that hinder success.

Many articles exist in the literature about specific GIS projects or about technical innovations, but fewer about the issues involved in implementing GIS. One issue that is rarely mentioned is how the expectations of what a GIS will do for an agency affects satisfaction with it once it is implemented. How people perceive GIS technology is as important as the capabilities of the technology itself. Like the advent of other new technologies in the past, GIS has been viewed initially as a panacea technology that will revolutionize many areas and

greatly aid managers, with only an initial outlay of funding. More often, those acquiring a GIS have inaccurately assessed the actual time and money required to implement, use, and maintain a GIS. If GIS technology is viewed unrealistically, in terms of its cost and its capabilities, then unrealistic expectations arise. When a GIS does not meet these unrealistic expectations, disillusionment may result. This may then lead to abandonment of the technology, for those who do not change their perception and resulting expectations of GIS. For those who stay with the technology, there is loss of a great deal of time and money as they scramble to change their perceptions and expectations of the technology. These unrealistic expectations that often exist for GIS capabilities, products, and costs, in addition to other barriers to effective GIS implementation for natural resource applications, may prevent GIS technology from fulfilling its real potential.

Other important issues arise with each step of the implementation process, due to the many choices of specific GIS platforms, due to the rapidly evolving nature of GIS technology, and due to the lack of knowledge and literature about GIS implementation and the necessary institutional changes for agencies. There are many barriers to effective GIS use, and they can be broken down into technological, as well as the more important institutional and economic barriers (Dueker, 1987, 1361). To some degree, many of these barriers are related to incorrect perception and unrealistic expectations, as mentioned before. The questions that arise are whether these barriers can be understood and overcome, and whether or not technological advances may relax institutional and economic constraints on the best and most realistic use of GIS technology. This is especially important given the increasing public concern about environmental issues, and economic trends in the U.S. such as the increased federal budget deficit, reduced budgets, and uncertainty about the country's economic health. Possibly the biggest questions are whether new technology, such as GIS, can really enable wiser future

management of natural resources, and if the cost of such technology outweighs the potential benefits.

Objectives and Scope of the Thesis

Scope of the Thesis

Is GIS technology being used successfully, for various applications, given its capabilities, the perception and goals of its use, and the barriers to its effective use? These uses include: building land information databases, performing analyses and modeling of spatial data, and aiding in land use and natural resource decisions. Before one can examine the success of GIS implementation in the field of natural resource management, one must somehow define success. In order to do this, there must first be an understanding of GIS technology: its background, capabilities, limitations and the way it is implemented. Once a common understanding is achieved, then its use can be examined and recommendations made.

First, a description of GIS technology is necessary to enable the reader to better understand issues in, and barriers to, implementation of a GIS. A definition of geographic information systems and how they differ from related computer technologies, such as database management systems and computer aided drafting (CAD), is presented in Chapter II. In addition, Chapter II identifies the many technological, institutional, political, and economic developments which have contributed to the development of this emerging technology. The essential components of a GIS, the capabilities of GIS technology, its limitations, the goals of GIS use, and a brief summary of GIS applications for natural resource management and related fields, are also described. Chapter II is meant only as a brief description of GIS technology,

and essentially a means to point the reader into the literature and to lead into Chapter III. By describing GIS technology in such a way, not only may the barriers and issues of GIS implementation be better understood, but more realistic standards by which to measure successful implementation of GIS technology may result.

Once a background about GIS has been established, Chapter III can deal more specifically with the process agencies go through in acquiring and implementing a GIS. It is important for the reader to not only understand what a GIS is -- its components, and its capabilities, and limitations, but additionally to understand this process. Chapter III establishes a conceptual model, of the process of GIS implementation, generated by this author with support from the thesis research and literature. Such a model will facilitate later identification of stage(s) at which the technological, institutional, and economic barriers arise in the implementation process. Additionally, Chapter III gives a more detailed look at the methodology this author used in researching the use of GIS technology in governmental agencies, and why it was conducted in such a way. This leads the reader to Chapter IV, the results of this research.

Chapter IV is the presentation of the results of independent research of various state and federal agencies. These agencies are located in Northwest Oregon and have similarities in goals, mandates, and natural resource and environmental monitoring and planning activities. These results include the identification and description of each individual GIS user, how each specific GIS was chosen and implemented, and summaries of the issues that concern each GIS manager interviewed, in implementing a GIS. A matrix of each represented agency and the particular issues that concern them is presented.

After specific issues have been identified in Chapter IV, through the agency responses, Chapter V analyzes the results of Chapter IV and can address each issue, concerning

successful implementation, in more detail. In addition to the state and federal agencies who contributed to this information through the survey, Chapter V relies on the conclusions of this author with some support from the GIS literature.

Chapter V will redefine issues and describe some important barriers that prevent the fullest use of GIS technology. These barriers to effective GIS use can be broken down into technological, economic, and institutional areas (Dueker, 1987, 1361). In addition, for each barrier, where it may arise in the process of implementation, as established by the conceptual model from Chapter III, is identified. How each barrier may result from incorrect perceptions is explored. With the various obstacles to effective GIS use, several issues are raised that will also be addressed in Chapter V, with discussion of possible solutions for these issues, new innovations, and areas of needed research.

Chapter V will also briefly examine the future of GIS technology. The implementation of any new technology involves much bigger issues. A major issue is whether or not a new technology really makes a difference in the decision-making process; does better, more accurate data actually result in better policy decisions? Is GIS like other new technologies, in that the inaccurate perception of it as a cure-all may cause disillusionment once the real costs are realized, and result in abandonment of the technology? Or will the relationship between GIS technology and GIS users evolve and change to a more healthy one where GIS capabilities, costs, and its ability as a tool in the decision-making process are viewed realistically resulting in more appropriate use of GIS technology? Is there a point of diminishing returns where additional funds will not result in more accurate data in a GIS? Geographic information systems technology is evolving rapidly. Particular barriers are more significant than others, and these obstacles to effective use of GIS technology may prevent worthwhile benefits. Sometimes, technological innovations may relax other kinds of barriers.

One may wonder if this will be true for GIS technology. Can new technological innovations help offset economic and institutional constraints? The future of GIS is unknown, and it remains to be seen how current economic and political conditions will affect its continued development.

Purpose and Goals of the Thesis

The overall objective of this thesis is to investigate the use of GIS technology for natural resource management and other environmental applications. More specifically, to narrow in on its effectiveness as a decision-making tool, in light of the lack of literature about issues in the implementation and use of a GIS. To do this, the thesis must follow some logical steps. First, the thesis must give the reader a brief background in the broad area of GIS use. Chapter II gives a background in the definition of a GIS technology, its development, differences between GIS and similar technologies, its capabilities and limitations, and a description of its components. The purpose of Chapter III is to help the reader understand the process agencies go through in implementing a GIS. The process is described from first investigation of acquiring a GIS, all the way to use of the system and its integration in the day-to-day activities of an agency. Chapter III also describes why the particular questions are asked of GIS managers, and how these questions fit into the scheme of the thesis. Chapters II and III establish the setting for Chapter IV, the results of surveying various GIS managers at Northwest Oregon state and federal agencies who are implementing a GIS for natural resource management or other environmental applications. The goal of Chapter IV is to establish the commonality between the agencies not only in their goals, mandates, and activities in resource use, but also in their reasons for acquiring a GIS, and in their stage of implementing a GIS.

In addition, the survey is meant to identify perceptions and the expectations that these GIS managers hold, to describe any dissatisfaction with the GIS, and to list the issues and barriers that have arisen in their use of a GIS. Recommendations are also solicited and listed from the GIS managers when possible. Once these issues are identified, they are discussed in more detail in Chapter V. The implications of these issues for the success of GIS use in natural resource management, environmental planning and land use planning, are also explored.

Secondly, this thesis will focus on these important issues which have often surfaced in the survey and the literature. As stated earlier, each issue is described, and when possible, divided into barriers to effective GIS implementation (technological, institutional, and economic barriers) in Chapter V. When possible, the stage(s) within the implementation process (based upon the model in Chapter III) is identified where each barrier may arise. Possible recommendations are developed for each barrier, with input from recent developments in GIS as found in the literature, as well as input from governmental agencies in Northwest Oregon.

In Chapter V, these issues are described in such a way that shows how they pertain to the much bigger issue of the perception of GIS -- how GIS technology is viewed by the agency personnel using it, by people in the academic area of GIS, and by other GIS experts cited in the literature. As stated earlier, this is an important underlying issue because the way people view a technology's capabilities determines the goals which are set for its use. If the goals are not realistic, inappropriate expectations are formed. Like other new technologies, there is a relationship that managers have with GIS and it is in the process of changing from a view of GIS as a panacea for many institutional problems toward a more realistic view. With failures in the implementation of that technology, disillusionment may occur despite an otherwise promising future for that technology. This may result if the view of GIS technology

does not change to a more realistic one -- the reality of not only its possibilities, but also the costs involved in using it.

Interviews of Northwest Oregon state and federal agencies using GIS are used as a source, along with the GIS literature, to identify and describe these issues and generate recommendations. Personal interviews with GIS managers in the field provides additional insight into the issues that concern GIS users most. There are many issues and concerns that are involved in GIS use and volumes would have to be written to address all the issues. The identification of barriers and issues, and the recommendations made reflect a natural order and can be broken down into elements, yet some of the delineation is necessarily artificial. The use of geographic information systems is very complex and inter-disciplinary. The literature, as well as contributions from the GIS managers interviewed, are used to support this author's identification, description, and analysis of the issues involved in GIS implementation.

Geographic Scope of the Survey

Federal and state agencies, who deal with or manage public lands, natural resources, land use, or environmental quality, were chosen as information sources (Table 1). These agencies were selected based upon several criteria: (1) All had to be within a geographic scope, and Northwest Oregon was selected as a reasonable scope. (2) All had to have similar mandates, goals, and activities, and deal with similar issues. Thus, agencies that manage natural resources or deal with environmental planning of public lands were selected. (3) All had to be similar with regard to institutional aspects and governmental level, therefore, agencies at the federal and state level were selected. (4) All had to be well along in the GIS implementation process. Some agencies had just one central GIS, while others have a more

TABLE 1. GIS Managers Who Responded to the Survey, and the Agencies They Represent

Name of GIS Manager	Department or Division	Name of Agency	Location	Primary Resources or Activities
Phillip Orlowski	Cartography & Remote Sensing	U.S. Army Corps of Engineers	Portland	Water Resource Development
Steve Sherer	Facilities Engineering	U.S. Dept. of Energy, Bonneville Power Administration	Portland	Hydroelectric Power Development
Bob Klaver	Land Services	U.S. Dept. of the Interior, Bureau of Indian Affairs	Portland	Various Natural Resources
Pat Green	Information Services	U.S.D.I. Bureau of Land Management	Portland	Forest Resources
Andy Herstrom	Terrestrial, Ozone Team	U.S. Environmental Protection Agency	Corvallis OR	Monitor Ozone on Forests
John Steffenson	Information Management	U.S.D.A. Forest Service	Region 6, Portland	Forest Resources
Curtis Day	Planning	U.S.D.A. Forest Service	Mt. Hood National Forest, Gresham	Forest Resources
Dale Cummins	Planning	U.S.D.A. Forest Service	Columbia River Gorge National Scenic Area, Hood River	Natural, Scenic, Cultural, Economic Resources
Bryan Armel	Planning	U.S.D.A. Forest Service	Siuslaw National Forest, Corvallis	Forest Resources, Oregon Dunes
Ken Adee	Planning	U.S.D.A. Forest Service	Willamette National Forest, Eugene	Forest Resources

TABLE 1. (Continued)

Name of GIS Manager	Department or Division	Name of Agency	Location	Primary Resources or Activities
Mon Yee	Western National Technical Center	U.S.D.A. Soil Conservation Service	Portland	Soil, Water
Bruce Fisher	Water Resources	U.S. Geological Survey	Portland	Water - Surface, Ground
Doug Terra	Water Quality	OR Dept. of Environmental Quality	Portland	Water - Surface, Ground
Mike Ciscell	N/A	OR Dept. of Water Resources	Salem	Water, Water Rights
Scott Smith	GIS Service Center	OR Dept. of Energy	Salem	Provide GIS Services

distributed structure with an individual GIS for several departments.

Other governmental agencies in Northwest Oregon are GIS users. Some of these other agencies do not deal primarily with environmental quality or natural resource management, some are outside of the geographic area, and some were not interviewed for other reasons (such as this author not knowing about them). Several agencies are just now implementing or will soon implement a GIS system. With the growing enthusiasm and use of GIS, almost all governmental agencies in Northwest Oregon are somehow involved or impacted.

Scope of the Literature Review

Almost all of the literature: books, conference proceedings, and articles are cited as published since 1986. Despite the up-to-date literature, the field of GIS is changing so rapidly that it is difficult to pinpoint current issues, trends, and developments as they occur. The role of the literature is mainly to support the issues and recommendations made, and to point readers to the sources themselves for further study. This thesis is not meant to describe GIS technology in detail, but to identify just a few key issues and to list bibliographic sources for additional information. Entire texts could be devoted to describing GIS technology and the issues involved in its use.

Methodology

Literature Review

The literature was chosen based upon its date of publication and its source. The most

recent articles, since 1986, were chosen due to the fact that the field of GIS technology is evolving so rapidly. Articles from the most prominent authors are emphasized, as well as articles with extensive documentation and from well-known GIS literature. The literature represents a variety of sources including books, governmental publications, conference proceedings, and periodical articles. The most prominent publications are those from the U.S. Geological Survey, the American Society for Photogrammetry and Remote Sensing -- its conference proceedings, the journal from the Urban and Regional Information Systems Association (URISA), special publications and books. The most prominent periodicals include Photogrammetric Engineering and Remote Sensing, GIS World, the International Journal of Geographical Information Systems, environmental periodicals such as Environmental Management, natural resource periodicals, and cartographic periodicals. Geographic information systems is a very broad field and there is a great deal of overlap with remote sensing, photogrammetry, and cartography, as well as natural resource management, land use planning, geography, forestry, wildlife and fisheries sciences, hydrology, and other fields.

Most Common and Significant Issues

The most common and significant issues are generally those mentioned most often in the literature and by survey participants. Despite the lack of literature concerning issues in GIS implementation, both the literature that was available and the GIS managers interviewed aided in the selection of the issues described in this paper. The thesis focuses on an issue of major concern, the perception of GIS technology and how the other issues relate to this perception. It was decided that this type of analysis is within a reasonable scope of what could be accomplished within a thesis.

Survey and Interview of Agencies

The design of the survey evolved over several weeks with input from various sources. These sources included a 1980 GIS survey designed and conducted by Oregon State University and the Oregon Department of Forestry (Brooks, 1980), and input from various local governmental GIS users, college professors, and other people in academia (see acknowledgements). A survey such as this is considered independent research and thus, a primary source of information. Participants were chosen based upon a reasonable balance between geographic scope and sample size. A GIS manager from each agency office was selected with the intent to maintain a consistency between the managerial level of each person for each agency. More specifically, each GIS manager was selected to be interviewed based upon his/her availability, and upon the fact that they are in the middle management level of the agency. For some agencies there are several managers at equivalent levels, but only one is chosen to be interviewed, to be within a reasonable scope. The process is subjective; it is difficult to find identical institutional frameworks for all the agencies and thus select exact identical GIS managers with respect to their managerial level and work responsibilities. The selection process was conducted with as much consistency, with respect to the level of each GIS manager among the agencies, as is manageable within the scope of this thesis.

Each GIS manager was interviewed in person, during a period between April and May, 1990, with the exception of the Willamette National Forest's GIS manager (interviewed October 1991). Chapter III identifies the questions asked and the reasons for asking specific questions. The survey results are presented in a systematic arrangement, from each agency, in Chapter IV. As stated earlier, the results are used to help formulate impressions about the process of selecting and implementing a GIS, to establish commonality among the agencies

with respect to the goals and types of resource use, to identify issues that are most important in the implementation process, to discover how these GIS users perceive the technology, and to solicit possible recommendations from the GIS managers, as well as areas of future research.

The survey results are used as a guide to study issues in GIS implementation due to the subjective nature of surveys, the geographic scope of the participants, and the rapidly evolving nature of the field of GIS. The survey results are used to supplement information from the GIS literature concerning the use of GIS technology for the field of natural resource management and environmental planning. Surveys can be very useful, and a similar, yet, more detailed survey with a narrower scope can be conducted in the future to further assist Oregon agencies in implementing and using GIS technology. Again, it is difficult to quantify subjective results. Several factors contribute to this difficulty. These factors include the probable time lag of responses behind the most current issues in the field, and the difficulty in quantifying qualitative responses, in addition to the stage of GIS implementation at which these Oregon agencies are at, compared to other agencies nationally. This makes the survey results less applicable if used as more than just a guide and supplement to the literature.

CHAPTER II

AN INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS

Background of GIS

The development of GIS technology is the result of technological innovations and institutional, economic, social, and political pressures. Combined, these forces have created the need for automating and managing spatial data in new ways. Natural resource management has always involved a great deal of management, manipulation and analysis of spatial data. Advances in technology have created new ways of managing spatial data and consequent change for managing natural resources.

A description of GIS technology is necessary to enable the reader to understand the remainder of this thesis: the conceptual model of the process of GIS implementation for governmental agencies (Chapter III), the results of interviews with Northwest Oregon GIS managers (Chapter IV), and the issues of GIS implementation for natural resource applications for governmental agencies (Chapter V). This chapter will briefly describe spatial data, the past methods of handling spatial data, the development of GIS, the definition of a GIS. It will also discuss how it differs from related technologies, and the components, capabilities, and functions of a GIS for natural resource management. This chapter is meant to give the reader a adequate working knowledge about GIS technology.

Spatial Data

Before exploring GIS technology in detail, spatial data must first be defined. Spatial data are about locations on the Earth's surface and are important in everyday life. More specifically, spatial data represents "delimited geographic areas, with...different kinds of associated attributes or characteristics (Star and Estes 1990, 9)." These attributes represent qualitative and quantitative characteristics about the land (Star and Estes 1990, 15,29). Maps traditionally store this kind of data. A map serves as a snapshot of situations on Earth (Burrough 1986, 3) and serve to transform a curved Earth's surface into a two-dimensional medium (Star and Estes 1990, 15).

Through traditional maps, spatial data is expressed with symbols as lines, points, and areas (Parker 1987, 10) with tones, colors, textures, and patterns (Star and Estes 1990, 16). Spatial data is used for a wide variety of purposes including general purpose or specific-purpose maps (Burrough 1986, 1). The spatial data is often arranged into data sets pertaining to a particular land activity or use. These data sets are also called themes or thematic layers (Star and Estes 1990, 4). A theme may be qualitative (land use classes) or quantitative (elevation variation) (Burrough 1986, 1). Frequently, questions about the inter-relationships between different data sets arise (Marble, Calkins, and Peuquet 1984, 1-3). In recent times, the demand for maps and for answers to these types of questions has accelerated greatly. The technology to allow mapping of large areas with greater accuracy (Burrough 1986, 2), and the technology to meet these demands has also grown.

Manual Methods of Spatial Data Management and Analysis

Until recently, meeting the demands for map making and analyzing the relationships between different kinds of spatial data was done by manual methods. Many problems are inherent to manual methods of spatial data analysis. It is difficult to effectively integrate different datasets due to problems in registration of their different coordinates. The consistent locations of spatial characteristics, as well as, the accuracy of the coordinate system is ..."essential to the successful integration of spatial data sets (Marble 1987, 4)." It is also difficult to compare different spatial data due to each also having non-spatial attribute data (descriptive information). Using maps as a spatial database makes it difficult to compare thematic layers because there is a limit to how many datasets can be compared manually (Parker 1987, 75).

Many of these difficulties are related to the sources of error in maps and spatial data. There are the obvious sources in compiling spatial data: out-of-date source data, inappropriate map scales and the corresponding data type, problems in data quantity or quality, insufficient numbers of observations to determine spatial patterns of data, and meager funding and staffing to produce adequate information (Star and Estes 1990, 16). There may have been problems with the original observations as they pertain to natural variation of the data. These include problems with positional accuracy and attribute errors from misidentification or compilation problems (Star and Estes 1990, 16-17). There is also error in spatial data processing. It creates numerical errors and errors in logic in classification and generalization of data (Star and Estes 1990, 17). These data quality issues will be discussed in Chapter V.

Forces Leading to the Development of Digital Methods

There are two types of forces at work which require automation of spatial data. These forces are affecting governmental agencies who manage natural resources and who monitor the environmental quality of the land. The first kind of pressures are institutional, the second kind are political, social, and economic forces from both outside and within these agencies.

Institutional

These kinds of agencies collect and use information about the land -- it is essential to their operation (Dueker 1987, 1361). This information is about different natural resources, the cadastral layer (land ownership), land use activities, zoning, and other characteristics. This data has become more diverse and greater in quantity through time. In addition, the data about the Earth's surface is constantly changing, and traditional analog maps cannot capture this change (Burrough 1986, 3).

There are additional problems with traditional maps. Maps cannot communicate data that is not in a map form such as graphs, text, and statistical tables (Star and Estes 1990, 18). Furthermore, map data is generalized which results in problems of accurately portraying the Earth's surface. It is difficult to retrieve data off of static maps, in addition to the problems involved with the great number of different map sheets covering any one area (Burrough 1986, 3).

When map information is at different scales and in different coordinate systems more difficulty arises in managing spatial data. Cadastral data is usually defined by the public land

survey system (township and range). Most spatial information about natural resources is in the latitude and longitude or state plane system. It is difficult to translate between these different cartographic systems, and this makes it difficult to register property lines correctly with respect to other land characteristics.

There are also institutional problems inherent to agencies. Planners and natural resource managers use spatial data for different areas and activities. They use it to measure environmental parameters, to develop maps to portray information about the Earth's surface, to monitor changes in the environment in space and time, and to model alternatives of actions and processes as they may affect the land (Star and Estes 1990, 12). Each agency or divisions within it, maintain these kinds of data for their own needs. This results in duplication of effort consequently resulting in higher costs of acquiring and maintaining spatial data, and limited utility and accessibility of information between agencies, divisions, or to the public (Dueker 1987, 1361). These issues are discussed in Chapter V.

There are problems in traditional methods of map compilation and analysis of the resulting data. The study of the spatial distribution of various natural resources and environmental phenomena usually starts with environmental surveys. The first objective is inventory: to observe, classify, and record this kind of information. The initial description of quantitative data is difficult due to the large volume of data, the lack of quantitative observation, and the lack of mathematical tools to describe spatial variation (Burrough 1986, 3). Automated methods can address problems in map compilation and analysis.

"Traditionally, integration of spatial data sets is carried out by transforming the two or more spatial data sets to a common map scale, creation of a transparent or translucent overlay for each set, registration of these overlays so that the coordinate systems are aligned, and then manually creating a composite overlay sheet that shows those areas where the various

phenomena classes being studied occur in juxtaposition. This procedure is laborious and time-consuming and is being supplanted by automatic procedures (Marble 1987, 4)." In fact, since the 1960s, computers have taken on the tasks of mapping and analysis of such quantitative spatial data (Burrough 1986, 3).

A GIS can do more than handle large volumes of data, in different scales, formats, and coordinate systems - the impact of GIS technology is much greater. The "key to coping with this information explosion is the employment of systems - systems that will take the data, analyze it, store it, and then present it in forms that are useful (Star and Estes 1990, 14)." This technology has the potential to change how we view natural resources and environmental planning, and change the way management is performed. "GIS have the potential for improving our understanding of the world around us (Star and Estes 1990, 12)."

Political and Economic Forces

There is a growing concern for balancing competing uses of natural and human resources, especially those held in the public's trust. Changing views and concerns are an outgrowth of a changing political and economic climate. This has been manifested in four ways. First, there is more complexity in the spatial data about the land and the resources we use, and greater intensity in their use. Second, there are more demands from the public in the form of environmental and social concerns. Since the 1960s, and through the 1970s, there is a realization that different aspects of the earth's surface do not function independently of one another. This has resulted in a desire to view the earth in an integrated, multi-disciplinary way (Burrough 1986, 4). There is renewed interest in environmental/social responsibility combined with the realization of the need for improved urban planning (Parent and Church 1987, 65).

This has created more demand for resource inventory and modeling of physical processes of the land (Parent and Church 1987, 65). Third, with increasing complexity and demands, agencies have decreased response time when dealing with environmental problems and change. Fourth, reduced federal spending affects the economy and complicates these issues. Agencies are seeking more efficiency and are promoting a boost for technology. "...more public agencies at all levels are seeking new, more efficient, and lower cost approaches to the business of resource management (Parker 1987, 78)."

The use of GIS technology can help agencies realize many benefits and respond effectively to these changes. It can answer new questions that are not possible to answer using conventional methods of spatial data analysis (Burrough 1986, 9).

Automation of Spatial Data

GIS technology is a computer technology; spatial data is transformed in a way that the computer can understand. Each aspect of spatial data is changed. Where each feature is located geographically becomes a locational attribute. Descriptions of each feature becomes its qualitative attributes. How geographic features relate to each other becomes topology (Parker 1987, 73). "Over the past 15 years a number of computerized systems have grown up to automate the manipulation and integration of spatial data files. These geographic information systems permit the user to bring together information from numerous spatial data sets into a composite for either visual display or analytic modeling purposes (Marble 1987, 5)."

Technological Advances

The development of GIS technology is due to "parallel developments in automated data capture, data analysis, and presentation in several broadly related fields" that process spatial information (Burrough 1986, 6). These fields are cartography (high quality drafting), computer-aided design and computer graphics, surveying and photogrammetry, spatial analysis using rasterized data from thematic maps, interpolation from point data, and remote sensing technology. Together, these disciplines have the single goal of development of a system for automation of the processes involved in spatial data acquisition, storage, analysis, and presentation for particular applications (Burrough 1986, 6). These technological advances enable automation of spatial data handling and processing. They provide analytical tools and motivation to researchers and professionals in a variety of applications. Some of these new developments include:

1. Refinements in cartographic technique (Star and Estes 1990, 19).
2. Rapid developments in digital computer systems: computer hardware has evolved into microprocessors, new storage capabilities, and new graphics capabilities (Parker 1987, 78) for spatial data processing systems during the past 20 years (Star and Estes 1990, 20). Computers can now handle large volumes of data efficiently and can perform numerical analysis of a computerized map (Berry 1987, 1405).
3. Quantitative revolution in spatial analysis (Star and Estes 1990, 19).
4. Development of stacking layers of thematic information (Star and Estes 1990, 20). These are manual analytic procedures which involve overlaying transparent copies of maps for a given area and were popularized by Ian McHarg's (1969) Design with Nature. This is a "gestalt" method of spatial data analysis. By combining information

in this way, one may identify ecological units not recognized by other methods. Such units can be mapped and described by the integration of independent land features such as landform, geology, soil, vegetation, and water (Burrough 1986, 4).

A concept of land suitability/capability analysis, based on McHarg's work, led to a model to produce land use planning maps by overlaying spatially referenced data layers for the planning process. "These techniques mark an important turning point in the use of maps -- from one emphasizing physical descriptors of geographic space, to one spatially characterizing appropriate management actions. This...set the stage for revolutionary concepts of map structure, content and use (Berry 1987, 1405)." Despite this innovative approach to land use planning, the problem was that these integrated surveys were too general to be useful (Burrough 1986, 4).

5. Computer-assisted cartography: by the late 1970s, many governmental and private agencies invested in the development and use of computer cartography. Agencies realized that digital databases could be used for analysis of spatial data, but such systems did not always result in fewer costs (Burrough 1986, 5). Acquiring and developing new technology is expensive, and the shortage of trained staff presents a problem. Organizations did not respond with a restructuring of work procedures in order to better use technology, and technological change happened faster than managers could keep up (Burrough 1986, 5). This institutional issue is one of trying to automate existing tasks instead of looking at new procedures of managing spatial information (Burrough 1986, 6). This issue will be discussed in Chapter V.

6. Advances in image processing and remote sensing systems (Star and Estes 1990, 22): Satellite images, in addition to aerial photography, make it possible to see landscape changes over time (Burrough 1986, 3). Satellite imagery is digital data

encoded in picture elements (pixels): cells within a two dimensional matrix, with each cell given a value of strength of reflected electromagnetic radiation. The resulting patterns of values must be interpreted and checked against ground survey to have any meaning (Burrough 1986, 3-4). Other technical advances include raster-vector data format conversion, and geometrical corrections and registration (Star and Estes 1990, 22). Raster and vector data formats will be reviewed later in this chapter.

A GIS can process large amounts of data for advanced analysis and modeling not possible through previous conventional methods of spatial data analysis. Berry quotes Dangermond that GIS technology provides a means for quantitative modeling of spatial relationships and enables managers to address complex issues in entirely new ways (1987, 1405). There are still difficulties in converting geographic data to a digital form. This is due to the sheer volume of data, the complexity of the earth's surface, and to the fact that geographic phenomena are difficult to define (Burrough 1986, 11). As stated earlier, digital data is prone to be imprecise and generalized. The ways geographic data are described tends to be specific to each application (Burrough 1986, 11). There are problems when a particular GIS designed and implemented for a specific class of problems is used for other purposes. This problem can lead to inappropriate uses of GIS technology. There is the need for GIS plans and policies to meet the changing demands for the different activities of various GIS users (Star and Estes 1990, 23).

Definition of a Geographic Information System

How GIS technology is defined is important to enable one to distinguish the unique capabilities that set it apart from other computer technologies. According to Cowen, past

definitions of a GIS have been vague, usually defining GIS in such a way that GIS could be any automated spatial data handling. This has been a disservice to the field, allowing any software system that can display a map image to be called a GIS (1987, 46). Can a GIS be simply defined as an "information technology which analyses, stores, and displays both spatial and non-spatial data (Parker 1987, 73)?" According to Cowen, this definition is too inclusionary to be useful. It does not distinguish GIS from computer cartography and doesn't even imply that procedures are automated (1987, 27).

Several authors describe and define a GIS in several ways. Berry states that "these systems can be defined as internally referenced, automated, spatial information systems designed for data management, mapping and analysis (1987, 1405)." According to this approach, the value of systems is determined by the usefulness of the final information produced. Therefore, to be considered a GIS, it must include subsystems that perform in all areas and with an emphasis on modeling (Marble 1987, 4).

The process-oriented approach defines a GIS by describing the components that make up a GIS (Marble 1987, 3). The components are the subsystems that convert spatial data into useful information (Cowen 1987, 47). The data input subsystem collects and/or processes spatial data. A data storage and retrieval subsystem organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections to be made to the spatial database. A data manipulation and analysis subsystem performs a variety of tasks. These include changing the form of the data, and producing estimates of parameters and constraints for various space-time optimization or simulation models. A data reporting subsystem is capable of displaying all or part of the original database, as well as, manipulated data and the output from spatial models in tabular or map form (Marble 1987, 3).

A GIS can be described either by the operations it performs or by its end use. The toolbox approach defines a GIS as consisting of a sophisticated set of computer procedures and algorithms. Such definitions "provide very complete delineations of the operational software functions that should be required in a full featured GIS." This implies that all of these processes must be present and work together to handle diverse spatial data and result in end information. According to Cowen, using a "checklist" of necessary functions is inadequate as a definition (1987, 47-48). A database approach to defining a GIS is based on the toolbox approach, yet stresses the ease of interaction of the tools with the database itself. There is an emphasis on developing the best system for linking geographic coordinate information with attribute data and the corresponding spatial entities. The application approach is a definition based upon the type of information being handled, and more specifically, according to the application. For example, it can be defined as a multi-purpose cadastral system, a multi-purpose land information system, or a natural resource inventory system. The problem is that this approach doesn't distinguish GIS from other forms of automated spatial data processing (Cowen 1987, 47).

A final and perhaps best definition is one of input and output. The focus is on the functions that a GIS provides, in addition to the flow of data through a GIS and the types of questions the GIS can answer at each point of the process. According to Cowen, this may be best way to overcome confusion over differences between different computer based technologies (1987, 48). Parent and Church broadly define a GIS as a system that "created new information by the statistical analysis of different data layers and displayed the output on a computer graphics device in a format that fostered effective decision making" and that a true GIS can "create new information layers and generate graphic output to support the decision-making process (1987, 66)."

How GIS Differs from Related Technologies

Understanding GIS technology also requires one to understand how GIS differs from related technologies. GIS technology has much in common with computer-aided design (CAD). CAD systems are also called electronic drafting and can draft a wide range of technical objects. "Different types of geographical features are placed on different layers that are then combined and printed with different colors and line styles to generate the final product (Cowen 1987, 49)." CAD is especially beneficial for editing and updating data (Cowen 1987, 49). CAD technology does have limitations, especially in the area of analytical tasks. It is "difficult to link attributes in a database to specific geographical entities and then automatically assign symbology on the basis of user defined criteria" (Cowen 1987, 49). A CAD system could then be seen merely as a graphic system.

GIS technology differs from CAD in significant ways:

- (1) a GIS can handle a much greater volume and diversity of data input (Burrough 1986, 7);
- (2) The specialized nature of analysis methods used in GIS (Burrough 1986, 7);
- (3) information in a GIS represents the real world with real world coordinates. This makes GIS useful for "studying environmental processes or for analyzing the results of trends, or of anticipating the possible results of planning decisions" (Burrough 1986, 7).

Unlike a GIS, computer mapping does not create new information (Parker 1987, 75).

Computer mapping or computer cartography provides an elementary linkage between a database and a graphical display system (Cowen 1987, 50). Symbology is assigned to spatial entities based on attributes in the database. This technology is "restricted to the functions of

data retrieval, classification, and automatic symbolization" according to Cowen (1987, 50).

While an improvement upon CAD capabilities, linking a database with a graphic output falls short of the capabilities available in today's GIS (Cowen 1987, 50-51). "A true GIS can be distinguished from other systems through its capacity to conduct spatial searches and overlays that actually generate new information. A GIS also differs not only in creating new information, but in the types of data handled, the geographic coordinate referencing, and the fact that GIS models the real world (Parker 1987, 75).

The Unique Capabilities of a GIS

As stated earlier, geographic information systems have many similarities to similar technologies but are also quite unique in other capabilities. According to Parker, "the treatment of topology constitutes a fundamental difference between modern geographic information systems and older ones as well as most other types of computer graphics systems (1987, 75). Berry adds, "Internally referenced schemes identify a true GIS. These systems have an automated linkage between the data (or thematic attribute) and the whereabouts (or locational attribute) of those data (1987, 1405)." A full featured GIS can support the entire creation of a database, as well as the storage, retrieval, analysis, and report generation required. A GIS actually generates new information instead of merely retrieving previously digitized data (Cowen 1987, 51). This ability to "automatically synthesize existing layers of geographical data and update a database of spatial entities is the key to a functional definition of a GIS (Cowen 1987, 51)."

GIS as a Management and Decision Support System

GIS technology has been defined and the similarities and differences between GIS technology and related technology identified. Other factors are important to consider in understanding the role of GIS technology in the decision making process. There is the need to identify the GIS users, for analysis of the objectives of using a GIS system, and for an outline of the organization's decision making system when implementing a GIS (Cowen 1987, 54). Most view a successful GIS as one that will support the management of a resource or deal with a problem solving process (Cowen 1987, 54). GIS makes it "possible for planners and decision-makers to explore a range of possible scenarios and to obtain an idea of the consequences of a course of action before the mistakes have been irrevocable made in the landscape itself (Burrough 1986, 7)." In conclusion, it is "a decision support system involving the integration of spatially referenced data in a problem solving environment," according to Cowen (1987, 54).

Chrisman has a very different view of how a GIS is defined and designed. He sees a danger in the excitement for technological advances and a "lack of fundamental theory for GIS (1987, 1367)." He sees many issues arise in the implementation of GIS technology. The wide variety of choices in developing technology requires a unifying theory or principles for making selections. This is to make the entire process accountable politically, socially, and ethically. This can be achieved by identifying social goals, instead of merely focusing on technological efficiency. The issues of equality (rights and other concepts which are allocated to all citizens identically) and equity (a less absolute sense of fairness) are fundamental concerns (Chrisman 1987, 1369). Dueker states, "the advance of technology provides opportunities to automate land records processing. Yet, computerization of existing procedures is not of itself sufficient.

A more 'efficient' but badly structured system is not what is needed. The whole land records process needs to be reconsidered and redesigned (1987, 1361)." The institutional changes required for better GIS use will be discussed in Chapter V.

GIS Applications

GIS technology is useful for a wide range of applications. These applications include areas such as: business, economic development, education administration, engineering applications (such as civil, transportation, and environmental planning and design studies), facility management, hazardous waste management, infrastructure management, land use planning, logistics and distribution management, mineral assessment and extraction, national defense, petroleum exploration and production, political administration, census and demographic studies, public health, public safety, public transportation, taxation, utility and energy management, and natural resource management (forestry, wildlife, fisheries), and environmental planning. Some are briefly mentioned here and will be examined in greater detail in Chapter IV in case studies of different Northwest Oregon governmental agencies. For these applications and others, GIS technology is used in several areas. These include measurement of environmental parameters, development of maps, monitoring geographic changes in space and time and to model alternatives of actions and processes (Star and Estes 1990, 12). GIS is also used for many different environments: "arctic, alpine landscapes, prairies, tropical forests, subtropical regions, and arid and semi-arid deserts...highly developed and complex regions, as well as simple landscapes which have remained unaltered by man's influence (Dangermond, Derrenbacher, and Harnden 1987, 10)."

Essential Elements of a GIS

Overview

If one views a geographic information system as one in which data flows from primary source materials to an ultimate useful end-product, then five essential functional components of a GIS can be identified. According to Star and Estes, a GIS contains five kinds of essential elements: data acquisition, preprocessing, data management, manipulation and analysis, and product generation (1990, 24). Issues involving the process of implementing a GIS will be mentioned briefly as each relates to the functional components of a GIS. These issues will be discussed in more detail in subsequent chapters.

The goal of the data acquisition element of a GIS is to identify and gather information required for a specific application. This data may come from a variety of sources including maps, field observations, aerial photos, surveys, and other documents (Star and Estes 1990, 24-25). This is an important stage in implementing GIS technology because the "accuracy of decisions reached through spatial analysis is limited by the accuracy and precision of the underlying data sets (Star and Estes 1990, 25)."

Preprocessing is the process of manipulating data so it can be entered into a GIS (Star and Estes 1990, 26). This may include several operations. Data format conversion extracts information from maps, photos, and records. It is a time-consuming and expensive phase of any GIS project (Star and Estes 1990, 26). Systematically identifying the locations of objects in the original data is another important function in preprocessing. It requires a consistent system for recording and specifying locations and specific quality control criteria is vital (Star and Estes 1990, 26).

Data management is the creation of, and access to, the database. It requires consistent methods for data entry, update, deletion, and data retrieval (Star and Estes 1990, 26).

Manipulation and analysis of the database is the process of deriving new information from the database (Star and Estes 1990, 26). No single GIS platform possesses all analytical capabilities but, all must have specific facilities to be able to move data and information between systems to link other data processing and analysis systems (Star and Estes 1990, 27).

Product generation is the final output that a GIS can create, such as statistical reports, maps, and graphics of various kinds (Star and Estes 1990, 27). Output can take the form either as images on computer display or hard copy output on paper, film, tapes, or discs (Star and Estes 1990, 27). A GIS must be capable of taking the output of analysis and place it back in the GIS database for future reference (Star and Estes 1990, 27).

Data Acquisition

The quality of the data imputed into a GIS is of the utmost importance. The imputed data forms the basis for all GIS analyses and modeling. The ultimate usefulness of a GIS is dependent upon the quality, accuracy, and precision of its end products of analysis and manipulation. This makes data acquisition one of the most costly and time intensive phases.

Spatial data is available in many different forms and formats and a GIS must be able to accept this wide range of data for input (Star and Estes 1990, 61). This stage is usually preceded by a data needs assessment: a process of determining what types of information is needed, the scales and resolution required for the data, the goals and purposes of the agency and how that relates to the use of the geographic information system, and the types of questions, analyses, and modeling that will eventually be required using the GIS database.

The data needs assessment process is discussed in more detail in Chapter III.

Types of Data

Before exploring the many sources of data, the different kinds of data should be examined. Point data represents locations of discrete objects such as wells, buildings, and other features on the earth's surface. Network data represent roads, streams, utility infrastructure, and other features. Continuous field data may represent elevation, population density, land cover and use, or any way of dividing the Earth's surface into relatively homogenous discrete regions (Star and Estes 1990, 62). There is also the important non-spatial elements such as date of collection, observation criteria and source, positional accuracy, completeness, scale, resolution, coordinate system used, and the projection used (Star and Estes 1990, 63-64).

Data Sources

"Data collection involves the acquisition of geographic information sources such as maps, books, reports, imagery, aerial photography, and related documents supplied directly by the user, or acquired from other institutions" (Dangermond, Derrenbacher, and Harnden 1987, 13). The typical sources of data are in a graphic or tabular form and include the following:

1. Aerial photography of the earth is a type of remotely sensed data. Such photography is available as stereo photography, high and low altitude color infrared aerial photography, high and low altitude black and white photography, and other kinds of photography (Dangermond, Derrenbacher, and Harnden 1987, 20). One

usually thinks of black and white photography, which is available in scales ranging from 1:20,000 to 1:40,000 (used by the federal agencies), 1:500 to 1:2000 (for urban planning, recreation), and >1:40,000 for general resource analysis (Star and Estes 1990, 67). A key issue in the use of aerial photography is the lack of adequate interpretation and geometric control (Star and Estes 1990, 66). It is also important that the scale of the photography match the application; a small scale map such as 1:250,000 may have insufficient detail, while a large scale map such as 1:25,000 may contain too much information to sort through (Burrough 1986, 104-105).

2. Orthophoto maps are air photos with the relief displacement removed (which is inherent to aerial photography). These maps are often lithographed along with overlays of map grids, contour lines, or other cartographic symbols (Star and Estes 1990, 67). USGS orthophotoquads are photographic representations of USGS 7.5-minute series topographic maps with the control of geometry and interpretation. U.S.G.S. orthophoto maps include the contours and colors representing the earth's surface including water bodies, wetlands, forest, and other features. Together, both products are used as source material for a GIS (Star and Estes 1990, 67).
3. Analog maps are two-dimensional representations of the earth's surface and they are the most common form of spatial data. Like aerial photography, maps are available in many different scales and information can be extracted from maps for input into a GIS (Star and Estes 1990, 65).
4. Descriptive reports, files, and records from site visits may be available in both printed and digital formats (Star and Estes 1990, 61).
5. Computer records of descriptive information, digital maps, attribute information and tapes with information about topography, elevation models, or remotely sensed data.

Often these kinds of data require some kind of preprocessing in order to be appropriately placed into a GIS database (Star and Estes 1990, 61-62, 68);

6. A type of remotely sensed data are images of the Earth transmitted from satellites with multi-spectral scanners which can detect different wavelengths of light reflected from the earth's surface. This data is in the form of "spatially registered matrices of numbers...no different from any other grid cell layer of geographical data (Cowen 1987, 49)." The type of reflectance can be interpreted to give meaningful information about the earth's surface.

7. Developing new data is the final option after one has examined all of the kinds of spatial information already available (Dangermond, Derrenbacher, and Harnden 1987, 15). When existing data is too old or the accuracy is not known or not relevant, one can design a program to meet the exact needs of a GIS database. It is expensive to design, implement, and manage data gathering (Star and Estes 1990, 70). Such projects require field work, and the creation of new maps, in combination with satellite imagery and new aerial photography (Star and Estes 1990, 75). Overall, a quality GIS database must result from assessing the available data for the best, most reliable, and consistent data (Dangermond, Derrenbacher, and Harnden 1987, 17).

Data Layers

Extracting useful information from many sources results in the development of data layers or thematic layers for the GIS database. Most data types must be related to ownership to be useful. The cadastral layer, the assessor's map of property ownership, is a particularly crucial yet difficult dataset to develop and maintain (Dueker 1987, 1361).

When spatial data is already available in a digital form, there is great potential for saving time and expenditure. This kind of spatial data is available for entire thematic layers for particular areas of interest. Different kinds of agencies have, and make available, digital spatial data. These include: the Federal government, regional agencies, state agencies, counties and cities. The USGS provides different types of digital data, such as the U.S. GeoData tapes which have four thematic layers: transportation, hydrography, boundaries, and the public land survey system. These tapes correspond to USGS 7.5 and 15-Minute topographic maps. Another series of U.S. GeoData tape have land use and land cover information. The U.S.G.S. also makes available Digital Elevation Model datasets (Star and Estes 1990, 68). Other agencies such as the U.S. Census Bureau, the U.S. Department of Agriculture, the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the National Aeronautics and Space Administration make available digital data for demographic information, soils, wetlands, and remotely sensed data (Star and Estes 1990, 65). Commercial firms are also involved in making available remotely sensed satellite imagery. Eosat (Landsat series of remotely sensed data), and SPOT Image Corp. (SPOT series) are two commercial firms.

Several issues arise in the data acquisition process. These include issues involving the scale, resolution, accuracy, precision of the base data, as well as methods to document and enhance data quality. The importance of accuracy, precision and timeliness of data cannot be stressed enough, in addition to the documentation of the degree to which data meets standards for data quality. Quite often, the mapping standards in agencies may vary by county, organization, and between agencies (Star and Estes 1990, 62) resulting in varying degrees of data quality.

Standards for data quality are important for effective GIS use. These include standards

for the format, for the content of digital spatial data, and for standard layers such as the public land survey system, the cadastral layer, land use activities, surface features, land cover, and other characteristics. To address issues of standards and data quality, the U.S. government is in the process of creating a National Digital Cartographic Database (Marble 1987, 7). Other issues involving data quality in the data acquisition process will be discussed in following chapters.

Preprocessing or Data Capture

Preprocessing is essentially converting spatial data into a machine readable format with the desired detail, accuracy, scale, coordinate system, and attribute data. Star and Estes confirm that often, a large proportion of the data entered into a GIS requires preprocessing to conform to a data type and structure, geo-referencing, and other characteristics (1990, 76). Preprocessing results in thematic data layers. As stated earlier, "data entry is typically the most labor intensive and time consuming phase of any GIS project, yet also the most important. GIS computer processing cannot produce quality information from substandard digitized data (Logan and Bryant 1987, 1391)."

There are a number of actual processes involved in preprocessing spatial data:

1. Format conversion: Spatial data is often available in a variety of incompatible formats. Spatial data may be available in a vector format or a raster format. The preprocessing capabilities of any particular GIS are specific to this technology orientation. This will be discussed in more detail later in this chapter. Spatial data may also be available in different data media. For example, as analog maps, photographic prints or printed tables and must be converted into a format that is

computer-compatible (Star and Estes 1990, 77).

2. Data Reduction and Generalization: The input record of a GIS requires data reduction and generalization. Reduction could be reducing the number of measurements, averaging measurements, and changes of scale. Generalization is development of a less precise representation of spatial data when the original data is in such great detail that it consists of a great amount of data (Star and Estes 1990, 91-92).

3. Error detection and Editing: GIS software can detect errors caused by encoding or digitizing error. It is important that GIS software be able to detect attribute error (Star and Estes 1990, 93). An attribute may be missing or inappropriate (Star and Estes 1990, 94).

4. Merging: Merging is turning points into lines and lines into polygons. More specifically, this is the process of "building more complex objects from the elemental points." Some examples are vectors constructed by connecting points, polygons constructed by linking vectors, and adding attribute values (Star and Estes 1990, 95).

5. Edge Matching: The goal of edge matching is to create a seamless database. This is done when an area of interest is not covered by just a single map sheet or air photo or when features that cross the boundary between map sheets do not align properly (Star and Estes 1990, 96). This process can be done by manual or automated methods (Star and Estes 1990, 96-97).

6. Rectification/Registration: Star and Estes state that rectification and registration consist of "mathematical tools ...to modify the spatial arrangement of objects in a dataset into some other spatial arrangement." The purpose is to modify geometric relationships without changing the data content (1990, 97). Rectification is

manipulating the dataset to conform to a specific geocoding or coordinate system.

Registration is similar, but not based on an absolute referencing system. These two processes are done by operations such as rubber sheeting, ground control point rectification, bilinear and cubic interpolation, translation, scaling, and rotation (Star and Estes 1990, 106-111).

7. Interpolation: Measurements of the earth's surface cannot be taken everywhere.

One must estimate values for locations where there are no measurements. This is performed by using statistical methods based on an understanding of the data and how it varies spatially (Star and Estes 1990, 114). This is done by analytical descriptions of how to use the known information to estimate the unknown information. Weighting functions, trend surfaces, finite element approach, and kriging are such methods (Star and Estes 1990, 115-118).

8. Photointerpretation: Photointerpretation is important at several stages of developing a GIS database. Interpretation is vital for extracting useful information from photos and other images. The tasks of identification (recognizing features of interest), measurement (distance between features, photogrammetry) and problem solving are difficult (Star and Estes 1990, 119). This process also includes converting aerial photography into a digital form. The most common type, black and white aerial photography, is interpreted with the aid of interpretive keys, stereoscopic photography, other types of photography, and other remotely sensed data when available (Dangermond, Derrenbacher, and Harnden 1987, 20). Remotely sensed data of the earth from satellites (Landsat, SPOT, etc.) are already in a digital format, but also require interpretation.

9. Digitizing: This includes transforming analog information about the earth's surface

into a digital form through the process of digitizing maps. A digitizer is an electronic device with a cursor which can trace the graphic features: the points, lines, and areas of a map. The cursor's movements are translated and recorded by the digitizer table and converted into x,y cartesian coordinates (Dangermond, Derrenbacher, and Harnden 1987, 31). This results in the creation of digital files representing the map characteristics. Spatial features can also be detected through the process of scanning, in which an array of photodetectors sweeps across a map (Star and Estes 1990, 90).

Issues involved in preprocessing may impede the successful use of GIS technology. There are issues of map compilation scale differences, geodetic control, resolution, efficient storage and retrieval of spatial data (Cowen 1987, 49; Dueker 1987, 1362). Converting between digital formats can present problems as can poor data capture (data quality, registration, timeliness, etc.) which cannot be corrected at later stages except at a very high cost (Cowen 1987, 49). These issues will be discussed in more detail in Chapter V.

Data Management

Database structures are the ways in which spatial data can be organized, yet allow access and cross-referencing. As described earlier, each data layer or theme consists of different types of spatial data in the form of three primitive types of geometrical entities: points, lines, and polygons. Attribute data describes spatial objects in terms of geodetic location and other descriptions such as ownership (Star and Estes 1990, 32-33). The data structures must be able to represent these spatial entities.

There are three main data structures -- hierarchical, network, and relational (Burrough 1986, 16). A relational structure is most advantageous. This structure is flexible, can meet the

demand of queries formulated by Boolean logic (see Burrough 1986, 82-85) and mathematical operations. A relational structure allows different kinds of data to be searched and organized. Despite the time it takes to make such data searches, this structure is being applied for GIS (Burrough 1986, 18).

The topological relationships between spatial entities must be built into the way data is represented digitally in a GIS (Burrough 1986, 13). The choice of the data structure can affect data storage volume and processing efficiency. Because different GIS software may store and access data in different data structures, a system must be able to convert data between different data structures (Star and Estes 1990, 32).

Raster Format

Raster and vector data structures are two ways of representing spatial data in the computer either explicitly or implicitly (Burrough 1986, 19). Raster structures are explicit and are "a set of cells located by coordinates; each cell is independently addressed with the value of an attribute (Burrough 1986, 19-20)." Star and Estes state that a raster structure is a cellular organization with a value developed for every cell in a regular array over space (1990, 33). Each cell is given a numerical value representing an attribute and then represented in display by a color or gray scale (Burrough 1986, 19). The simplest form has rows for the horizontal dimension usually oriented east-west and columns, for vertical, starting at the top for the northern boundary (Star and Estes 1990, 34).

Because each cell in a two-dimensional array of cells can hold only one value, the raster format uses overlays to represent different spatial attributes (Burrough 1986, 20-21). The ability to specify a location in space is limited by the size of the raster elements (Star and

Estes 1990, 34). This is defined as a minimum mapping unit (resel for resolution element). This is the smallest element that can be uniquely represented in data. The choice of minimum mapping unit is important in the design of a GIS project (Star and Estes 1990, 37). Often a raster cell half the length of the smallest feature desired to be recorded is selected as the standard. The size of resels must be much larger than the size of raster cells or the database will lose spatial objects (Star and Estes 1990, 37).

There are advantages and disadvantages to a raster structure. Changes in the data may be achieved more easily in a raster format (Burrough 1986, 19). Updating is merely replacing the value of a cell. The ability to specify a location in space is limited by the size of the raster elements due to the inability to know anything about locations of objects within a raster cell (Star and Estes 1990, 48).

Vector Format

The vector format is an implicit format. It corresponds to the "three main geographical entities: points, lines and areas; lines and areas are sets of interconnected coordinates that can be linked to given attributes (Burrough 1986, 20)." Vector formats use a set of lines with definite starting and ending points and connectivity. These lines are vectors (Burrough 1986, 19). An element may be located at any location without the positional constraints inherent to a raster array (Star and Estes 1990, 48). The relationships between different spatial objects are represented "as exactly as possible...coordinate space is assumed to be continuous, not quantized as with the raster space, allowing all positions, lengths, and dimensions to be defined precisely (Burrough 1986, 25)."

Raster versus Vector Formats

As stated earlier, there are advantages and disadvantages to the two different spatial formats. Berry elaborates on the characteristics and differences of the two formats.

"Although there are significant practical differences in these data structures, the primary theoretical difference is that the grid structure stores information on the interior of areal features and implies boundaries whereas the line structure stores information about boundaries and implies interiors. Most modern systems contain programs for converting between the two data structures (1987, 1405-1406)."

The vector format has some strengths. It is more aesthetically pleasing, requires less storage, and its connectivity allows searches more easily. Despite the lack of these characteristics, the raster array is easier to update because changes in the vector format requires not only changes to vectors themselves, but also in connectivity. Connectivity is implied in the raster format due to the grid layout (Burrough 1986, 19).

The choice between the two formats is often dependent upon the type of GIS application. Natural resource applications often use satellite imagery. Often the raster format is selected for a GIS due to the raster format of satellite imagery. As stated earlier, satellite imagery is used to distinguish categories of land cover of the earth's surface (Star and Estes 1990, 39). A great volume of satellite imagery is available of the earth's surface. The Landsat satellites have a nominal pixel size of 30 meters which corresponds to 35 million raster cells or pixels for 30,000 km of U.S. (Star and Estes 1990, 40-41). Applications, such as use for cities, utilities, public safety, and transportation are concerned with linear features and the vector format is more appropriate.

Deciding between and exchanging data between there two structures was a technical

problem, but they are no longer mutually exclusive. More recently, data processing using algorithms can work for both structures, and storage capabilities and methods have improved which can convert between formats with algorithms (Burrough 1986, 34). Both are valid methods of representation of spatial data and are inter-convertible.

Manipulation and Analysis of Data

The internal operations of a GIS are complex. A background in computer science is helpful to understand how the software is designed and the different approaches to spatial data handling (Marble, Calkins, and Peuquet 1984, 4-1). Manipulation and analysis can be explored on a general level without too much detail. These kinds of operations affect both spatial and non-spatial data (Star and Estes 1990, 143). There are two classes of GIS analytical operations. Primary operations are basic area and distance measurements, buffer generation, reclassification, and boolean operations (Parker 1987, 76; Burrough 1986, 83-85). Compound operations are more experimental. They consist of strings of commands held together by macro software resulting in simulation modeling (Parker 1987, 76-77).

The more basic processing functions can be broken down into four types (Berry 1987, 1406). The first functions are similar to manual techniques of handling spatial data (primary operations), but are faster and more efficient. The second functions are unique to GIS technology (compound operations).

1. Computer mapping/automated cartography: Computer mapping is the preparation of map products.
2. Spatial Database Management: Once the GIS database has been created, the GIS database stores the data, and the software enables organization of data. It also

searches through large data sets to find coincidence among variables.

3. Spatial Statistics: Spatial information is represented numerically (unlike analog methods) and this digital representation allows quantitative and qualitative processing not possible with manual methods. Spatial statistics makes it possible to characterize the spatial distribution or pattern of spatial data (Berry 1987, 1406).

4. Cartographic Modeling: Cartographic modeling "uses sequential processing of mathematical primitives to perform a wide variety of complex map analyses (Berry 1987, 1407)." Use of this method controls the order of the operations executed upon the database. Each intermediate result is stored in the system as a new digital map. Like traditional algebra, map algebra can add, subtract, and multiply maps. In this process, "the spatial coincidence and juxta-positioning of values among and within maps create new operators such as proximity, spatial coincidence, and optimal paths (Berry 1987, 1407)." This cyclical processing results in the development of new derived layers to form the input to further analysis an important function of a GIS (Star and Estes 1990, 143). Cowen adds that spatial search and overlay are unique to GIS technology (1987, 52).

Product Generation

Data output is the presentation of the results of data manipulation. It is in a format understandable to the user and that facilitates transfer to another digital system. Output may be displayed as maps, graphs, tables, digital tape, or electronic transmission over a modem or other electronic link to another system. Products may take the form of paper, mylar, or other material, such as electronic displays. (Burrough 1986, 72). Unlike cartographic systems,

product generation is not the emphasis of a GIS (Cowen 1987, 52; Star and Estes, 1990, 175).

Maps of various kinds are the most common kind of output. Maps, or cartographic output, depict the spatial distribution of various phenomena. Maps use different tones, shadings, colors, and patterns, which are assigned to specific values of polygons or grid cells, to convey different values assigned to spatial distributions. Thematic maps depict the spatial distribution of a single phenomenon (timber stand condition) or the relationship between phenomenon (different classes of land cover). Choropleth maps depict the relative magnitudes of continuous variables as they occur within the boundaries of unit areas. Map analysis assigns a value per polygon to obtain the resulting map (Star and Estes 1990, 175). Proximal or dasymetric maps "focus on location and magnitudes of areas exhibiting relative uniformity" such as land cover classes, or where there are "boundaries based on changes in the data values themselves (Star and Estes 1990, 177)." Line maps show the direction and magnitude of a flow, for example, stream flow. Three-dimensional maps such as landform maps, can be created (Star and Estes 1990, 179). Three-dimensional maps may take the form of sophisticated maps which show a simulation of a particular perspective such as the view of an area from a low flying aircraft (Star and Estes 1990, 156). Animated maps, using computer graphics techniques, can display sequences moving in time. With recent advances in computer graphics, animation is a valuable tool. It has the ability to model changes over time and present information clearly to an audience (Star and Estes 1990, 179).

Graphics are the results of analyses which can be displayed in a non-map form (Star and Estes 1990, 180). One type, bar charts can display differences in an attribute between categories, for example, the number of hectares in different land cover classes. A pie chart can illustrate proportions of a whole, such as the amount of land in each category of land use (Star and Estes 1990, 180). A scatter plot can display behavior of one attribute versus another,

for example, the crop yield versus the amount of applied fertilizer (Star and Estes 1990, 181). Histograms show the distribution of a single attribute (Star and Estes 1990, 182). Output may also take the form of numerical products. This requires both a variety of statistical procedures be built into the system, and ways to extract data from system. Sometimes this kind of output requires the use of additional statistical software programs (Star and Estes 1990, 182-183). A GIS thus requires the ability to extract information and pass that information into other systems or into storage (Star and Estes 1990, 183). Non-graphic output takes the form of transfer of data between different systems or digital output to maintain records (Star and Estes 1990, 174). GIS hardware displays hard copy (paper and film) and soft copy data (temporary graphics). It consists of "character and graphic printers, plotters (pen and electrostatic), color and gray-scale cathode ray tubes, film recorders, and computer output microfilm devices (Star and Estes 1990, 183-184)."

Brief Descriptions of GIS Software

There are many different GIS software packages available from commercial firms and from the government. Few commercial firms offer a fully integrated GIS software package that can perform all functions. Often an agency or user will use several programs and integrate programs together for better results. More recently, the smooth integration of different programs has been possible on several hardware platforms. The complex hardware and software of a GIS requires expertise in a variety of geographic, computer science, and systems engineering areas. For this reason, technical and advisory support for the software is very important when an agency is selecting or purchasing GIS software. These aspects of software and hardware selection will be discussed in later chapters. Governmental agencies in

Northwest Oregon use several commercial and public domain software packages.

Public domain software are software developed by public agencies and free of charge. A maintenance fee is usually required for updates and technical assistance. Several public domain software are mentioned by the survey participants in Chapter IV. MOSS (Map Overlay and Statistical System) uses an older, simple polygon data structure which according to some, would not meet modern topological standards and definitions of a GIS (Parker 1987, 75). MOSS is used by the U.S. Forest Service and other federal agencies. GRASS is a vector based software program developed and used by the U.S. Army Corp of Engineers. It is also used by other agencies such as the U.S. Soil Conservation Service. SAGIS is also another program developed by the federal government.

Commercial software are software developed by private companies. ARC-INFO is an often used program. It has been described as the tool box approach, "creating, analyzing, displaying and managing computerized maps in vector format." It has four kinds of functions -- input, data management, analysis, output (Marble, Calkins, and Peuquet 1984, 4-43). Intergraph software is also commonly used GIS program. Other GIS related software are mentioned by the survey participants in Chapter IV, such as PMAP and ERDAS. These do not have GIS capabilities but are used in combination for functions such as linking to remotely sensed data.

Applications of GIS for Natural Resource Management and Related Fields

GIS technology is used for natural resource management, environmental planning, and land use planning in similar ways. According to Parker, "land and resource use alternatives are formulated and the GIS is used to evaluate each in terms of environmental impacts,

economic implications, land areas involved, and potential use conflicts (1987, 77)." GIS is used not only to determine land use conflicts but also for simulation modeling. This is the process of simulating and evaluating competing land uses. Some examples are: potential coal leases, alternate scenic area designations, timber sales, new fence construction, or utility corridors (Parker 1987, 77). Projects can also utilize GIS technology to conduct studies on a global scale. As stated earlier, satellite data is an important component of such studies (Parker 1987, 78). Chapter IV describes the uses of GIS technology for various Northwest Oregon governmental agencies for these kinds of applications.

GIS has the potential for improving our understanding of the environment. Parker believes "we are on the verge of major advances in the use of modern computer technologies in resource management...In many ways, this is by far the greatest challenge (1987, 78)." As stated earlier, particular issues may limit the utility of GIS technology for future use. There is always the need for quality data for input into a GIS. Caution is necessary in relying on GIS analyses due to the misinterpretation of the degree of accuracy of data output. GIS technology must be used wisely and appropriately. There are also problems when a GIS designed and used for a specific class of problems is then used for other purposes (Star and Estes 1990, 23). One must guard against inappropriate uses of GIS technology and agencies must seek to establish priorities and long range policies regarding GIS use. Many of the issues involved in GIS use will be addressed in Chapter V.

Regardless of the barriers to effective use, a GIS can perform modeling and analytical functions that were once unfeasible. The challenge is how GIS users will understand the complex spatial relationships and physical processes on earth given the information overload that is the result of new technology (Cowen 1987, 53). Parker believes that "the future is bright for GIS technology." The "convergence of technology, new requirements for more

intensity in land resource management, global social and environmental concerns, increasing consciousness of the benefits of GIS, have produced an exciting time and opportunity (1987, 78)."

CHAPTER III

A CONCEPTUAL MODEL OF GIS IMPLEMENTATION BY GOVERNMENTAL AGENCIES

Introduction

Agencies that manage natural resources and engage in land use planning activities need a wide variety of spatial information about their areas of concern. Governmental agencies, universities, and private industry are investigating new ways of acquiring, storing, and manipulating spatial data for the decision making process. This is necessary because there is "intense resource regulation, environmental protection, and public involvement in the whole process." Every special interest group "...has a legal say in how agencies do their jobs, and resource managers must listen and be responsive (Parker 1990, 67)." In a time of increasing and often conflicting land and resource use, limited budgets, and higher public demand for environmental quality agencies need accurate, timely and accessible data. Glenn Montgomery states that the impact of out-of-date maps and other geographic data used to manage our land facilities information is felt by everyone. "Taxpayers feel it in the form of higher costs and decreased response time to service requests. Public sector agencies feel it as they examine redundancy and productivity in records management activities...and make land use and infrastructure planning, design, and construction decisions (Montgomery 1989a, 10)." This pressure has led to an interest in acquiring a GIS so that the diverse data may be stored,

displayed, and combined for new kinds of analyses to help with the decision-making process. "GIS analytical capabilities and its ability to derive new information make it often well-suited to meet these demands (Woodcock, Sham, and Shaw 1990, 308)."

The decision to implement a GIS should be made cautiously, however. Agencies have had the tendency to jump into acquisition with little planning. According to Antenucci, "human nature, abetted by the industry's aggressive marketing, tempts both the experienced and inexperienced computer user to take on too much too quickly. Attracted by glitter and promises, practicalities are often ignored, along with consideration of budgets, human resources, and time (Antenucci et al. 1991, 211)." GIS technology is continually changing. There are many different types of GIS platforms with different capabilities. With limited funds, a poor choice can have disastrous affects for GIS users and for the future use of the technology itself.

Process for Implementing a GIS

Before talking in detail about the issues involved in implementing a GIS, a model of how agencies acquire a GIS should be presented. Many agencies spend weeks or months acquiring a system, from their first investigation of GIS technology to their final implementation. Figures 1 and 2 outline the steps these steps. This process may be directed by personnel at various institutional levels, depending upon the scale of the GIS acquisition. When a federal agency implements a system agency-wide, the entire GIS project may be directed by personnel at a national level. Smaller scale acquisition may be directed at the regional, area, or district level.

Agencies that manage natural resources, perform land use planning, or monitor and

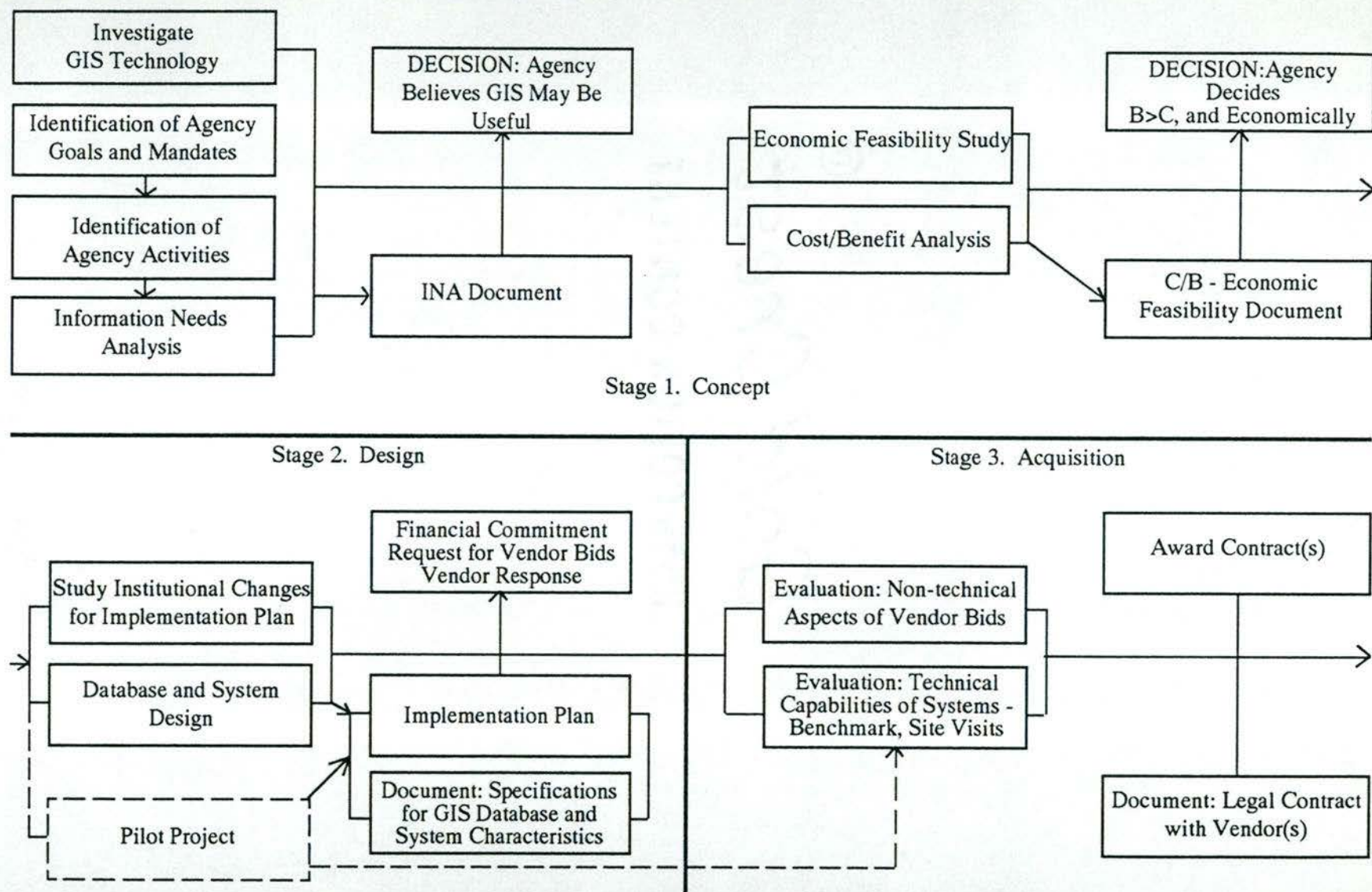


Figure 1. Steps in implementing GIS technology for governmental agencies (Stages 1-3)

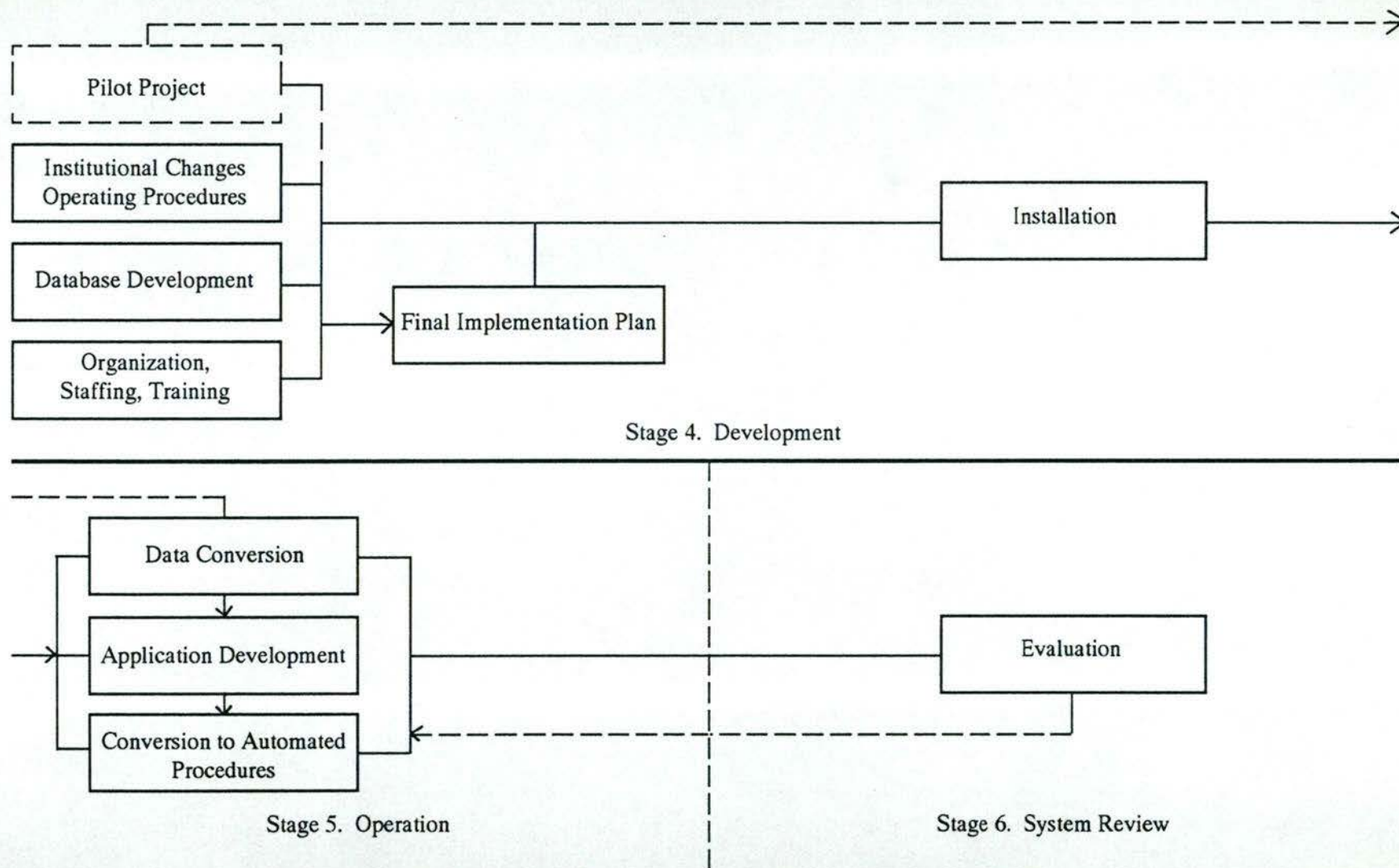


Figure 2. Steps in implementing GIS technology for governmental agencies (Stages 4-6)

manage environmental quality often have common institutional and economic characteristics. This is due to their similar legal mandates and agency responsibilities. This commonality, and their similar natural resource activities, all in the context of the same national political environment, results in similar agency needs and responses when implementing new technology. Thus, the implementation process may be very similar for different agencies. A general model can be presented that is fairly representative of GIS acquisition. The model presented here is flexible. Many of these steps may be concurrent, or in a different order. Often, for each step in the process, a resulting document may guide the decision whether or not to continue on in the implementation process. The following model of implementation is the result of literature review and original observations by the author.

Preliminary Outlook

Before the process even begins, it is important for an agency to have a clear goal and purpose in investigating GIS technology for implementation. Clear and purposeful direction will generate support for GIS acquisition (Antenucci et al. 1991, 212) and help the agency go through the process smoothly and effectively. The process of GIS implementation may have strongly-felt implications on the agency. GIS technology is very expensive and implementation will forever change work procedures, analyses and the way decisions are made. Poor planning, poor support, and resulting poor choices may cost time and money. It may also result in frustration and actual failure in implementing GIS. Chapter V will look more closely at issues in implementing GIS technology: barriers to effective use, how these issues are related to the perception of GIS technology and possible solutions.

The stages in implementation may be identified in several ways. For this model, each

stage results in documentation and a decision that leads to the next option. Each successive stage builds on the previous ones.

Model for Implementation

Stage 1: Concept

These steps are conducted simultaneously. The needs of the user, the characteristics of the institution, and the economic feasibility of the GIS implementation must be assessed (Antenucci et al. 1991, 216). User requirements analysis is identification of current activities that rely on spatial data, inventory of current spatial data, characterization of institutional procedures for handling spatial data, and analysis of future agency activities and resulting spatial data needs (Antenucci et al. 1991, 216). These assessments result in two documents: the INA (Information Needs Analysis) Document and an Economic Feasibility Document.

Information Needs/User Requirements Analysis

This is a detailed study of the needs of potential system users. It includes a clear statement of end product characteristics, required production rates, and estimated data volumes.

Basic GIS Awareness

In attempting to describe current data needs and procedures as well as future projections it is first necessary that all those staff involved in this stage have a common

familiarity and understanding of GIS technology. The agency personnel must have a thorough understanding of GIS capabilities, limitations, costs, issues in implementation, and trends.

This includes researching case studies of GIS implementation and applications. They must also differentiate GIS from related technologies, such as CAD or computer cartography. Other technologies may have severe limitations in the ability to store a certain amount of data, in analytical capabilities, in topology (or lack of) as well as in other areas making it unsuitable for many agencies' needs.

The agency personnel designated to handle GIS responsibilities at this stage should investigate GIS capabilities, limitations, costs, and its effects on current institutional framework. They also investigate specific GIS platforms in several ways. Their education may be accomplished through workshops, seminars, training sessions, conference attendance, and publications (Antenucci et al. 1991, 217). They may also research through visiting sites of GIS implementation, and through talking to vendors, GIS consultants, other agencies, or to state or federal GIS service centers. The goal is for lead people to develop expertise in the field of GIS before entering the market. Accomplishing this goal will help reduce future problems in the acquisition and implementation process that may result from improper perceptions of GIS technology.

Surveys, symposiums, meetings and presentations can improve the awareness of an agency's GIS plan in addition to awareness of GIS capabilities. This type of education extends to show others in the agency how GIS may affect them. This includes awareness of costs, staffing, and changes in institutional procedures, work flow, and work load. Expanding GIS awareness occurs as the agency's commitment to GIS technology increases, and especially after installing the new system.

Identification of Agency Activities

The goals and requirements of an agency affect the selection criteria for a GIS and development of an implementation plan. Before even implementing a GIS, the agency must evaluate its needs and public and legal responsibilities. The first question: Is GIS technology even appropriate for the agency at this time? "Managers should reflect on the goals and objectives of the organization and determine if a system based on, and products from, GIS technology fulfill both the letter and spirit of the organization's responsibilities (Guptill 1988, 23)." Even if the answer is yes, further analysis of agency activities is still necessary.

Agency mandates and goals determine the agency's activities and the resulting types of data collected for resource use and management decisions. An example of agency goals determining the essential data needs is the case of the U.S. Forest Service. This agency is involved in many activities. It allows timber harvest, provides recreational opportunities, manages mining claims, manages fish and wildlife habitat, provides fire protection and control, designs, constructs and manages buildings and facilities, among other functions (Willamette National Forest 1989, n.p.). Thus, the agency needs resource data in the form of maps, air photos, and databases of these particular resources. The activities of an agency can almost completely determine GIS needs. The end result of investigating agency activities is to help to develop a clear idea of how a GIS may help as a tool to meet objectives and make decisions. It also will help and agency determine what essential data is needed for the new GIS database, and to develop the institutional changes necessary for using a GIS. Antenucci sums up this philosophy: "applications must drive system design (1991, 212)."

Information Needs Analysis

The INA is the process of identifying and analyzing spatial resource information needs to support the agency's resource management goals and activities together with identifying available resources. The agency must inventory its current spatial data for accuracy, redundancy, timeliness, format and adherence to current procedures for handling spatial data. This will determine what data will be needed for the GIS database and what institutional changes are necessary. This in turn helps to generate objectives for new kinds of analyses and models that the GIS may perform, with an emphasis on future trends and needs of the agency. The agency may then determine data needs and project procedure changes. The result is an INA document of current and future data needs and procedures. This document is used for the successive steps of GIS implementation.

How the INA is Conducted

The INA may be performed by in-house staff or outside consultants. Agency employees have a greater understanding of the tasks which are being considered for automation but may lack GIS knowledge. When time and resources permit, agency staff members, who lack expertise, may be trained in GIS technology (Guptill 1988, 11). If staff have limited time, knowledge or expertise in the proposed GIS software, the agency should bring in outside assistance (Guptill 1988, 12). This assistance may come from its parent agency, for example, from the national level of a federal agency to help region or district, or from another party, such as a state GIS service center, or from a private consulting firm.

The INA is often conducted as an agency or department-wide seminar or meeting,

beginning with a presentation on GIS. The presentation includes the basic functions of a GIS, the analytical capabilities of a GIS, the description of typical GIS products, and how this can tie into the agency's mission, goals, and activities. It is very important for everyone to understand the principles and objectives in implementing a GIS and how it may change each department's work flow, procedures, and responsibilities.

Each subgroup or department can then complete its own information needs profile (Willamette National Forest 1989, n.p.). Each department is represented by individuals who are potential users of the GIS and the GIS products. This group determines who the direct, indirect, and potential users are. Direct users actually work hands-on with the GIS hardware and software to produce GIS products, and indirect users work with the GIS products (Guptill 1988, 12).

Assess Current Spatial Data

The group must examine the current spatial data that is used. The existing data may be in many formats such as files, inventories, maps, aerial photography, satellite imagery, or a resource database. For each type, the following types of questions must be asked: Does the data meet agency goals and requirements? Is the data essential? What are its sources? Are these sources accurate? Is the data still current and correct? How suitable is this data for agency needs? What analyses can be done with this data? How should this data be presented? (Willamette National Forest 1989, n.p.). These questions help to determine the quality of current spatial data and the requirements for new data.

New Spatial Data

The agency and department activities, and the resulting data requirements for decisions, determine the amount, types, sources, scales, resolution, and timeliness of spatial data that is collected and analyzed. The group can brainstorm about any new kinds of analyses. They will then determine the desired data, what new data is needed, the sources and methods for acquiring new data, and questions desired to be asked of a new database, including data themes. For example, a department within a supervisor's office for a national forest may want to know when and where to harvest timber. They will therefore need a map and list of acres available for harvest from the prospective GIS. A timber stand conditions data theme is needed from the prospective GIS database (Willamette National Forest 1989, n.p.). The Bureau of Land Management's Western Oregon Digital Data Base Project (WODDB) has several fundamental data themes: the public land survey system, hydrography, transportation, gross vegetation, topography, and cultural features, and 56 others (von Meyer 1990, 25).

Current Institutional Procedures

The group must also evaluate the current methods of handling, manipulating, and analyzing information, and the traditional methods of making decisions. Again, this will contribute to determining data needs for the GIS and the institutional changes necessary to make a GIS a part of everyday work. This is a good point in time to rethink how the agency's mission and its institutional methods have supported each other, and whether past and current methods have really been most appropriate.

New Institutional Procedures

A GIS can do more than increase the speed and efficiency of old methods. There must be special emphasis on the determination of possible future agency needs and those data needs for new types of analyses and models. This is important for dealing with changing requirements of the GIS in the future, in light of the resources necessary to implement and update a GIS. GIS implementation can lead to totally new approaches in analyses and new spatial data products, but institutional change may be difficult and painful. That is why it is important to conduct this step carefully and thoroughly. The implementation plan must determine the characteristics of the desired GIS database, and also the institutional changes needed in work load and flow, procedures, data update schedules, and individual and departmental responsibilities.

New GIS Functions

What kinds of functions can a GIS support? A typical national forest office provides a few examples of areas where a GIS can help:

- (1) decisions about forest uses and withdrawals by monitoring and recording changes in landownership and land status;
- (2) decisions about forest and rangeland uses by mapping land and resource inventories;
- (3) decisions about associated transportation systems, logging systems, waterways, fire access, etc.;
- (4) monitoring of environmental impacts and changes in vegetation, access, and

cultural features;

(5) production of maps and statistical analyses for special projects; and

(6) development and maintenance of natural resource assessments and inventories

(USDAFS Engineering Staff n.d., n.p.).

The agency must also differentiate between selecting a GIS with an emphasis on hard copy products versus a GIS emphasizing analytical capabilities (Guptill 1988, 18). Using a GIS that has its roots in computer-aided design versus GIS, with its strong geographical analysis capabilities, can result in wasted resources for an agency that needs the strong analytical capabilities of a true GIS. This initial investigation is not the process of merely trying to select a GIS. It is also the process of closely scrutinizing current agency responsibilities, institutional characteristics and procedures, and how procedures must change in anticipation of making GIS useful even in light of continual changes in agency needs, activities, resource availability, and public demands.

Final INA Document

The final INA document identifies the potential GIS users. It defines the required GIS products, including the information content, the user accuracy needs, the preferred media, scales, format (tables, graphs, maps), and data topology. It includes an evaluation of the work flow: the types of data used by each department, the types desired, and the types of products desired. It includes not only the kinds of data needed for input but also end product characteristics, such as required production rates and estimated data volumes (Guptill 1988, 11).

With the INA document developed, along with the Economic Feasibility Study, the

agency can make a decision whether or not to continue toward GIS acquisition and implementation. If combining information from a variety of sources and scales allow analyses that can support its decision-making process, and the resources are available to support changes, then the implementation of a GIS can provide managers with a powerful tool to store, retrieve, analyze and present spatially related information about geographic features and resources (USDAFS Engineering Staff n.d., n.p.). This can help the agency perform its activities more effectively, and thus help to achieve the agency's mission.

All of the data in the information needs analysis impacts the choice and specifications of the GIS database design, the GIS data input, and the GIS data output (Guptill 1988, 16). All of this information will be important, for writing up the technical requirements of the proposed GIS and an implementation plan that specifies institutional changes.

Economic Feasibility Study

Before making a major investment, an agency must conduct an Economic Feasibility Study to determine whether acquiring a GIS is practical. Both the quantitative and qualitative costs and benefits are assessed for different GIS configurations and databases. Proposing different GIS alternatives and estimating the costs of each requires expertise and knowledge of different systems. Often, an objective outside consultant is used at this point to help with the task (Antenucci et al. 1991, 217). Costs include the cost of hardware, software in addition to the cost of database development, system maintenance, and staffing. The quantitative benefits are those that can be assigned a dollar value. The most common is the benefit of saved time and greater efficiency.

The information generated in the INA is of importance here. By documenting current

operations, it helps to project a baseline condition (Antenucci et al. 1991, 218). In addition to the direct savings there may be indirect savings such as better decisions based on GIS analyses.

The INA also identified the resources available for investment toward a GIS. The agency must determine funding sources, and whether that funding is shared. GIS projects are becoming increasingly characterized by multiple funding sources and participants (Montgomery 1990a, 47). Additionally, the agency budget and staffing constraints are identified. "The objective is to determine the scale of a proposed GIS system that is reasonable for the organization (Woodcock, Sham, and Shaw 1990, 312)."

The Economic Feasibility Study is important to build a sound quantitative financial case to back up budget requests. Adequate funding must result or the agency will end up with a system that does not meet its needs (Montgomery 1989a, 10). The Economic Feasibility Study is often used to persuade upper management of the need for a GIS and communicate the depth of commitment required. It is important for all involved to realize that a GIS is a long-term investment requiring long-term commitment of time and resources. "Typically, a major GIS requires two to five years for full implementation before all nonrecurring costs and benefits are realized (Antenucci et al. 1991, 218). "Ultimately the costs of using the present system and methods will be compared to the costs of implementing and using a GIS, as will the agency budget be compared to the cost/benefit ratio of the proposed GIS.

Cost of the System

The initial cost of the hardware and software can be up to several hundred thousand dollars. The variety of software varies in costs and capabilities. The investment depends upon

the resources available to the agency and the cost of the software program which meets the functional requirements generated by agency personnel. Public domain software is less expensive than commercial systems, but often has lower capabilities than commercial software.

Cost of Maintaining and Expanding the System

As hardware becomes obsolete upgrades may be necessary. This may include new and additional CPU, workstations, plotters, and other hardware. Software expansion may be necessary to tailor the software to specific applications. This may include writing macros and pull-down menus. "Customized procedures and standardized user interfaces for accessing the GIS are important, so that professionals and specialists may use it as a tool without becoming GIS experts (Olivier, Greenwood, and McPherson 1989, 106)." Often, an agency must add in the cost of bringing in outside consultation, or training staff to adapt software to specific applications. There is also the cost of programs to integrate other GIS related software, such as programs that can access remotely sensed data, or to link other databases.

Cost of Database Development

Once data needs are determined in an INA, the costs of database development may be assessed. These costs include: converting hard copy (non-digital) data to a digital format; reformatting existing digital data; acquiring the required data, including additional field work; and acquiring digital data from other agencies, such as the USGS National Cartographic Information Center, or as digital remote sensing data, aerial photography and other sources (Guptill 1988, 17). Often, an agency may contract out this work to a consulting firm. The

data may be in several forms: "photogrammetric compilation and digitizing using an analytical stereoplotter, automation of existing maps using a digitizer or scanner, key entry of data, and transfer of existing data (Antenucci et al. 1991, 225)." The cost of using a contractor for database development must also be added to the entire cost in addition to the cost of creating new data such as new field research, new aerial photography, or remotely sensed data.

Database development may cost 10 to 1,000 times the cost of the GIS hardware and software (Guptill 1988, 21). "Development of the GIS database...requires substantial investment of personnel, time, and financial resources (Antenucci et al. 1991, 225)." It is very important to make this clear in the entire process of implementing a GIS. This fact must be reflected by the degree of funding committed if GIS acquisition is to be smooth and successful.

There are several different issues to consider in database development. Data input is important because decisions based on GIS analyses all ultimately depend upon the accuracy, precision, content, and timeliness of the data in the database. Here the old adage of "garbage in, garbage out" comes into play. A GIS analysis is only as good as the data it is based upon. Database design and development may well be the most important aspect of GIS use because all else depends upon it. The products from a GIS are attractive and appear reliable, but are not automatically accurate. Hence, accuracy is tantamount to successful GIS implementation. Because of the incredible cost, it is crucial that an agency select a GIS that does not make database development more difficult due to software limitations, despite any savings in the initial hardware and software costs (Woodcock, Sham, and Shaw 1990, 312). A cost/benefit analysis must also assess the cost of data accuracy and detail. A more detailed database makes possible many more applications. The high cost of data capture, storage, maintenance, and manipulation of the data must be weighed against such benefits (Montgomery 1989b, 36).

These issues will be discussed again in Chapter V.

Cost of Maintaining the Database

Maintenance costs occur mostly in the form of personnel time. They include checking for errors, storage of data, data updates, and sharing information from the GIS database with other systems. Staff costs include not only personnel salaries but also staff training. The cost must include lost production while the staff becomes proficient on the new system (Guptill 1988, 21). An agency must have skilled personnel for successful GIS implementation and this may be accomplished by training existing staff. Computer skills may initially range from basic to advanced within the staff. They must be taught about GIS technology in general, and once the contract is awarded, they must be trained in the specific GIS technology acquired. This includes training in the information structure, in conjunction with installation and implementation of the GIS (USDAFS Information Systems 1988, n.p.). An agency may also hire new staff.

Benefits

There exist both quantifiable and non-quantifiable benefits from GIS technology. Where practical, benefits are quantified. Less tangible benefits must somehow be described and assessed as well, because they are often the strongest argument for implementing a GIS (Guptill 1988, 21).

There are two kinds of benefits: those that help the agency become more efficient in traditional handling of spatial data and those that result from the new ways an agency may

respond to problems using a GIS. Of the first type, the most commonly mentioned benefits are faster agency response time and more flexible information output. Productivity increases include reductions in time required to produce products previously generated by manual methods, increases in the number of decision alternatives that may be considered, increases in the total number of decisions based on the GIS, and production of products not previously available by manual methods. This greater efficiency can be quantified by comparing it to the cost of traditional spatial data handling. It is more difficult to assign a dollar value to some benefits. These are: aiding the agency in achieving its mission, organizational efficiencies, better information management, and spatial and analytical capabilities not available through manual methods (Stutheit 1990, 69). It is difficult to quantify new analytical capabilities since there is no baseline agency cost to compare it to.

Choosing to implement a GIS based upon cost/benefit analysis has its pitfalls. Alan Flesch, procurement manager for the Forest Service, states: "What we found is that the technology architecture, which most benefit/cost studies concentrate on, is not the most critical factor for success. In fact, it turns out not to be a significant factor at all. What is a critical factor is the information's location and how it is organized (Stutheit 1990, 69)." A Forest Service team found that the benefits, overall, outweighed the costs by more than three to one despite the degree of uncertainty in trying to quantify intangible benefits (Stutheit 1990, 70).

Upon conducting the requirements analysis and Economic Feasibility Study, an agency may decide that GIS technology is not appropriate for the agency at that time. In some cases "...justification for applying GIS technology to some application may not be sufficient to support the high cost of collecting the required digital data (Guptill 1988, 17)." Yet, because of the environmental issues and increasing pressures involved in managing particular resources, along with the human tendency for quick and easy fixes, agencies may decide to acquire a GIS

despite all the costs, and often with little planning.

Pilot Studies

Because acquiring a GIS is such a large investment, agencies may undertake small-scale pilot projects at any of several points in the GIS acquisition and implementation process. Such pilot projects have several goals and functions: to provide valuable hands-on experience, to assist in evaluation of different GIS hardware and software, to develop changes in institutional procedures as well as to help in determining the best information structures, database design, and desired functional capabilities for the applications most important in agency activities. Pilot studies are small-scale projects implementing a GIS. The database for pilot projects is a model of the database that the agency would like to ultimately develop, but covers a limited area. Pilot projects are often conducted in conjunction with the steps in investigating, acquiring, and implementing a GIS. This step may occur at several stages in the acquisition and implementation process.

First, an agency may undertake a pilot project early in the process (Stage 1) to demonstrate the usefulness of GIS technology. It may be difficult to get all levels to support GIS acquisition because of their different needs, perspectives, and personalities (Olivier, Greenwood, and McPherson 1989, 105). Pilot studies are ideal for demonstrating GIS potentials to all administrative levels within the agency, including upper management who may not yet support the expenditures necessary for a GIS. By involving all of the potential users, the lead team may generate support through pilot projects. At one time, this was the primary emphasis of pilot projects (Antenucci et al. 1991, 231).

A pilot project may also be undertaken after Stage 1, once an INA and Economic

Feasibility Study are completed. It may be used at this point "to verify the costs and benefits estimated in the feasibility study (Antenucci et al. 1991, 231)." After an agency has made the commitment to acquire a GIS, a pilot project may be used in two ways. First, it can aid in building prototype databases that assist the organization in identifying the format and structure requirements of the selected GIS software. Secondly, it can help agency personnel evaluate the different vendor responses through benchmark testing of each GIS platform using the pilot project database (Antenucci et al. 1991, 231). Pilot projects are designed to test the ability of the GIS to meet the agency's operating needs (Guptill 1988, 25). This can result in useful information about production rates, memory and storage requirements, human interface functionality, and user response to GIS products (Guptill 1988, 25).

A pilot project may be useful after an agency awards a contract for a specific GIS platform because it may help verify procedures for data base development toward drafting the implementation plan for institutional changes, and also for input into the database design. It can also provide hands-on training for organization staff (Antenucci et al. 1991, 231).

Stage 2: Design

If the INA and Economic Feasibility Documents support the decision to acquire and implement a GIS, the agency moves to the next stage of GIS implementation. This is designated as the "design" stage by Antenucci. Several steps are conducted simultaneously. These are a preliminary implementation plan, specifying requirements for the system design (hardware and software), and further definition and description of the GIS database.

Preliminary Implementation Plan

Careful planning is important when implementing GIS technology. As stated earlier, many problems may arise when working with many different agencies or departments. Each department needs to understand its role and responsibility once the GIS is in place. The INA and the feasibility study, along with the information on data needs, responsibilities within the agency and its departments, and projection of future needs, are used to formulate the plan. A plan also helps to provide smooth transition from manual spatial data handling methods to automated methods. It also helps to alleviate other problems in the areas of sharing information and allocating resources.

The plan consists of documenting and describing several steps to give "an understanding of individual roles and responsibilities and the relationships among tasks, and it defines and controls all subsequent steps in the process (Antenucci et al. 1991, 219)." First, the plan begins with identification of all tasks involved in the implementation project. A standard set of information is recorded for each task: description, identifying name and/or number, responsible organization and/or person, funds, personnel, and other resources allocated, planned and actual beginning and ending dates, products or deliverable items, and the relationships to other tasks (Antenucci et al. 1991, 220).

Expertise in specific applications is central to this stage of GIS implementation. The study of other GIS implementation projects is also necessary and outside expertise may be needed. Without a thorough plan, problems may arise in cooperation, in the understanding of responsibilities in the remainder of the implementation, and regarding the GIS database, its use, and its products, and in sharing information. The issues are institutional and will be discussed in more detail in Chapter V.

An updated plan is crucial throughout the implementation process. This keeps the participants informed of their changing roles and responsibilities. Just as the INA document contributes to the development of the preliminary implementation plan, the preliminary implementation plan contributes to a final plan once the system is acquired.

Specifications for Functional Requirements of a GIS

Two steps occur simultaneously when writing the functional requirements of the GIS. The required functions of the hardware and software are developed as well as the detailed description of the future GIS database. These description will form criteria for selection of a GIS, and for formulation of a final implementation plan. "Acquisition of the GIS hardware and software often is the primary focus of the GIS project, even though several others steps are equally important (Antenucci et al. 1991, 222)." It is important to have a detailed implementation plan and a database development plan.

System Design

This step documents a precise description of the requirements of a GIS, including "the capabilities of systems to perform the functions involved in a GIS (Woodcock, Sham, and Shaw 1990, 312)." Many GIS systems are available on the market, each one having individual strengths and weaknesses. An agency can make the best choice of GIS platform based on the agency's needs, within its budget and resource constraints by describing the desired functions of the hardware and software (Antenucci et al. 1991, 220). It is important that someone with expertise in GIS platforms perform this step. Due to the changing nature of GIS technology, it

is vital to properly document systems needs and recognize the capabilities of the available systems.

The functional requirements are based upon information generated in the Information Needs Analysis. The description of current products produced through manual methods, and those desired of a GIS is used as the criteria for selecting a GIS. "The final product definitions should reflect the flexibility of the GIS technology in generating products, meeting the needs of user groups, and incorporating the information gleaned during preceding activities (Guptill 1988, 18)." Other information such as the desired information structure (vector versus raster), the cost/benefit information, and information from pilot projects are vital input at this point. Now the agency may describe desired functions. These includes: the requirements for the hardware and software such as workstations, plotter capabilities, communications devices for networking and linking together the separate devices, the ease of use, future stability and the development potential of the software.

System specifications cover several areas, including the user interface, specifications for data input, manipulation and analyses, future stability of the system, and the capabilities for designing more specific applications programs. Other non-system factors are also evaluated. These include maintenance costs, vendor support, and compatibility among software and hardware already used by the agency.

The user interface specifications include the ease of using the GIS and its commands, and the availability and development of macros and pull-down menus to allow inexperienced users access to the GIS. Some systems have a high degree of intelligence built in as pull down menus, and have command sequences carried out automatically to eliminate the need for the user to know complex commands and sequences (Montgomery 1989c, 46). The ease of use is important because it affects the cost involved in GIS implementation. Extensive training

can add significantly to the cost of system (Woodcock, Sham, and Shaw 1990, 312). Once trained, employees may leave the agency that made the investment in training them, thus taking that investment with them. The trade-off between ease of use and functionality of the system may lead to the decision to acquire a less user-friendly, yet more complex system for its stronger analytical capabilities. Some easy-to-use systems may not have the flexibility and power needed by the agency.

Specifications for creating the data base generally describe the data input characteristics. These include:

1. Digitizing: These are the methods of entering point, line, and area data, tagging, assigning topology, and delineating attributes. It includes information about spatial entities and also about the geographic relationships (topology) between spatial entities to allow sophisticated analyses (Guptill 1988, 32);
2. Error detecting and editing: This includes errors of the attributes and feature names/codes. The software automatically detects inconsistencies (Guptill 1988, 33);
3. Import/export capabilities: Importing satellite imagery into a GIS through image processing software, which runs in combination with the GIS, is a desirable option for natural resource applications. The limits of many GIS systems occur in this area. The greatest limitations in a vector-based system are in their raster-processing capabilities and vice versa (Woodcock, Sham, and Shaw 1990, 312). A GIS must be able to incorporate different digital terrain data, for example, digital elevation models and other data. A GIS must also possess the ability to communicate with other databases, and to share data within the agency and with other agencies. When agencies are implementing a GIS, they need to take into consideration the ability of particular systems to share data with other computer software and hardware platforms,

particularly for specific applications important to agency activities. With increasing interagency coordination and shared funding, the ability to share data among different systems is a critical issue.

Analytical abilities are very important when selecting a GIS for environmental management. Most commercial systems are geared toward the larger markets of facilities management and tax assessment. These systems may not possess the desired analytical capabilities for environmental applications (Woodcock, Sham, and Shaw 1990, 312). Data manipulation specifications include data retrieval, data restructuring, data transformation, vector or raster overlay, raster cell operations, and statistical operations (Guptill 1988, 34). The map scales and projections desired for the new GIS database may be specified at this point in addition to the types of queries and models desired of the GIS database. Data restructuring includes converting between data structures, that is, vector and raster. This is important when an agency is accessing raster-based satellite data for use in a vector-based GIS. More recently, commercial GIS software is increasingly able to perform this function.

When considering a particular system, the ease of integrating new application programs is important. For example, a program may be needed for the more specific task of hydrologic modeling for a watershed. Will the vendor offer application programs in addition to the GIS "tool box?" If so, this could reduce future software development costs and lost time. Often the GIS must be able to interface with analytical models, and that includes the ability to automate the task of loading data into models (Guptill 1988, 18).

Vendor support is a non-technical area that will also be evaluated for each system. There are two kinds of support: (1) "the ability to get technical help regarding the functioning of the system;" and (2) the "ability to get help determining how to apply the GIS to the problems of interest (Woodcock, Sham, and Shaw 1990, 313-314)." Vendors vary in

providing support for developing more specific software applications. Training and documentation provided by the vendor must also be evaluated at this point (Montgomery 1989c, 46). Maintenance is important as is the relationship between vendors, if different vendors are selected for hardware and software (Antenucci et al. 1991, 222). In addition, the stability of the vendor is important. Will the vendor still be in the GIS market in the future? With the changing GIS market, agencies may be left without support when the GIS vendor goes out of business.

Hardware issues must also be identified and the ability of the GIS to run on current hardware or on new hardware must be stipulated. The quality and number of hardware devices must be designated including: data capture devices, output devices, storage devices, workstations, plotters, printers, screen copy devices, and the required computer processing units (CPU). An agency decides whether to use a mainframe, minicomputer, or micro (PC) at this point. Each has differences in memory and response times and number of users that can access the database at one time. Minis are becoming a frequent choice due to increased response time, memory and ability to add new applications and user interfaces (Montgomery 1989c, 37). Workstation differences lie in the areas of performance, software functionality, ease of use, quality of displays and ergonomics (Montgomery 1989c, 46). Ease of use is both a software and hardware issue. The better the user interface, the less training and technical sophistication needed to operate the GIS.

The issue of whether or not to have distributed processing must be decided. In distributed processing, the GIS database resides in multiple locations and is shared among users via software that monitors transactions. This allows flexibility to expand the system and add workstations without disturbing system performance (Montgomery 1989c, 46). This kind of set-up may require greater investment and different institutional procedures. Due to the

many system users in distributed processing, the importance of data definitions and standards for information exchange, query language, and communication protocol are critical to keeping the GIS database consistent and accurate (Montgomery 1989c, 46). This issue will be discussed in more detail in Chapter V. All of these hardware specifications cost money but in recent years the costs have come down as performance has increased.

It is difficult to quantify production rates for a GIS intended to support analytical needs. The number of expected users must be specified. The rate for analyses and GIS products is limited by the system's ability to retrieve, analyze, and display information. The resolution, speed, and capacity are functional capabilities that can be evaluated. These capabilities may be tested in benchmark tests of each specific GIS platform. Hard copy production is limited by the availability of digital data, the availability of trained personnel, the system's ability to process data, and the output device speed (Guptill 1988, 20). Maintenance costs are another factor specified and assessed. These include the money and time required for hardware and software updates, and the time required to maintain the system (Woodcock, Sham, and Shaw 1990, 314).

The field of GIS technology is dynamic in nature. Thus, the ability of the system to be flexible with changing future needs is vital. Each specific platform must be evaluated, to the extent possible, for its future stability in the face of changes in GIS technology. It is important to have expertise to make this kind of evaluation. Often, an agency may have a team of evaluators with expertise in the areas of hardware, software, communications, applications, maps, data issues and other areas. This team not only creates the specifications document but may also evaluate each vendor response (Antenucci et al. 1991, 223-224).

In the process of documenting precise specifications for the GIS platform, the agency must ensure that vendors understand what the agency is talking about. The specifications must

be very clear to both the agency and to the vendors. With a request for bids from vendors, the document must include vendor answer schedules corresponding to each specification section. This informs the vendor of the time schedule the agency desires for testing the platforms, and for other evaluations. By writing a comprehensive document on the specifications, an agency can reduce the chance of misunderstanding, and facilitate selection of the optimal GIS and a competent vendor.

Vendor Response

Selection of GIS hardware and software is often a formal process. An agency submits its requirements as described in the Technical Specifications Document. Requirements also include the non-technical aspects of GIS procurement. The request for proposals "solicits details on items such as documentation, training, maintenance and other support services, and the relationship between the vendors of software and hardware if the sources are not the same. The request for proposals also describes the terms and conditions for the purchase, including insurance requirements, installation dates, payment schedule, and the organization's standard contract language (Antenucci et al. 1991, 222)." Each vendor responds to these requirements by submitting a bid. With each response, the agency may decide if it wants to respond and which method to use for evaluating the responses.

Stage 3: Acquisition

Evaluation of Responses

The agency team scores the different systems submitted in response to the bid request. From a shorter list of potential systems, the team evaluates each one (Antenucci et al. 1991, 224). Different systems are evaluated for their ability to meet written specifications and also to meet each desired functional capability. Evaluation is conducted through interviews of each vendor, and benchmark tests or site tests to observe each system in operation. Both the technical requirements and non-technical requirements are evaluated. The costs of each systems are usually evaluated separately from the technical requirements to ensure that each system is evaluated with proper emphasis on its technical capabilities (Antenucci et al. 1991, 224).

Benchmark testing evaluates and documents the performance of the proposed GIS for essential and critical requirements. Development of appropriate tests is critical to this part of the acquisition process. The "success of benchmarking as an evaluation technique depends upon the extent to which benchmark tests can be constructed that are representative of expected workloads (Guptill 1988, 45)." Therefore, tests are based on the characterization of workloads based on the products and capabilities identified in the Information Needs/User Requirements Analysis and in the GIS Specifications Document completed in earlier steps. Pilot projects can play a vital role in evaluating different systems. In a pilot project, the prototype database that is created can be used for such tests (Antenucci et al. 1991, 231).

Several functional areas are tested (Guptill 1988, 46-52): data entry and data base creation including digitizing, edgematching, and connecting polygons, labeling, reformatting,

listing, display and edit operations, updating, and browsing. Data manipulation and analysis functions are tested (Guptill 1988, 52-57). These include: the reliability, resolution, and accuracy of operations; the system's ability to handle large amounts of data; its storage capacity, its processing speed and response time. Tests also identify the types of GIS products, the data format, and the compatibility with current databases, hardware, and software. The ease of operation is tested in addition to the ability of the GIS to interface with already existing databases, with other software, and with users. More recently, the focus of benchmark testing is on testing a system's performance for the specific applications needed by the agency (Antenucci et al. 1991, 224).

The other approach to evaluating each system is the site visit. The agency team may visit a site where the particular system is already in use. The team can observe the system in use, interview the other agency's personnel, and ask questions to get an estimation of how the system performs (Antenucci et al. 1991, 224).

Overall, the GIS software's tools must be adequate to tailor to the user's requirements. Benchmark tests can aid in distinguishing between different vendors' products. The agency may use the results from a small scale pilot project here to redefine evaluation criteria (Guptill 1988, 25).

Agency's Budget Office Review

The final costs of the hardware and software are evaluated separately from functional capabilities so that each may be evaluated without bias (Antenucci et al. 1991, 224). The estimated budgets over the entire lifetime of the GIS must be determined. A firm commitment, from the agency budget office, for funding for the entire lifetime of the system is

necessary. This commitment must allocate both financial and human resources. Any fluctuation in funding can hinder the implementation plan and have disastrous effects not only for the agency, but for any other agencies that are participating in the procurement and use of the proposed GIS.

Award Contract

After reviewing each system being considered, the agency team will make a recommendation for the best vendor bid. At this point, the agency will submit modifications needed in terms of the vendor proposal and the contract between the vendor and the agency. The agency will also restate agreements for documentation, support, maintenance and other terms and conditions as appropriate. Both the agency and the vendor final terms of contract are put into writing.

Stage 4: Development

Final Implementation Plan

The final implementation plan has many elements. It includes the project schedule and the plan for ongoing management of the system and maintenance of the database (Montgomery 1989b, 46). It also includes the schedule for hardware/software installation. The plan involves delineation of responsibilities among agencies, departments, and personnel for the data in the GIS database. A schedule and procedure for data acquisition, conversion, and entry is documented, in addition to, the strategy and guidelines for converting existing data and

acquiring new data. Guidelines may be defined at the local, regional or national level of an agency and include data specifications such as relevancy, accuracy, consistency, scale, and the amount of data types.

A plan for smooth implementation is vital for many reasons. The cost of database development may be more than 75% of the total cost of implementing a GIS. Overall, implementation will require institutional changes. It is important that all personnel be aware of new responsibilities and duties, new procedures, and changes in work flow. The plan must remain flexible in order to allow for response to institutional changes within the agency or agencies, and to changes and advances in GIS technology.

Effective implementation and use of GIS technology depends on carefully thought-out and documented procedures for using GIS. These procedures must be designed with conscientious regard for the agency activities. Procedures "cover the operation and management of the system, maintenance, update, and administration of the database, application and use in each participating organization, and production of the standard and special products of the system (Antenucci et al. 1991, 228)." Overall systems operation guides many activities. These include: the flow of data within the GIS, the methods of retrieving and storing data, and the production of GIS reports, displays, and maps. These procedures govern all aspects of the GIS operations including the day-to-day operations, backup of the database and software, designating system access, upgrading the hardware and software, developing software applications, and monitoring use of the system (Antenucci et al. 1991, 228).

Another issue arises at this step: the integration of GIS technology into the activities of the agency. It is important that the procedures for system use in functional activities focus on the effectiveness of those activities rather than on the GIS itself. "To be effective, the GIS should be an integral part of the operating activities of each unit rather than an appendage that

must be dealt with separately (Antenucci et al. 1991, 228)." This issue is closely connected to the perception of GIS technology and will be discussed in Chapter V.

Site preparation precedes installation of the system. This step consists of selecting the optimal site for the GIS with respect to the location of GIS operators, allocating adequate space for all of the components, and providing the necessary requirements of power and ventilation. Site preparation and system installation occur at the same time as database development, staffing, training, generating the final implementation plan, and initiating institutional and procedural changes within the agency or agencies. After installation, the vendor may test the system. Clear communication of vendor responsibilities, in terms of GIS capabilities and vendor support, is vital. If the agency is satisfied with the performance of the components, final payment is made and future vendor support is reaffirmed.

Pilot projects may aid in testing the system, once it is installed. As stated earlier, pilot projects are important tools for several steps of GIS implementation, including verifying operational procedures for the system, providing training experience for agency personnel, and providing a smaller, more manageable model database for developing more specific software applications (Antenucci et al. 1991, 231). These functions can help the agency save money by testing the GIS and anticipating technical problems that may arise in full implementation.

Database Development

Database development consists of data acquisition and occurs concurrent with system acquisition, training of personnel, and initiating institutional changes in response to GIS implementation. It consists of conversion of hard-copy graphic and non-graphic data, and reformatting existing digital data (Antenucci et al. 1991, 225). More specifically, it involves

four types of data entry: (1) photogrammetric compilation and digitizing using an analytical stereoplotter; (2) automation of existing maps using a digitizer or scanner; (3) key entry of data; and (4) transfer of existing data (Antenucci et al. 1991, 225)."

Data conversion activities are based on information and specifications developed from the INA, the Document of GIS Database and System Specifications, the Final Implementation Plan, and input from any pilot projects. Subsequent re-evaluation of data needs, and anticipated applications of GIS technology for agency activities, combine for further refinement of data specifications. The specifications for data conversion include the degree of accuracy and precision, the description of data sources and data products, and the description of the characteristics of the data itself, both graphic and non-graphic features.

This work is often contracted out to vendors who specialize in data acquisition services and is especially true of governmental agencies. For example, the Willamette National Forest contracted out this kind of work for a recent inventory of forest stand conditions. These vendors have the personnel and equipment necessary that agencies may not possess. Sometimes several contractors are involved in the data acquisition (Antenucci et al. 1991, 225). Data acquisition vendors are evaluated based on their response to specifications for GIS database. Additionally they are evaluated based on "conversion procedures and techniques, quality-control procedures and standards, management and staff's experience and availability, equipment and software resources and availability, existing work load, outstanding proposals and potential work load increases, and delivery schedules for preliminary and final products, both hard copy and digital (Antenucci et al. 1991, 225)." They are also evaluated based on quality of service to prior clients and the relationship between quality and cost. An agency may also purchase already existing digital data from private companies. Two issues are related to the area of contracting out GIS data acquisition work. These are the relationship between

quality and cost, and the practice of awarding contracts to the lowest bidder with little emphasis on the vendors' capabilities, and past performance.

It is vital that personnel with expertise in database development and map compilation be involved in this stage (Antenucci et al. 1991, 226). Effective management of database acquisition and contracting any services is vital to smooth implementation of GIS technology. More importantly, since all analyses and decisions are based on the data, the quality of the data is of the utmost importance. The issue of data quality, that is, the content and accuracy of the data, will be addressed in Chapter V.

All of the work involved in database acquisition and development requires substantial investments of personnel, time, and money. The cost of database development will exceed the combined costs of all other GIS components. The process may take several years for large areas or for detailed databases (Antenucci et al. 1991, 225-226). A return on the investment in GIS technology may not be realized for several years. It is important that agency personnel view the investment as a long-term one and adjust their perceptions and expectations to that reality. The issue of unrealistic expectations of GIS technology will be discussed in Chapter V.

Organization, Staffing, Training

Organization, staffing and training usually occur concurrently with the processes of generating the Final Implementation Plan, deciding GIS operating procedures, developing the database, and installing the system. This is very important, yet often underrated step in GIS implementation. A GIS that is managed effectively and staffed properly contributes significantly to successful implementation and use (Antenucci et al. 1991, 226).

Not knowing the relevance of organization, one may first ask the question: What is the organizational structure and what are its implications for the use of a GIS in an agency? "The GIS organizational structure defines the authority, responsibility, chain of command, staffing level, and other management characteristics" of the agency or agencies involved in the GIS implementation (Antenucci et al. 1991, 226). The organization is determined by the policies, structure, and activities of the agency involved. For example, an agency may have a very centralized structure, with one division providing GIS support services for the agency. In another case, an agency may have a more distributed structure, where GIS workstations are distributed throughout with personnel working independently of each other.

The organizational structure influences GIS implementation and use. For example, in a more decentralized agency, two issues are very important: data definitions, and compatibility of software and hardware. If different individuals are working on the GIS database simultaneously, it is important that they understand and document data definitions to guarantee fewer misunderstandings, and protect the consistency of the database. It is also vital that digital data be shared between different workstations or systems and compatibility of hardware and software is key. Data standards will be discussed in Chapter V.

The overall structure of an agency will determine the work flow, the responsibilities of individuals and departments, the chain of command, and the amount and level of staffing. It is important to clarify the roles and responsibilities of all personnel involved to insure smooth and effective management of the GIS and effective implementation. Again, the organizational structure determines the structure of staffing and responsibilities. In a more decentralized or multi-organizational project, each individual agency or department will create its own GIS group. Often, in a more centralized project, personnel will be assigned to an already existing core GIS group (Antenucci et al. 1991, 227).

In staffing GIS projects, several positions are fundamental. These positions include: an implementation project manager responsible for all aspects of implementation; a system manager responsible for day-to-day management of the system; a database administrator to oversee the resources, quality, maintenance, and use of the database; and a system analyst to develop and maintain specific applications programs. GIS operators, those who digitize and produce maps, retrieve data, and perform analyses, are spread out throughout an organization. They are engineers, planners, geologists, managers and other personnel (Antenucci et al. 1991, 227).

Planning for GIS skills training is also part of the Final Implementation Plan. It includes the costs and the time frame (Montgomery 1989b, 46) as well as the number and types of personnel to be trained. Training includes "GIS system management, system software programming, and general GIS concepts (Antenucci et al. 1991, 227)." Personnel receive training through several ways including training from vendors, continuing university education, seminars, in-house classes, conferences, and workshops (Antenucci et al. 1991, 227). The lack of adequate staffing and training is widespread and meager attention has been given to this step.

Stage 5: Operation

Many steps may occur concurrently at the time of system installation. These steps include: the actual budget changes, training of managers and users, delegation of database responsibilities performed by various departments and database development.

Data Conversion

As stated before, database development is the most costly and time-consuming aspect of implementation. It may take several months or several years depending upon the level of detail, the availability of source data, and the size of geographic area covered. At this point, the database manager gives close watch to quality control, making sure data entered meets requirements for data definitions, positional accuracy, precision, timeliness and consistency. The database is monitored and updated in accordance with the documented operational procedures. Once these steps have occurred, users can manipulate and analyze spatial data for the decision-making process. Manipulation and analysis of data may occur before the process of database development is completed. Often, only portions of the database are loaded, especially for database coverage for large geographic area or for areas requiring a great deal of detail. The remainder of the database is created according to a prescribed schedule, and as adequate source data becomes available. The database will require constant management and input even as the GIS aids in the decision-making process.

Applications Development

The true significance of GIS technology is through its application to support agency activities. Software applications support standard uses of the GIS such as linking together a series of tasks, storing and organizing spatial data, and performing calculations and logical tests. All of these functions use standard GIS macro commands and the software tools that come with the software. Use of more advanced applications may require a vendor or other third party, and in some cases, support organizations who use GIS for similar applications.

Advanced software applications almost always require additional training. The system manager and system analyst oversee the development, maintenance, and control of all application programs. This is to ensure that the applications do not interfere with day-to-day operation of the GIS (Antenucci et al. 1991, 253).

Conversion to Automated Operations

GIS implementation occurs in phases, over a period of months. Integrating the GIS into agency activities requires conversion of manual operations and procedures to automated ones. As the GIS database is developed, manual activities continue until the transition to automated procedures is complete. Keeping source materials current is critical. "Because time will have passed since the source materials were committed to conversion, it will be necessary to bring all records up to date (Antenucci et al. 1991, 234)." It is vital that the transition to automated operations go smoothly with "no gaps or lapses in updating records, that no data enter the database without proper verification, and that resources are not wasted during the transition effort (Antenucci et al. 1991, 234)." This transition involves all of the GIS staff.

Stage 6: System Review

In this audit stage, the agency evaluates all features of the GIS and plans for changes, improvements, and expansion as needed. Evaluation is necessary due to changes in agency responsibilities and activities, changes in staffing, the availability of new technology and new GIS techniques. Periodic evaluation will help make the use of the GIS technology more effective.

Evaluation consists of interviewing GIS personnel, and reviewing all the prior planning and implementation documents, goals and objectives, and budget and expenditure histories. It requires objectivity and identifies problems and issues. The result is a revised statement of agency goals, mandates, policies, procedures, and actions to be taken with respect to the GIS. A new time-line and budget are established for any actions and changes to be made (Antenucci et al. 1991, 234).

Due to the ever-changing nature of GIS technology, changes for the software and hardware are often necessary. Software updates become available as well as new software products. Hardware technology is also continually changing with new hardware available at lower prices, while other hardware becomes obsolete. The costs of systems have come down, and progress has been made in the integration of raster and vector technology and in automated data capture. Developments in optical disk storage systems with their ability to store large volumes of information, has allowed larger databases. There has also been development of high speed communication networks (Montgomery 1989c, 46). It is easy to become caught up in the sensationalism of exciting new products and the hype present in the field, and this makes it necessary to review and expand the GIS cautiously and conscientiously.

Successful GIS Implementation

Agencies desiring to acquire GIS technology face complex choices. The strategy for selecting a GIS and the final choice of a GIS will impact the agency in time, resources, and costs to implement the GIS (Montgomery 1989b, 46). The goal is determining which GIS best suits the agency's requirements and objectives, within their resource constraints. There is no

single best GIS package. GIS technology will change work procedures, change analyses of data, and change the way agencies perform their activities.

What does a successful GIS project look like? Glenn Montgomery states that "a successful GIS project is one that continues to receive sustained annual funding, long-term user and decision-maker support, and necessary resource commitment. By developing a detailed and realistic strategic implementation plan, the costs and schedules of data conversion, hardware and software acquisition/maintenance, ongoing database maintenance, and operations can be projected with a realistic degree of certainty (Montgomery 1989b, 46)."

Agencies must not underestimate the time required in selecting a GIS, and in implementing a GIS. The GIS database should last for an indefinite future, twenty or more years. The process of acquiring and implementing a GIS is a long and arduous one. With increasing experience and documentation of the process, agencies have a better chance of completing the process successfully.

Due to the great amount of resources involved in implementing a GIS, agencies should devote a great amount of energy to ensuring successful implementation. Such resources consist of the required money, time, and personnel. Agencies implementing a GIS do not want to waste these resources, especially given the current political and economic climate. In addition, to lose these resources often means missing the great potential of this technology as a tool toward performing agency activities more effectively. With the growing environmental crisis, and increased public concern over environmental quality, smooth, effective GIS implementation is critical.

This model for the implementation process was generated by the author, with minimal aid from the literature. It was only after developing the model that the author found agreement from the book by Antenucci et al. Not all agencies have necessarily followed this

model. Many agencies do not follow a well thought-out process. In many cases, it is a model of how agencies may want to consider approaching implementation. For that reason, this model can act as an important guide to help ensure success, to help agency personnel foresee problems, and to help them to develop a thorough yet flexible plan.

Questions Asked of Survey Participants

Now that the model has been presented, it makes sense to describe the questions asked of GIS personnel from the participating agencies. The questions asked were not for contribution to development of the implementation process model, that was the role of the literature. It is difficult to document an implementation process that occurs over a long time period after the process is complete, or even at one point in time in the process. Interviews of these personnel was better suited for identifying issues. The questions in the survey focused on issues involved in implementing and using GIS technology.

Corresponding to the conceptual model of the process of investigating and implementing GIS technology, questions may be asked to identify agency missions, goals, and objectives, where the agency is at in implementing a GIS, and what issues and concerns have arisen in the process. The objective of asking such questions is to determine if the survey participants believe implementation of GIS technology has been successful. The previous text has addressed the question of how to define successful implementation. The following chapter contains the responses of state and federal agency GIS managers when asked to assess the success of GIS. Chapter IV uses the survey as a case study of GIS implementation.

Two types of questions are asked of GIS personnel: those that describe the background of the agency and those that ascertain perceptions and expectations of these personnel

concerning GIS use. The background questions help to establish where these personnel are coming from, with respect to the GIS manager and agency's background, institutional characteristics, natural resource activities, data needs, and reasons for implementing a GIS. The purpose of these background questions is to support the case that all of these agencies are similar in their institutional characteristics, activities, and reasons for using a GIS. Perception questions elucidate the expectations these personnel have for the use of GIS technology. It gives them the opportunity to describe the issues that concern them in GIS use, and to present any recommendations that they may have for better GIS use.

By establishing all other factors being equal among these agencies, one can compare the different responses from the GIS managers, with respect to issues in GIS use. This is analogous to conducting an experiment where all factors are held constant, except for one, to establish cause and effect, and to generate theories for observed behavior.

Background Questions

As stated earlier, these questions identify the basic goals, mandates, activities, and spatial data needs of different agencies. All of these agencies are similar with respect to these characteristics, they manage natural resources and/or engage in environmental monitoring and planning. Additionally, all are similar in relative size; they are state and federal agency offices. All personnel interviewed were at approximately the same institutional level; they are all in middle management. The survey was designed for agencies who are all similar in the stage in implementing GIS; not those agencies just starting out, and not those who have had a GIS for a long time. The background questions also included one question to demonstrate that these are not pilot projects, but full GIS database and implementation.

What are the Objectives of this Agency/Department that Involve GIS? What Natural Resource Problems and Issues do you Address?

Which Types of Land Does This Agency Have Jurisdiction Over in Terms of Ownership, Land Cover, and Uses?

For What Types of Natural Resources does this Agency Compile Data?

How Does a GIS Help Fulfill Agency Objectives? Why did Your Agency Acquire a GIS?

As stated earlier in this chapter, the agency mission is set by law, and agency goals, objectives, responsibilities, and management activities logically follow from its mission. These questions were asked with the goal of identifying agency data needs and establishing commonality among the agencies surveyed with respect to goals, objectives, and resource use. These questions correspond to three steps in the first phase of GIS implementation: identification of agency goals and mandates, identification of agency activities, and the information needs analysis (See Figures 1 and 2: Steps in implementing GIS technology for governmental agencies).

How Long has this Department Used this GIS?

This question was asked to identify commonality among the agencies in terms of where they are at in the implementation process.

Which GIS Software Programs Does the Department Utilize?

Whether the agency uses commercial or public domain software is an important issue. The implications of this choice will be examined in more detail in Chapter V.

Is this a Pilot Project or a Full-usage Project?

It is important to identify whether the GIS being implemented is for a small-scale pilot project or for full implementation. This difference affects how the agency responds to

questions about the issues that concern them in GIS implementation. If all agencies respond that their's is a full usage system, that will contribute to commonality among the participants.

Is the Department Going to Use the GIS for Inventory and Database Management Only, or also for Analysis and Modeling?

What Data Variables are Involved in this Project?

What is the Source of the Data?

What Data is not on this List but is Desired? What Data do you Most Wish Were Readily Available?

Do you Have Data Variables that Are too Dynamic or Difficult to Represent Spatially?

These questions seek to investigate any commonality among the agencies surveyed, with respect to the types of data collected, the sources of that data, and the issues involved in data acquisition.

How Often Do You Plan to Update the Database?

This question identifies the update schedule and indicates whether the agency has a clear plan for database maintenance.

Perception Questions

Perception questions have a different objective than background questions. With all other factors being equal, this is where the uniqueness of each agency's response can be investigated. The goal is to explore what concerns these GIS managers most, how they view GIS, whether they are satisfied with the GIS, how the GIS is used, and how they feel it should be used. All of these responses reveal the issues and how those issues may be related to how GIS technology is viewed.

Why Was This Particular Program(s) Chosen?

As stated earlier in this chapter, different software programs are sold under the GIS umbrella. Some have their roots in CAD, while others may be a true GIS with full analytical capabilities. Hopefully, agencies will choose a true GIS if it is analytical capabilities that they desire. This question can also identify how GIS is perceived by the agency. Whether a GIS is chosen based on several variables such as cost, reputation, ease of use, analytical capabilities, map products, or because it is already used by the parent organization or other agencies, is a barometer for the perception of GIS capabilities. It can indicate whether or not agencies choose a particular GIS for the correct and appropriate reasons corresponding to agency needs.

Is the Department/Agency Satisfied With the GIS for Database Management and Its Ability to Answer Analytical Resource Use Questions?

If Not, Why?

These questions help the survey respondent identify problems they see in GIS implementation overall. They may state inherent problems and technical, economic, and institutional barriers to implementation. It may also indicate some mistakes that the agency made in the process of GIS acquisition and implementation.

Can You Answer Questions That You Could Not Answer Before Without a GIS?

Acquiring a GIS is expensive. A GIS may be used merely to handle spatial data and perform tasks that were once done manually. Without fully taking advantage of the new analyses and models that a GIS permits, the agency may be losing opportunities to use GIS as a tool for new kinds of analyses for the decision-making process. Tied into the choice of a particular GIS program, one may assess whether the agency is using the GIS to its fullest potential.

Is the Department/Agency Satisfied With the GIS Platform?

If Not, Why?

These questions help to identify dissatisfaction with the particular GIS platform that the agency is using. The issues here will differ from overall dissatisfaction in implementing GIS technology.

Do You Think GIS is Best Suited For Monitoring or Also For Modeling and Analysis?

This question is similar to the one which asks if the agency can answer new questions. It can identify whether the agency is using its GIS for analyses, or merely for basic functions like map production and database management.

Do You Have Any Recommendations For Better Application of GIS For Natural Resource Management?

What Other Deficiencies Do You Perceive With GIS as a Natural Resource Management Tool?

Do You Have Any Further Comments For Better Utilization of GIS as an Analytical Tool For Natural Resource Management?

Each respondent has the opportunity to generate an individual response to the issues that concern them in using a GIS. This may help to break issues down into different kinds of barriers to implementation. It is interesting to see if there is commonality among the different participants with respect to their responses and which issues concern them. It is also noteworthy how their comments relate to recommendations for better GIS implementation as stated in the GIS literature.

Do You Think Using a GIS Has Improved Your Ability to Communicate Effectively With the Public and Gain Support and Consensus?

This last question focuses on the ability of GIS technology to meet the goal of communicating effectively with the public. All of the agencies surveyed are state and federal

agencies that have as part of their mission to serve people and to be accountable to the public. Public access to GIS information is an important issue in GIS use, as is the effectiveness of GIS as a communication tool.

There are two overall objectives of the survey. The first is to establish commonality among the respondents with respect to their agencies' institutional characteristics, natural resource activities, and spatial data needs. The second is to identify the issues that concern them, how these issues are related to their perception of GIS technology, and to generate possible solutions.

Chapter V will analyze all of the related issues, grouped into institutional, economic, and technical areas. For each issue: a description is presented, the agencies' response for that issue summarized, where that issue may occur in the implementation model identified, how that issue is related to the perception of GIS technology is examined, and possible recommendations are made.

The greater issue of perception is focused on throughout this thesis because it is the core issue to most other issues. Wrong perceptions may contribute to and result from many of these problems areas. By pointing this out, this thesis can help agencies toward better GIS implementation and use in the future.

CHAPTER IV

AGENCY RESPONSES TO SURVEY

Given a background to the field of GIS, and the process by which agencies implement GIS, the interview results presented in this chapter can provide valuable information about the concerns GIS managers have about GIS. All of the responses are from the interviewed GIS managers and not from this author. Additional comments from this author are in parentheses.

There exists variation among the responses in several aspects. The amount and detail of information about the agency/division mission may vary. Some agencies, such as the Oregon Department of Environmental Quality, provide in-depth information about its agency mission and specific information about their GIS use, while other agencies such as the Soil Conservation Service, do not. In those cases, the mission is omitted. The responses may not exactly fit with the questions asked, and because these results are subjective, some GIS managers may be more open to discuss concerns than others. Chapter V presents an analysis of these results, especially the implications they have for successful implementation of GIS technology.

Federal Agencies

U.S. Army Corps of Engineers, Portland District, Oregon

Interviewed Phillip Orlowski, geographer, of the Cartography and Remote Sensing Section,

who has been at the present position for approximately six and one-half years.

Mission Statement

The U.S. Army Corps of Engineers (U.S.A.C.E.) is one of the nation's oldest engineering organizations and is managed by the U.S. Army, but most of its workers are civilians. They employ engineers, archaeologists, biologists, ship captains, laborers, and other workers. The Portland regional office is headquarters for one of twelve regions whose boundaries correspond to river basins.

Through its civil works program, the Corps of Engineers provides a wide range of water resource development projects: hydropower and flood control dams, levees, harbors, waterways, and locks throughout the U.S. The emphasis of current civil works programs is directed towards production of renewable energy, water conservation, protection of the environment and the domestic economy (U.S.A.C.E. 1986, n.p.).

The mission of the Portland District is to protect and develop the water resources of 79,405 square miles in western and central Oregon, and 8,740 square miles in southwestern WA. Major responsibilities include providing safe entrance to Oregon coastal and inland harbors, and generating hydroelectric power for the region at Bonneville, The Dalles, and John Day dams on the Columbia River. Lake projects in the Willamette and Rogue river valleys provide flood control, some hydropower, recreation, and improved water quality for areas downstream. Recent projects include the Bonneville Second Powerhouse to double Bonneville's previous power generating capacity, construction of a new navigation lock at Bonneville, and a variety of dredging operations associated with debris from Mt. St. Helens (U.S.A.C.E. 1986, n.p.).

The Cartography and Remote Sensing Section of the Engineering Division has the

following responsibilities: (1) Prepares contracts for orthophotography, various types of aerial photography and miscellaneous photographically derived products such as enlargements/reductions, positives, negatives, etc; (2) Maintains District aerial film and photo files and miscellaneous related cartographic materials, and assists both in-house and outside agency users in the search and procurement of these materials; (3) Investigates and procures various imagery and cartographic products from other agencies and private firms; (4) Produces photogrammetric topographic maps and digitized cross-sections using precision stereoplotters; (5) Prepares cartographic and cadastral overlays, photo river books, and aerial photo mosaics; (6) Generates cross-sections, areas, lengths, volumes, and other digital products using computer-aided mapping equipment; (7) Utilizes various stereoscopes and zoom transfer scopes for data compilation, feature identification, and terrain analysis; (8) Prepares various thematic and taxonomic cartographic products for lithographic printing; (9) Provides remote sensing, geographic information system, and image processing services for a variety of applications in the District and Division offices including land and water use/cover classification, environmental studies, change detection, etc., using an image processing system; and (10) Passes control between various dated aerial photo diapositives using a precision-point transfer device (U.S.A.C.E. 1989, P-12,13).

Objectives of a GIS

The Portland District acquired a GIS for its ability to perform manual tasks faster, and to expand application of a GIS to new areas. In 1983, the GIS was used for planning of dredging activities on the Cowlitz and Columbia rivers to remove volcanic debris from Mt. St. Helens, which caused potential navigation and flooding hazards.

Implementation Stage

The current GIS was acquired in Fall 1983. Even with output of GIS map products, the database is still being built. The GIS is used on a project-by-project basis, for example, Columbia River channel deepening. For this project, 99% of the desired database has been built for a two phase approach: (1) a reconnaissance phase -- building the database with consequent output of GIS map products; and (2) a feasibility phase -- use of the GIS to analyze the impact of different agency activity decisions by Fall 1990.

The Corps uses several software programs: Intergraph for cartographic products, ARC/INFO which is heavily used for analyses since 1989, and ERDAS, image processing software for the use of remotely sensed satellite data.

The Section compiles digital data for the following resources: water resources, wildlife habitat, wilderness areas, fishery resources, vegetation resources, timber stand conditions, endangered species information, wetland areas, soils, and archeological/cultural resources.

The Section would like to expand the use of its GIS to detection and management of wetland areas, to aid with fill permits, and for more emphasis in use on managing hydroelectric resources. For the Columbia River channel deepening project, 85% of the workload for the reconnaissance phase is toward database development and 15% toward cartographic output. In the feasibility phase, the Division will emphasize use of ARC/INFO for GIS analyses and map products. Hydrologic data is desirable yet difficult to acquire. The Corps would also like rain gauge, water quality, and stream gauge information. Data layers are not updated on a regular schedule but individually as update for each data layer is desired.

Reasons for Choosing the GIS Software

In 1983, ERDAS, an image processing software program was selected because of the limited choices of GIS software packages, and deficiencies in available programs for Corps needs. ERDAS facilitates use of remotely sensed satellite data and was updated in 1989. In 1985, Intergraph Corporation software was purchased by a special agreement, to support cartographic and photogrammetric functions. This software does not possess the analytical capabilities of "true" GIS software and was not able to integrate with another software called TIGRIS. In 1989, ARC/INFO was purchased to address this problem. The more recent Intergraph software is a recompilation of earlier modules, but is not yet available and the Corps could not get a guarantee that the new software would be compatible with the ERDAS software. In addition, many other agencies are already using ARC/INFO, and it is desirable to have compatibility with other agencies in the Pacific Northwest. The Corps may not stay with ARC/INFO, but for now it is used, especially as a translator of digital data between different digital formats (such as ERDAS, TIGRIS). In the future, the Corps may procure the newest version of Intergraph software which may possess greater analytical capabilities.

Satisfaction and Concerns with the GIS Overall

The Division is satisfied with the GIS overall, yet there are many concerns. It is difficult to train staff in-house due to the ever-changing nature of computer technology. Competent staff can overcome many of the hardware and software problems which arise in the use of a GIS. Communication with upper management could improve, especially for funding of hardware, such as workstations, and the cost of acquiring data. When one group or division foots the bill for

database development, it is difficult to find additional funding. There exists a need to demonstrate the benefits of a GIS to all divisions and to encourage cost-sharing. There is also a desire to make the GIS user interface easier to use. This would make the GIS more accessible to greater numbers of users to promote understanding of GIS capabilities, to promote effective use of a GIS, and to satisfy the demand for GIS products. It is the managers who have control over project budgets. Therefore, the Division finds that it must continually sell the GIS as a way of doing everyday functions to management, as well as, to Division staff.

Satisfaction and Concerns with the GIS Platform

The Division is not satisfied with the GIS platform. The software is run on SUN 386i workstations, but its manufacturer will no longer support developments for this particular machine because technology is changing so fast that hardware companies must move on to new models. These companies expect the users to upgrade to new hardware. In addition to problems with the workstation vendor, other hardware doesn't work well such as, the ink jet thermal printer.

The ability of the different software programs to exchange digital data is weak. The Division has Intergraph software, ERDAS, and ARC/INFO to try to alleviate this problem and improve import and export of digital data which are in different formats. The Division found that not all GIS functions could be performed with just one software program. Because the Division cannot get software updates for hardware no longer supported by its vendor, software companies like that which markets ERDAS, are in a bind. They develop software and also sell the hardware, and then the hardware becomes obsolete. Updates also proceed at different rates and the Division finds itself up to speed with one program, and not with others. This requires continual outlays of financial and personnel resources.

Best Role of a GIS

The GIS is well suited for a wide variety of functions. The Division finds that once the digital database is built, a GIS can answer old questions in one day's time for what once required weeks. They are also able to perform modeling studies not possible before. It is also possible to develop a very diverse database with attributes and interrelationships not known previously. For example, data such as soils, land cover, slope, and distance to streams, are all used in combination to determine suspended sediment levels for rivers.

Recommendations for Better Utilization of a GIS

To deal with rising costs and the fast pace of technological change, the agency could do more leasing and less procurement of hardware. It is possible to negotiate with different companies to lease equipment, and thus allow for access to the latest technology while helping deal with equipment depreciation cost. This may help alleviate the cost of projects having to pay for equipment depreciation, as well as labor. The other divisions within the Corps are consumers of the GIS products produced by this Division, and the other Divisions could provide additional help with these costs.

There is the concern that technological advances are much farther ahead than the knowledge and skill of the personnel. Better understanding, from upper management, of GIS capabilities, the fast rate of change, as well as costs, may help deal with the issue of politics involved within, and between agencies concerning GIS use. Technological changes make it difficult to keep up, not only with equipment and funding, but also with training.

Progress has been made, however, in the ability of software programs to import and export

digital data of different formats, and this is a really necessary development. The Division would like to see managers get more involved in GIS use and GIS conferences. This would improve communication and selling the use of GIS technology. A desirable activity would be the existence of a GIS clearinghouse of data and documentation of all agencies' GIS activities.

Communication Using a GIS

A GIS is a great tool for communication. For example, the personnel responsible for planning USACE uses of a lake can show slides of GIS digital images of different management scenarios at public meetings. This could enhance not only clear communication but elicit favorable and timely responses from the public.

U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon

Interviewed Steve Sherer, Geographer, of the Environmental Section of the Branch of Facilities Planning in the Division of Facilities Engineering. He has been at his present position for ten years, and has been using the current GIS for two years.

Mission Statement

The objectives of this Division is to quantify the environmental impacts of various transmission routing projects. BPA markets electricity from federal hydroelectric projects in the Pacific Northwest, and locates transmission facilities. The 1980 Northwest Power Planning Act requires the BPA to enhance the environment surrounding facilities. For example: construction

of fish hatcheries to offset losses due to hydroelectric facilities and other activities.

Objectives of a GIS

The National Environmental Protection Act (NEPA) requires that agencies determine and examine the environmental consequences and impacts of their projects and activities. This is usually in the form of some kind of environmental study to predict, quantify, and summarize environmental impacts for projects. A GIS was acquired to help meet this need. It was also acquired to function as a regional database for the agency.

Implementation Stage

Mainframe ARC/INFO was implemented two years ago for database management, for manipulation and analysis using data layers, and for the output of GIS map products. It is used to meet NEPA guidelines for project analysis, and the BPA is in the process of acquiring digital data for its GIS from other agencies at anywhere from 1:100,000 to 1: 2,000,000 scale. There is no set update schedule.

Some analysis is performed on a project-by-project basis with data that is already pre-processed and in the GIS. Some digital data is for a greater regional geographic coverage. This division collects digital data for these broad natural resources areas: water resources, wildlife habitat, wilderness areas, fisheries, vegetation resources, endangered species, wetland areas, and soils. Data at quad scale, 1:24,000 or larger is desired, as well as, more complete coverage of digital data in 7 1/2 minute DLG (available from U.S.Geological Survey) with its transportation information, hydrography information, and digital terrain model.

Reasons for Choosing the GIS Software

Mainframe ARC/INFO was chosen for several reasons. It is suited to the particular needs of the agency and has strong analytical capabilities. Its reputation is good with good support from the vendor. Many other agencies use it. This encourages inter-agency cooperation and data sharing if different agencies use the same software.

Satisfaction and Concerns with the GIS Overall

The agency is satisfied with the GIS overall, but there are several areas of concern. In the area of personnel, it is difficult to use in-house contractors to do GIS work without a little bit of tension among workers. It is more difficult to give them the same status and rights as BPA employees, such as sending them to training or to conferences. This results in some dissatisfaction on their part.

There are also several concerns with the area of data acquisition and pre-processing of data. It is very expensive to acquire base data no matter what method is used to acquire it. It is also difficult to ensure that the content of the data is of high quality. If the data is from another agency there is often the problem of the data being in a different digital format. This is especially a problem when transferring attribute data. First, one software program may not have the same file capabilities. For example, ARC/INFO is a relational database with many attributes encoded to any one polygon in the spatial data. MOSS (used by other agencies such as the Forest Service) is capable of only one attribute description of any feature. Secondly, the definitions of the attributes from one agency may not be understandable to the other agency -- incompatibility of the data itself. The GIS coordinator does feel that there is good facilitation of inter-agency

cooperation through the Northwest Land Information Network (NWLIS), an inter-agency committee.

Satisfaction and Concerns with the GIS Platform

This Section of the BPA is satisfied with the GIS platform overall. Concerns with the hardware include the fact that data input is never fast enough, and that there can always be more storage space in the form of discs and tape.

Despite the low user-friendliness of ARC/INFO, there are minimal problems in this area due to a very competent staff. The biggest cost of GIS implementation is data acquisition, and automated methods to capture data could help alleviate this cost. The difficulty is not only in pre-processing data into a digital format, but converting raster data (e.g. Landsat Data) to a vector format. The GIS industry has been slow to develop the necessary tools for data capture which involves image processing. The links to remote sensing are not being fully exploited because of a weak integration between the GIS software and raster-based software (e.g. ERDAS) that incorporates image processing. ARC/INFO is a vector-based GIS software and its vendor, ESRI, is trying to incorporate more raster functions into the software by providing translators for converting raster digital data to vector-based digital data.

Best Role of a GIS

A GIS is best suited for all its capabilities and functions -- monitoring, database management, data manipulation, analysis, and graphic products. Previous tasks are performed more quickly, old questions are answered faster, and new analyses are done with the GIS.

Recommendations for Better Utilization of a GIS

Automating the data acquisition stage could save time and money not only for the data acquisition stage, but also for pre-processing of data, that is converting one digital format to another. In this area of concern it is important for the GIS software to be able to have such capabilities, especially for stronger links to, and use of, image processing like LANDSAT data. The use of image processing techniques is highly related to the natural resource management field. LANDSAT, and other remotely sensed data, are valuable as a source of data for a GIS. For example, land cover classification may be derived from image processing. Not only is remotely sensed data timely, but in many cases it has good resolution. SPOT data has a resolution of 10 meters. The GIS software vendors need to develop stronger links between vector-based software and raster-based software, such as ERDAS, to help natural resource managers have access to, and utilize valuable image processing data.

Inter-agency cooperation is not an easy task. It is not within each individual's job description to participate in meetings. If it can be shown to be worthwhile, agencies can get more personnel involved in GIS and better application of a GIS as a planning tool.

Agencies need to get beyond the data acquisition and data pre-processing stages of GIS implementation, and use it for its analytical capabilities. Natural resource professionals need to recognize the power of a GIS as a tool. A GIS needs to become integrated into day-to-day work. It needs to be accessible and easy to use, and the personnel need to be aware of its capabilities, and how to use it in order for its better utilization as an analytical tool for natural resource planning and management.

Communication Using a GIS

The BPA's GIS has improved the Department's ability to communicate due to the clear, attractive GIS map products.

U.S. Department of the Interior, Bureau of Indian Affairs, Portland, Oregon

Interviewed Bob Klaver, GIS coordinator for the Land Services Division of the BIA, Portland Area Office. He has been with the BIA for four years at the present position, and has used the current GIS for two years.

Mission Statement

The Portland Area is committed to the strengthening of tribal governments, to providing assistance by converting the ideals of self-determination into reality, to enhancing the quality of life of Indian people through improved social programs, and to fulfillment of the federal fiduciary responsibility for financial and natural resources held in trust for tribes and their members. Tribes are encouraged to take the lead role in developing economic self-sufficiency through their own internal policies, as well as, through the self-determination process. Assistance is provided to tribes to stimulate economic and human development, and through cooperative efforts among state, federal and local governments on a government-to-government relationship. Additional emphasis is placed on working within the entire social and economic development infrastructures.

The special role of the Portland Area Office in carrying out the mission is accomplished by providing management, leadership, technical direction and administrative support services to

Portland Area field units in the delivery of services to tribes and individual Indians (BIA Portland Area In-house Mission Statement 1988).

Objectives of a GIS

The GIS was procured as a cost-effective tool to manage resources and planning activities such as natural resources management, transportation planning, some census data (from 1988 pre-census), and land appraisals. It has also been used for timber sales management, to plan and map roads, to map water rights, and for wildlife management. The BIA's GIS is not a corporate (centralized) database. Each reservation has its own GIS and an appropriate base data.

Before implementation, each reservation conducts an Information Needs Analysis to identify, on a project-by-project basis, the most important data layers for specific resource questions. Therefore, the BIA's GIS progresses on a project-by-project approach with base data layers. Additional data layers are digitized as activities, needs, and interests dictate.

The proportions of types of GIS uses and the extent to which the GIS is used is up to each reservation. The use of GIS has passed through stages. Currently, activity centers more on attribute database development: building more specific information for more detailed data layers and breaking up data attributes into finer descriptions. Most reservations are far enough along that GIS is used to perform analysis. There has been a shift in emphasis from map products to GIS analyses and modeling.

Many kinds of data are desired for different GIS projects. There is a need for more archaeological information. It is sensitive information with limited availability to the public for security reasons. Both the Yakima and the Warm Springs are working on forest management plans. On the Yakima, there is a need for more data pertaining to suburban areas for land use

planning. On the Warm Springs, information for a new soil survey is needed.

Implementation Stage

The Portland Area Office acquired and used MOSS from 1983-1988, and mainframe ARC/INFO and pcARC/INFO since 1988. GIS projects are developed on the Colville, Flathead, Metlakatla, Nez Perce, Quinault, Spokane, Tulalip, Umatilla, Warm Springs, and Yakima reservations.

Reasons for Choosing the GIS Software

The Portland Area Office decided on ARC/INFO based upon its analytical capabilities and compatibility with many different hardware platforms. The software was also procured at a good price and was already used by the BIA Central Office in Denver.

Another advantage of ARC/INFO is that spatial data need only be captured once and one can add specific attributes later. For example, for soils, data layers can be broken down into texture, permeability, and hazards -- a system of building derived data layers within broader themes.

Satisfaction and Concerns with the GIS Overall

The Portland Area Office is satisfied with the GIS overall and has some concerns in the areas of personnel, data acquisition, and cost. It is difficult to find trained staff and this will become an issue on the reservations as they move toward independent use of GIS. The reliability

of data can always be improved, and the agency plans to go back and check soft data upon which digital data is based.

Satisfaction and Concerns with the GIS Platform

The Portland Area Office is satisfied with the platform overall with concerns over costs. They had no negative comments on hardware; ARC/INFO runs on a PRIME mini-computer. The software enables good plotting, power, and speed, and it is relatively easy to update data. ARC/INFO has one format for editing, analysis, and plotting, so that one does not have to re-digitize to update. It is also easy to create new layers. The agency does have a ERDAS-ARC/INFO link for remotely sensed data on land cover. ARC/INFO has all the tools to write pull-down menu programs for more user-friendliness. The ARC/INFO toolbox approach allows flexibility, but the agency is not really to the point where they can specify a particular route through the software to use for particular applications.

Best Role of a GIS

The agency can perform the same tasks as before more quickly, and can perform new tasks and analyses with the GIS. For example, the Yakima is developing a forest plan, and what used to take six months with several staff now takes 3-4 days. Personnel are freed up to be more responsive to issues at the area office and responsive to resource questions brought up by tribal councils. Most of the GIS work is done at the reservation level with the area office in the role of guiding. Overall, a GIS is definitely useful for analysis and modeling, in addition to inventory.

Recommendations for Better Utilization of a GIS

Agencies need to train field resource professionals how to create appropriate, accurate databases for input into the GIS. There is also the need for deeper staffing -- consistent numbers of personnel to cover the loss of trained personnel. Software user- friendliness could be improved. The Portland Area office has as an objective to consult with each reservation's GIS personnel to identify routine procedures and develop pull-down menu programs. For example, they have developed a pull-down menu for fire management where the user can specify the geographic area, time frame, latitude and longitude, and display all the fire information on a map. The advantage of a pull-down menu is that one needs minimal GIS expertise, and this makes the GIS more applicable for all personnel for daily tasks.

GIS is cost-effective over the long run, maybe 5 years, despite its high up-front cost. It is always difficult to get funding. The data acquisition stage is also time-consuming and may lead to frustration. The GIS coordinator recommends contracting GIS work out if it exceeds 80 hours. Agencies need to make sure emphasis is on GIS as a tool. It will not replace the professional; it will only help them to be more efficient.

Communication Using a GIS

A GIS does improve the agency's ability to communicate. It is a helpful aid for field personnel to talk to upper management, tribal councils, and to the public. It also assists in the decision-making process because of the degree to which people respond to visual stimuli and thus respond to visually attractive GIS map products. The natural resource professional also gets a better feel for the spatial distribution of resources, situations concerning the quantity of a resource,

and environmental problems. As a tool, a GIS facilitates the decision-making process and helps with recommendations. A GIS enables people to ask "what if" scenarios and develop models.

U.S. Department of the Interior, Bureau of Land Management, Portland Area Office, Oregon

Interviewed Pat Green, Chief of GIS of the Information Services Division, GIS section. He has been at his present position for six months, and was a User Analyst previously. He has been using the current GIS for three years.

Mission Statement

"The Bureau of Land Management is responsible for the management of the Public Lands (275 million acres nationwide) and its resources, and their various values so that they are considered in a combination that will best serve the needs of the American people. Management is based upon the principles of multiple-use and sustained yield; a combination of uses that takes into account the long term needs of future generations for renewable and non-renewable resources. These resources include recreation, range, timber, minerals, watershed, fish and wildlife, wilderness, and natural, scenic, scientific and cultural values (BLM In-house Mission Statement n.d., n.p.)."

The BLM administers the use of a wide range of natural resources on nearly 2.4 million acres in Western Oregon. These areas support some of the most productive forests which contribute to the community economies of Western Oregon. Traditionally, forest management focuses on timber production, yet other important natural resource commodities like wildlife habitat, streams, and recreation areas are also important (Dippon, Wright, and Metzger 1989, 56).

Management activities on BLM lands are guided by two main pieces of legislation: (1) The Oregon and California Sustained Yield Act of 1937 which mandates forest production under sustained yield principles, protection of watersheds, regulation of stream flow, to provide recreation facilities, and to provide economic stability to local communities; and (2) The Federal Land Policy and Management Act of 1976 (FLPMA) which mandates and emphasizes forest management under multiple use principles in addition to sustained yield.

Objectives of a GIS

In order to comply with federal laws mandating that forest practices be governed by sustained yield and multiple use principles, the BLM must calculate the allowable harvest levels every 10 years for lands under forest production for timber management plans. Resource Management Plans (RMPs) for twelve Sustainable Yield Master Units (SYMUs) in western Oregon, must be developed using such calculations. Each new plan requires extensive re-inventory of the forest, planning, and environmental analysis. Great amounts of data are required from numerous sources, and data must be accurate and precisely mapped to avoid devastating effects on the implementation of Forest Plans. (For example, precise locations and accurate information about stand conditions and spotted owl habitat are necessary to avoid timber harvest in sensitive areas). With increasing public scrutiny of forest planning methods, and litigation of USDA Forest Service Plans in the Pacific Northwest, it appears that traditional planning procedures are inadequate and new methods are required. A new and different procedure has been implemented by the BLM for the development of RMPs for the 1990s (Dippon, Wright, and Metzger 1989, 56).

"The new planning strategy relies on the availability of spatial and relational data which

can be manipulated to evaluate spatially oriented natural resource management policies. A GIS is expected to provide natural resource planners with the capability to employ a highly complex inventory data base for the appraisal of a variety of policies in an efficient and timely manner (Dippon, Wright, and Metzger 1989, 56)."

The Western Oregon Districts of the BLM are developing a 7 million acre GIS. Concurrently, they are involved with a 10-year harvest scheduling planning effort for the 1990s.

Implementation Stage

The strategic planning process for RMPs of the 1990s, "consists of a combination of activities including the design of alternative management scenarios, simulation of management through harvest scheduling analyses, evaluation of analytical techniques for measuring effects, reporting, public input, and plan implementation with strategies for monitoring, maintenance, and evaluation. The development of the 1990 plan is predicated on the availability and utilization of data from the Western Oregon Digital Database (WODDB) Project (Dippon, Wright, and Metzger 1989, 57)." The decision was made to do six simultaneous RMPs, one for each district in western Oregon, and to use GIS technology to deal with the complexity of competing land uses.

The WOODB project was initiated in 1985 for the construction of a digital database required for the support of the RMPs planning process, and for future planning activities. It involves the digital mapping of over 7 million acres at scales ranging from 1:4800 to 1:2,000,000 with 75 base and thematic layers. A detailed timber data coverage will be completed for the 2.4 million acres of BLM commercial timberlands in western Oregon (Dippon, Wright, and Metzger 1989, 59).

The BLM has identified 183 planning issues that will need to be analyzed in the 1990

RMPs. The majority of issues result in spatially oriented conflicts. With the advent of computer technology and the implementation of a GIS, "natural resource policy conflicts can be more rapidly displayed and computational analyses implemented to discover and evaluate the compromises relevant to natural resource management (Dippon, Wright, and Metzger 1989, 60)."

In the past, large scale harvest scheduling models were predominantly two-dimensional in nature. The unanswered question has always been the spatial distribution of the harvested stands. In the past, spatial issues were ignored so that stands could be aggregated to determine the number of acres to be harvested and the harvest schedule. This approach worked while the goal of forest management was the conversion of large stands to a managed forest. Today, other issues and the increasing complexity of public lands planning call for a need of a spatial approach (Dippon, Wright, and Metzger 1989, 60). A GIS will help the agency get through the difficult spatial problems that would require a new technology, and to analyze spatial conflicts. The GIS will enable planners to deal with competing uses for the BLM land and to make decisions concerning land use. The BLM collects digital data concerning water resources, wildlife habitat, wilderness areas, fisheries, vegetation, timber stand conditions, threatened and endangered species, wetland areas, soils, air quality, recreation areas, and other resources.

The current GIS, MOSS running on a PRIME system, has been used for three years and the BLM is in the process of building the database which consists of 80 data themes with the first seven as common themes for the land base at a 1:4800 scale. The data layers have been manipulated (for small areas involving all 80 themes) to prototype technical procedures for future use of the GIS for resource management and analysis. Stand maps have been produced for an inter-agency, scientific spotted owl committee based on manipulation of the seven basic layers for all of western Oregon. The GIS is being built up for eventual use for analysis for all of western Oregon.

Data that is still desired includes current timber sales and what areas have been recently harvested. There are several themes which are too dynamic to be represented well spatially (such as roads) but must be represented for the GIS to be effective. The goal is for every district to update the data layers as land activities occur, and as needed. Making the updating process a part of day-to-day business will enable more effective use of the GIS, and more current, timely data. Once all of the software is in place and procedures set, updates will occur on a theme-by-theme basis, as often as needed.

Reasons for Choosing the GIS Software

The BLM, as an agency, supports MOSS software. They have staff available for technical support and software updates to other MOSS users. Therefore, the use of this software was mandated by the agency, and was already used elsewhere in the BLM. In addition, its cost was low because it is public domain software.

Satisfaction and Concerns with the GIS Overall

Overall, the GIS section of the BLM Regional Office is satisfied with the GIS. The GIS Chief expressed several concerns. There are high expectations of a GIS yet it requires time, funding, and people. There exists a perception that GIS analyses are easy to perform because they are performed with a computer. A GIS must have good support from upper management. Often, they do not always understand what is involved, and there is an unrealistic desire for quick answers, analysis, and maps. With its big up-front investment, a GIS still requires at least five years to pay back on that investment. Some problems exist with the reliability of answers with

MOSS, and the high cost involved to make the data more reliable.

In the area of personnel, the BLM is using a contractor to perform data acquisition, pre-processing of data, analysis, and support. The BLM staff is guiding the contractors. It is very difficult to train personnel in-house due to the high cost of training. Communication within the department and with upper management is always a concern with big projects. The WOODB project has been going well due to good coordination, through meetings, within the agency.

The data acquisition phase is costly, and the data changes with time. The data must be "frozen" in time for the RMPs. The database is artificially set at October 1989 for input into the planning process. The database is more flexible when doing spotted owl analysis, timber sales planning, and data on roads. These types of data are more dynamic than others. The BLM has set good standards for data acquisition, yet, this is an area of concern and it limits the degree of individual specifications of particular field work.

Satisfaction and Concerns with the GIS Platform

The GIS section is moderately satisfied with the platform. There is always a desire for more CPU. The GIS software is not considered user-friendly. It is poorly linked to other databases, and the BLM has decided to implement a MOSS-ORACLE (ORACLE is a database software) bridge. They are also looking at LIDES (software for point, line, polygon, and attribute labels) for data capture, and working on enhancements for plotting capabilities. The support for the software is not free. MOSS is designed to run on a mini- computer yet in the current situation it runs on a mainframe computer. All of the GIS users are competing for the same CPU, in addition to non-GIS uses, on that mainframe. The ability to update the data easily is poor. It is difficult to update and one must update an ADS file which has no attributes. It is a three step

process: (1) one must update the spatial data; (2) then update the attribute data; and (3) link them together again. The analytical capabilities of MOSS are limited. Spatial data is not in an arc-node structure and MOSS is not a relational database. There are also "bugs" in MOSS and there are many functions that it cannot do. The BLM also uses MAPs, a raster-based software, and finds it to be adequate for their needs.

Best Role of a GIS

A GIS is suited for monitoring, modeling, and analysis. As an operational system, it must be used for all of these functions to pay back the investment. A GIS answers questions faster and more efficiently. It also allows resource managers to do more "what if" scenarios and look at more alternatives. If managers try to perform such analyses for RMPs by hand, time constraints would not allow them to look at many alternatives.

Recommendations for Better Utilization of a GIS

There is a need for better understanding from upper management, the degree of which is unknown. An information needs analysis (INA) is also necessary before a GIS is implemented. It is important not to confuse precision with accuracy, and that is key to the INA process. The INA can help avoid expenditures of money to get very precise, yet inaccurate data. One must also understand that difference when building a GIS. Whatever an agency does, the procedure must be prototyped first; one can never do enough prototyping.

The up-front cost of a GIS is large. It must be viewed as just another tool. People tend to look at it as an answer to resource management. It is only as useful as the data in it and the

manager using it. GIS technology keeps evolving and a GIS is just a way to get the work done.

Communication Using a GIS

It will be interesting to see if the GIS improves the ability to communicate with the public concerning spotted owl and old growth issues. The map products are mostly used in-house except for the owl habitat conservation areas. The GIS is used to show spatial conflicts between different forest uses and between the Jack Ward Thomas scientific committee's (inter-agency owl team) recommendations, the current habitat conservation areas (HCAs), and current BLM land use conflicts. GIS analysis involves overlaying two corresponding layers. The results of analysis and mapping are shown to the national office, and possibly to congressional subcommittee hearings.

U.S. Environmental Protection Agency, NSI Technology Services, Corvallis, Oregon

The EPA has one national headquarters, ten regional offices and six labs. This lab has three divisions: terrestrial, watershed, and ecotoxicology, with each division having various teams. Interviewed Andy Herstrom, GIS Coordinator for the Ozone Team of the Terrestrial Division. He has been at his present position for five years, and has used the current GIS, mainframe ARC/INFO and PMAP, for five years.

Mission Statement

The EPA National Center for research on aquatic and terrestrial ecosystems is located in Corvallis, OR. The Terrestrial Ecosystems Division studies adverse affects of human activities

on the environment. Their particular project examines the affects of ozone on coniferous forests of Western Oregon. Other divisions work on different projects.

The EPA is concerned with environmental problems worldwide, yet has no jurisdiction over any particular area (doesn't manage an area of delineated geographic scope such as the Forest Service manages national forests). This lab also studies issues worldwide. The terrestrial division mainly studies environmental problems at a national level. The Ozone Team concentrates 50% of its efforts at the global level, and 50% at the national level. The data the Ozone Team is mainly concerned with are climatic, air quality, vegetation resources, endangered species, and soil data.

Objectives of a GIS

The EPA, and the Ozone Team more specifically, acquired a GIS to inventory data in a digital form and display it. They acquired the GIS as a tool to determine the spatial distribution of phenomenon and geographic features, and to perform analyses.

Implementation Stage

The lab and the Ozone Team are in an ongoing process of building the database, producing GIS maps, conducting analyses, monitoring, and performing sophisticated modeling. Digital data on vegetation, forest type, hydrology, water quality, endangered species, wilderness areas, soils, climate, and air quality are collected by the ozone team. The Team desires more updated data for data layers already in the GIS concerning air quality, climatic conditions, and wind patterns for the areas that concern them. Updating will be done as needed, and as data is

available.

Reasons for Choosing the GIS Software

ARC/INFO has a variety of capabilities and is very strong in the areas of database management (INFO) and its map products. It also has a good reputation, good support from the software company, and is well-suited for this lab's particular needs.

Satisfaction and Concerns with the GIS Overall

The Ozone Team is satisfied, in general, with the GIS overall, but specific areas need improvement. The high cost is a concern, especially in CPU, hardware, and disc space. It is difficult to continuously train staff in-house for advanced GIS use. There are problems of duplication of effort within and between agencies, of acquiring digital data, and sharing data with other agencies. There is a need for stronger communication between the staff within the lab, and to headquarters. High expectations of the GIS exist. It is difficult to know how to use the data, and to know what data is needed. Data acquisition is expensive and time-consuming.

Satisfaction and Concerns with the GIS Platform

The Ozone Team is satisfied with the platform overall. It is the plotters, and the map products from the plotters, that sell upper management on GIS, but they are often the weakest link in terms of getting output. Good plotters would help, but are very expensive. The GIS software is strong in plotting and in its ease of updating data. It is weaker in the areas of its analytical

capabilities. There are inherent software anomalies (bugs) which sometimes are not fixed until the next software update. Spatial interpolation and statistical capabilities are weak. The software needs distance weighted algorithms and kriging functions (methods of analyzing spatial data). ARC/INFO has limited ability to tie in with statistical packages.

Best Role of a GIS

A GIS is best suited for all capabilities: database management, analysis, modeling, and map products. It is best used for many particular uses. The GIS has been able to answer sophisticated questions with modeling and data layer overlay analysis.

Recommendations for Better Utilization of a GIS

The source of the data needs to be accurate, up-to-data, and consistent. Agencies need to avoid duplication of effort, especially financially. To reduce high expectations, there is a need for better understanding from upper management of what is involved in using the GIS. The software needs better links between statistical packages and ARC/INFO.

GIS is still in its infancy. A GIS needs to be a complete package with spatial interpolation and statistical capabilities, as well as, being able to incorporate remotely sensed data. GIS use is very fragmented with different software packages everywhere. The old raster-based systems were very strong in analytical capabilities due to raster-based algorithms, but today's vector-based systems are very attractive to upper management because of the charismatic appeal of their map products. The true need is for a complete GIS platform with elements of both raster and vector based systems with strong analytical capabilities and attractive hard copy output.

Communication Using a GIS

Map products are effective to portray "what if" scenarios and such maps are in high demand. They are what sells a GIS. Maps communicate a lot of information -- to politicians, to upper management, to the public, and to lay people -- succinctly and effectively. The map products provide a visual frame of reference that tables, graphs, and text do not provide.

U.S. Department of Agriculture, Forest Service

The Forest Service is a federal agency with the responsibility for multiple use management of 191 million acres of land nationwide. In this role, the Forest Service manages a wide variety of natural resources, and responds to a variety of legislation and public issues related to use of this land and these resources. Resource managers need to know what resources there are, where they are, what condition they are in, and how they are changing. They need to plan and carry out projects to meet management goals, and must monitor the effects of those activities. This type of information must also be made available to the general public and to increasingly sophisticated special interest groups.

U.S.D.A. Forest Service, Region Six, Portland, Oregon

Interviewed John Steffenson from the Information Management Division of the regional office. He has been at his present position since October, 1989, and has been using MOSS for two years.

Mission Statement

The regional office is concerned with the following issues: (1) Inter-agency issues include managing wild and scenic rivers, old growth forest, and spotted owl habitat. The regional office gets its information concerning these issues from the Forests themselves in order to study the regional impacts of these issues. The Forest Service manages any natural resource that is on a national forest, and some cultural resources (pre-historic and historic archaeological sites) on the forests. The Regional Office is also concerned with socioeconomic impacts of natural resource use, especially related to timber-dependent communities of the Pacific Northwest Region; (2) The Information Management Division of the Regional Office is also concerned with staff work (management of personnel). This includes the required resources of personnel and equipment for GIS-related work. It gives budget advice throughout the region, conducts GIS workshops and training, and manages the GIS software for the Forests. The Supervisor's Office of each Forest acts as a hot-line to the Division of Information Management of the Regional Office concerning GIS problems, or more specifically, problems involving MOSS software.

Objectives of a GIS

The Forest Service acquired a GIS in order to do the tasks of natural resource management more quickly and effectively, and also to perform new analyses. Traditionally in the Forest Service, paper and mylar maps have been used to track spatial locations, and tabular records have been kept using a variety of media: paper, card files, microfiche, and computerized databases. Spatial analysis and preparation of maps for display have been carried out largely by laborious manual processes. It is expected that implementation of a GIS in the Forest Service will help the

agency achieve its mission through better resource information analysis and improved graphical display, and in a more rapid fashion than was previously possible.

Implementation Stage

In early 1988, the Chief and Staff of the Forest Service approved a plan for implementing a Service-wide geographic information system by 1991. A national procurement of hardware and software is a part of this plan. It has not yet been decided what specific brands of hardware or software will be purchased. The hardware configuration is anticipated to include use of intelligent workstations. The workstations are to be connected to the minicomputers which currently reside on each Forest Service unit and comprise its nationwide distributed processing network. This will facilitate the sharing of GIS related information within the organization. The Forest Service has defined additional software requirements beyond the full range of capabilities available in GIS today. It would like to have the GIS software interfaced with its current information architecture and easily accessible (user-friendly) to non-technical resource managers.

The Forest Service is a decentralized organization. Within each of nine regions in the country are 128 separately managed Forests. Within a given forest there are several districts. The National GIS Plan calls for a certain amount of information to be standardized at each successive level -- nationally, regionally, and within each forest. Due to different environmental characteristics and differing management practices at each of these sites, even a minimal amount of standardization will take a concerted effort to achieve (Mt. Hood In-house Report on INA n.d., n.p.).

The databases of the forests are not fully done at this time. Some analysis has occurred on the forests, as well as, GIS hard copy output including maps. MOSS version E (soon to be

version F) is used on most forests with pc and mainframe ARC/INFO at a few select locations. MOSS is for full-usage on the forests. Some of the data is temporary and will not live beyond MOSS when the Forest Service moves to its new GIS after procurement. Data layers are updated as available and needed. The GIS is used for all functions -- database management, analysis, modeling, and map production.

The National Forests, the National Recreation Areas, the Columbia River Gorge National Scenic Area, and the Mt. St. Helens National Volcanic Monument all collect digital data for water resources, wildlife habitat, wilderness areas, fisheries, vegetation resources, timber stand conditions, threatened and endangered species, wetland areas, soils, and geology. They also collect digital data for other non-natural resources (such as transportation, buildings, public land coordinate system and other data).

Some desired data is missing in some geographic areas but not in others. Primary base series data is off of 7 1/2 minute quads available in digital form from the U.S. Geological Survey (USGS), and the forests add to this data. It includes transportation, hydrography, the public land survey system, political boundaries and other data. Digital elevation models are desired. The five year plan is to capture data in a digital form for all 119 national forests nation-wide.

Reasons for Choosing the GIS Software

The Forest Service is in the process of procurement of a national GIS software and hardware. Therefore, forests cannot buy new software on their own. The current software, MOSS, is public domain software and is free of charge. Its use avoids any conflict of interest concerning the vendors of GIS software. It fulfills some needs of the Forest Service that can be met with a GIS in the interim.

Satisfaction and Concerns with the GIS Overall

The Regional Office is satisfied with the GIS overall, considering the objectives of the GIS use. It currently meets agency objectives, but would not if it continues to be the GIS platform for the Forest Service in the future. Almost all issues are of concern, including personnel and staffing issues, database and data acquisition problems, and communication and funding issues. There is a need for better trained staff, and for better understanding of the role of a GIS from upper management.

Satisfaction and Concerns with the GIS Platform

There are concerns with the hardware, specifically the minicomputer that the current GIS runs on. It runs on the Data General and thus the GIS must compete with other uses for CPU. This impact could be distributed, if the GIS were on workstations which provide for multiple users. MOSS is not an adequate software program for database management. Additionally, it does not have good linkages to other database software.

Best Role of a GIS

A GIS is best suited for analysis and modeling. The use of a GIS in the region has enabled the agency to perform old tasks faster, and to answer new questions and perform new analyses. This frees up middle management to do better resource management out in the field.

Recommendations for Better Utilization of a GIS

GIS technology is a field that is still maturing. There need to be standards -- for information definitions which get weak with subjective calls and for exchange of digital information. It is the GIS vendors' role to correct the technical aspects, and the vendors that subscribe to a high standard will survive. GIS software also needs to be more user-friendly. There also seems to be a lack of leadership from the academic community in Oregon. They are missing the opportunity to be on the forefront of GIS technology and GIS applications. Deficiencies of GIS application for natural resource management is not a problem inherent to the GIS itself, but is due to a lack of education and awareness of GIS as a tool.

Communication Using a GIS

Using a GIS has improved the agency's ability to communicate. When used properly, a GIS can lend credibility to an analysis. The Forest Service can use GIS map products in court cases. GIS products are also used to aid internal decision-making. Not all GIS products are suitable for public display (He did not specify which ones).

U.S.D.A. Forest Service, Mt. Hood National Forest, Gresham, Oregon

Interviewed Curtis Day, GIS coordinator for the Planning Division. He has been at his present position since August 1989, and has used the current GIS since December 1989. The Mt. Hood National Forest has used the current GIS since 1988.

Mission Statement

A mission statement, specific to the Mt. Hood National Forest, was not available.

Objectives of a GIS

The Mt. Hood National Forest conducted an information needs analysis (INA) which "...coincided with an accumulated critical mass of management interest in acquisition of GIS capabilities. Many factors contributed to this interest: (1) resource management decisions are visible and controversial -- the Forest is in close proximity to Portland, the predominance of the timber industry in the Oregon economy, and the public interest in fish and wildlife habitat, supplies of water and timber, and recreation opportunities; (2) the internal needs of Forest; and (3) the inadequacy of current methods for handling mapped resource data. Current digital database systems are not able to perform automated mapping or spatial analysis functions.

Implementation Stage

The Mt. Hood, along with other forests, implemented a GIS on an interim basis preceding the national procurement of a permanent system. The Forest uses MOSS, a public domain software. They use hardware that will be compatible with the future hardware and software that results from the national procurement. Digital data entered into the interim system will be converted to the new system in the future. The Supervisor's Office (S.O.) implemented its GIS in 1988, and implemented it on several districts since November 1989.

The S.O.'s first use of a GIS was for input into FORPLAN, the Forest Service's linear

programming software, to use for creation of the Mt. Hood National Forest Plan. This entailed digitizing basic data layers. More recent district use has emphasized digitizing layers decided upon as a result of the INA.

Currently, the Forest continues to digitize new data layers and to create map products for the S.O. and districts. The Forest collects digital data on water resources, wildlife habitat, wilderness areas, fishery resources, vegetation, riparian areas, timber stand conditions, threatened and endangered species, wetland areas, and soils. Some spatial analyses are performed, including forest fragmentation studies, and spotted owl habitat analysis (acres, location). In the future, all layers resulting from the INA will be digitized. Seventy-eight GIS products aimed for by the INA will be produced, and the GIS will be used in monitoring for the Forest Plan.

Data that is desired includes digital elevation models, which are due in 1991. Data that either changes too quickly or is difficult to represent includes: (1) a plan and sold layer consisting of timber sales. One must change polygons and attributes for the GIS every time a sale occurs. Managers must also run prospective sales through planning, the US Fish and Wildlife Service, and the Citizens' Advisory Board for every sale. The internal operations of the Forest change every day; and (2) Tracking down and mapping all land use activities on the district level is difficult. For example, it is difficult to get data on cultural resources, spotted owl nests, land surveys, recreation use patterns, timber stand exams, and reforestation surveys, all in a timely digital form.

Reasons for Choosing the GIS Software

MOSS is public domain software, and is therefore free of charge. It was already used throughout the agency, and its use was mandated by the Forest Service. One must have special permission to use any other GIS software. MOSS also has a short start-up time, good support,

and upgrades every three months.

Satisfaction and Concerns with the GIS Overall

The Planning Section is satisfied with the GIS overall. There is good support, good funding, and a high awareness of GIS capabilities. Two of the District rangers are involved in GIS implementation at the national level.

There are some concerns with the GIS overall. Upper management wants products quickly. They do not always understand the amount of time required to ensure validity of GIS products that they desire. It is difficult to train staff in-house due to time constraints. The S.O. needs a database manager. There is also a need for a standardized data dictionary of how attributes will be coded, how data is organized, and definitions of particular resources. Effective GIS use requires national data standards to enhance inter-agency cooperation. This agency still suffers from being overwhelmed with GIS map product requests. There is not enough time to ensure data integrity including accuracy, precision, and currency.

Satisfaction and Concerns with the GIS Platform

The Planning Section is satisfied with the GIS platform. MOSS does have good raster-based analysis capabilities. The agency is working on better links to remote sensing. There are some concerns. For the hardware, there is competition for computer resources in terms of CPU ; there is competition between GIS use of the CPU and the other uses of the Data General system, the minicomputer which runs the GIS software and other Forest programs.

There are concerns with MOSS. Updating data is difficult; one must export spatial data

and attribute data every time one edits. MOSS is twenty years old and hundreds of updates and programs have put band-aids on its weaknesses. Some modules of MOSS are obsolete and it was written for 64K RAM hardware which makes it slow today. Saving, merging, and sorting require a lot of time and there is no dissolve function.

Best Role of a GIS

A GIS is best suited for all its functions -- database management, monitoring, map production, modeling, and analyses. Old questions can be answered more quickly such as questions concerning the number of acres of owl habitat, simple spatial analyses, and the number of acres of sold timber sales within x number of miles of known owl nest sites. New questions can be asked, for example, by performing forest fragmentation models (models of how patterns of timber harvest may be changed to result in less fragmentation of the forest).

Recommendations for Better Utilization of a GIS

An information needs assessment determining the kinds of data needed, its scale, and format, as well as, an assessment of the potential questions to be asked of a GIS database, is a must. An INA is the starting point for GIS implementation.

The data pre-processing stage needs improvement. Converting data from one digital format to another is necessary. MOSS cannot convert some digital files from other GIS software. Understanding other agencies' data standards, data formats, and data definitions will ensure inter-agency cooperation and avoid duplication of effort. GIS data acquisition requires better links to remotely sensed data. Software should allow one to be able to automatically update spatial and

attribute data. More emphasis on Global Positioning Systems is needed.

The emphasis from upper management is to get answers in the form of map products and simple data manipulations for the regional office and for congressional committees. Most Supervisors Offices and Districts on other Forests are still in the Land Management Plan use of GIS. On the Mt. Hood National Forest, the emphasis is on map products, not only due to upper management requests, but also to the need for more time to ensure accuracy for doing analyses. The Mt. Hood National Forest is still building the basic data layers for its GIS. There is not enough time to produce all the desired map products, conduct training, and perform new data acquisition that is accurate, and also have time to check that data layers are updated, and to manage the database. Therefore, the agency needs less focus on map products and more on data integrity. The focus should be on making sure that base data is accurate, precise, appropriate, and up-to-date.

Use of a GIS as a planning tool will free up the Forest Service to be an information manager and not so much a natural resource manager. Yet like this quote, "GIS -- fast, cheap, and accurate, pick two," GIS implementation is an enormous investment of time and money that will only pay back in the long run. Ten years from now, GIS will be huge and will create the opportunity for personnel to cross functional lines and organizational lines. Duplication of effort within and between agencies will be avoided. GIS will allow personnel to look at the big picture and to view the Forest resources in an inter-disciplinary way. It will free up the natural resource managers and allow them access to other natural resource data outside their functional areas and disciplines. Because the personnel will be less pigeon-holed, there will be better integration and communication among different disciplines within forest management.

Communication Using a GIS

The use of a GIS has improved the ability to communicate about resource issues concerning the Mt. Hood National Forest. The biggest use of the GIS is to gain support, answer questions, and to communicate with the Citizens' Advisory Board (result of the section 318 Northwest Timber Compromise), in-house, and with other agencies. For example, all of the maps in the Forest Plan were generated by the GIS.

U.S.D.A. Forest Service, Columbia River Gorge National Scenic Area, Hood River, Oregon

Interviewed Dale Cummins, the GIS coordinator for the USDA Forest Service Columbia Gorge National Scenic Area, Hood River, OR. He has been at the present position for two and one-half years and has used the current GIS for two years. The current GIS, mainframe ARC/INFO has been used for two years for coverage of the entire scenic area.

Mission Statement

The Scenic Area was created by the "Columbia River Gorge National Scenic Area Act," November 17, 1986. Its purpose: (1) to establish a national scenic area to protect and provide for the enhancement of the scenic, cultural, recreational, and natural resources of the Columbia River Gorge; and (2) to protect and support the economy of the Columbia River Gorge area by encouraging growth to occur in existing urban areas and by allowing future economic development in a manner that is consistent with resource protection.

Non-federal lands within the scenic area are administered by the Columbia River Gorge

Commission. The governor of each state, Oregon and Washington, appoints six members, one from each of three counties of each state within the scenic area boundaries and three more members from each state. At least one member is a resident of the scenic area, and another is a non-voting member who is a Forest Service employee.

The management of the Scenic Area is occurring in several steps. First, studies were developed within one year after the date the Commission was established, for use in preparing the scenic area management plan. Three studies are prepared: a resource inventory, an economic opportunity study, and a recreation assessment. The resource inventory is of all existing land uses, natural features and limitations, scenic resources, natural resources, cultural resources, archaeological resources, and recreational and economic opportunities and activities. In addition, the studies incorporate, without change, the resource inventory for special management areas: the Gates of the Columbia River Gorge, Wind Mountain, Bursoin Mountain, and Rowena areas. An Economic Opportunity Study identifies opportunities to enhance the economies of communities in the scenic area in a manner consistent with the purposes of the Act. A Recreation Assessment is an assessment of recreation resources and opportunities for enhancement of these resources in the scenic area.

Second, within two years after the commission was established, it shall develop land use designations for the use of non-federal lands within the scenic areas. These designations will be based on results of the resource inventory to protect and enhance different uses and areas. Designations include: agriculture, livestock uses, forest lands for production of forest products, open space, areas suitable for commercial development, areas suitable for residential development, and designated urban areas.

Third, within three years after the date the Commission was established, a Management Plan will be adopted. This plan will be based on the results of the resource inventory, include

land use designations, and incorporate management direction for the use of Federal lands and guidelines for the adoption of land use ordinances.

At the end of this management process there will be agency consultation and public involvement. Consultation will include federal, state, and local governments having jurisdiction within the scenic area or expertise pertaining to its administration, and with neighboring Indian tribes. Public hearings and solicited public comment will result in a final plan to be submitted to the Commission Secretary for concurrence with the Act. The Commission then votes to adopt the Plan. The Plan will be revised between five and ten years after adoption.

The Forest Service has jurisdiction over the national forest lands within the scenic area, and an administration role in land use direction over the remainder of the scenic area. The Commission has direction over residential areas. The Forest Service is mandated to manage resource values in accordance to the Columbia River Gorge National Scenic Area Act -- to protect recreation, scenic, cultural, and economic values, while facilitating cooperation with other involved agencies.

Objectives of a GIS

The Planning Section is dealing with public resistance to the land use planning and land use designation elements of the Columbia River Gorge National Scenic Area Management Plan. The conflict is how to manage many different resource values when so many agencies are involved, especially due to the political nature of the final decisions.

The Forest Service acquired the GIS for several reasons: (1) to ease public resistance to land use planning for the Scenic Area. They hope to use GIS products to help gain support for the planning process, and to be on the forefront of GIS use; (2) the Forest Service must manage

national forest lands and provide direction for other lands in terms of land use designation for the Management Plan. They hope to use the GIS as a tool, due to its ability to communicate the spatial distribution of resources. Map products provide spatial display of resource data, and these products can be used to influence planning decisions and facilitate public input; and (3) to carry out legislative objectives within the given time frame. The Management Plan is due sometime in 1990. The resource inventory information must be pre-processed into a digital form for better data management. All of the digital data must then be consolidated for input into the management plan.

Implementation Stage

The Forest Service Columbia Gorge National Scenic Area office acquired mainframe ARC/INFO in March 1988 with the guidance of the Oregon State GIS Service Center (located within the Oregon State Department of Energy). They are in the process of building the database, and emphasis is on the output of GIS map products. There is little emphasis on analysis or modeling, and the agency needs criteria for analysis. The map products at this time are full coverage of the scenic area. Database management is probably the next greatest use, but slow compared to map production. The agency is trying to accomplish two tasks at once: (1) to use map products for input into management plan decisions; and (2) to use the analytical capabilities of the GIS to aid in management up-front. This conflict is due to point at which the Columbia River Gorge National Scenic Area is at in the planning stage, and the emphasis from within the agency and from other participants on GIS map products rather than GIS analyses. The agency collects digital data on water resources, wildlife habitat, wilderness areas, scenic and visual resources, vegetation, forest resources, threatened and endangered species, wetland and riparian

areas, range lands, and soils. The agency desires remotely sensed data for monitoring land use changes.

Reasons for Choosing the GIS Software

Mainframe ARC/INFO was chosen for several reasons. It has a good reputation, and good support. It is well-suited for creating excellent map products. It allows easy transfer of digital data from other agencies, in other digital formats. In addition, it has strong analytical capabilities, which hopefully will be fully utilized in the future.

Satisfaction and Concerns with the GIS Overall

The agency is satisfied with the GIS overall, but does have some concerns. There exists high expectations of the GIS. It is not as easy to implement as commonly believed. GIS implementation requires much time and effort to build the database. Data acquisition and pre-processing are the most cost- and time-intensive stages. There are unrealistic expectations for map product output in terms of the amount of time required for plotting. The level of knowledge about the capabilities of a GIS is not where it should be. More education on GIS could lead to a greater role of GIS in the planning of the scenic area. Its strong analytical capabilities are more difficult to express to, and sell to, upper management and lay people. It is also difficult to find trained staff. The agency would need more personnel to take advantage of the analytical capabilities of ARC/INFO.

Satisfaction and Concerns with the GIS Platform

The agency is satisfied with the GIS platform, but there are concerns. There are high expectations of the plotter capabilities. The GIS coordinator would like more support for hardware in areas of a modem and multi-plexor. The GIS software was procured with the help of the Oregon State GIS Service Center, located at the Oregon Department of Energy. With the help of the Service Center, the Forest Service is in the process of developing a pull-down menu for ARC/INFO which would make it more user-friendly. ARC/INFO is an expert system and has a large learning curve. Its toolbox approach allows a great deal of flexibility, yet may present too many options for the less experienced user. There are many paths between points A and Z and some inherent anomalies (bugs) in the software.

Best Role of a GIS

A GIS is ideal for database management, monitoring, map products and especially analytical functions involving spatial information. The use of a GIS has helped make preparation of the management plan faster and more efficient. The agency is not using the GIS to its fullest analytical capabilities, due to the heavy emphasis and many requests for map products from within the agency and outside the agency.

Recommendations for Better Utilization of a GIS

Upper management needs to be encouraged to have the goal to increase awareness of the capabilities of the GIS throughout the agency. All department personnel should be aware, to the

same level of proficiency, of the big picture of GIS use and its capabilities. They should be aware that: (1) GIS requires money, time, and expertise; (2) the GIS capabilities, including analytical ones, need to be understood. The agency must get beyond the use of the GIS for merely generating map products. The high price of the GIS can be paid back if it is used to its fullest capabilities, otherwise, the agency is paying for fancy computer cartography; and (3) the GIS needs more personnel to perform GIS analytical tasks.

Such support from upper management could be in the form of a statement of the importance of the GIS in the Scenic Area's planning process. The GIS coordinator is not in the most appropriate position to encourage awareness and training. Yet, time constraints on other department managers in the area of time required for GIS training, must somehow be resolved. There is a need for an overall commitment to GIS, a follow-up commitment, and incorporation of this technology into the day-to-day workings of the agency.

Communication Using a GIS

The GIS map products serve as an effective tool for gaining support from the public, the Columbia River Gorge Commission staff, the Commission itself, and within the Forest Service. It is not necessarily why the GIS was acquired, but now it is the greatest emphasis.

U.S.D.A. Forest Service, Siuslaw National Forest, Corvallis, Oregon

Interviewed Bryan Armel, GIS coordinator of the Planning Division. He was at that position for four years, since August 1987.

Mission Statement

A mission statement, specific to the Siuslaw National Forest, was not available at the time of interview.

Objectives of a GIS

The objectives of the GIS system are: (1) to get timely information on land use activities and be able to make that information accessible; (2) to acquire a good system for updating information; (3) to help respond to the public; and (4) to get a better handle on field conditions in order to make better decisions. The Siuslaw National Forest staff will use the GIS mainly for analysis and inventory, that is, essentially knowing what resources are where.

Implementation Stage

The Siuslaw National Forest acquired mainframe ARC/INFO in August 1987. The Forest also has workstation ARC/INFO on two districts. They have built approximately 60% of the desired database for many different data layers for full forest coverage. Each forest district will have its own GIS software by summer 1990. In the S.O., forest-wide analyses have been performed, as well as, production of map products, continued data acquisition and data layer updates. The role of the S.O. is to make sure that data acquisition from the districts is consistent.

The Siuslaw National Forest collects digital data for these natural resources: water resources, wildlife habitat, wilderness areas, fishery resources, vegetation, timber stand conditions, threatened and endangered species, wetland areas, soils, and land use activities. The Forest is

working on getting soil series data and a digital elevation model. Slope and aspect data layers have not yet been derived from the digital tapes. There is the desire for more site-specific data, for example, vegetation data taken from photo interpretation of air photos. The Planning Division would like more field checking. They would also like to have all activities mapped, and some kind of database format to handle temporal, as well as, spatial information for any particular site. Some data layers will be updated immediately and other data layers will have a set schedule. The schedule is in the process of development.

Reasons for Choosing the GIS Software

The national headquarters of the Forest Service asked for forests as volunteers, one forest per region, for implementation of ARC/INFO. Environmental Systems Research Institute, the vendor of ARC/INFO, bid for this procurement and won based on the fact that the software had the analytical capabilities that the Forest Service desired. ARC/INFO has a relational database (INFO) connected to the spatial component of the software. The Siuslaw National Forest was chosen, for the region, based on workload analysis. The Forest has been using the mainframe ARC/INFO since August 1987 on the Data General (mainframe system). Two districts have workstations.

Satisfaction and Concerns with the GIS Overall

The Planning Division is satisfied overall with the GIS. Personnel concerns include: the high turnover of trained staff, the difficulty of training staff, and communication with upper management. It is difficult to find the time to train personnel. The level of awareness from upper

management of GIS capabilities, and what resources are required to implement and use a GIS, needs to increase. GIS expertise is often at the lower ends of personnel.

There are also concerns over data quality. It is difficult to acquire data and field check data for accuracy and precision. There is a desire for more detailed data to be available to answer questions, and that requires more funding.

Satisfaction and Concerns with the GIS Platform

The Planning Division is generally satisfied with the platform. There is a problem with data storage with the system on the individual forest districts, and it is difficult to get enough output from the plotters during peak use times. Speed and power are always a problem. It would be desirable to switch hardware to workstations, because everyone would have their own CPU. The Forest just recently converted to a larger mini-computer which is faster and has more memory.

The software is not user-friendly. Having the software run off the Data General prevents multi-tasking (ability for computer to conduct multiple functions at the same time). ARC/INFO does runs on workstations at two districts to minimize that problem. It is always preferable to have more speed and power.

Best Role of a GIS

A GIS is suited for all capabilities including monitoring, modeling, and analysis. It is now possible to look at different outcomes of natural resource policies given different constraints. For example, the number of acres of habitat with a particular distance of spotted owl nests can be

determined. One can change the x = distance variable and quickly generate results in terms of acres. Natural resource managers have a better handle on what is out there and can therefore better answer questions.

Recommendations for Better Utilization of a GIS

The sources for data need to be accurate, up-to-date, and consistent. There also needs to be more modeling capability from the software, and better and more sophisticated database management tools. Better understanding from upper management is needed, along with more staff training in GIS and better incorporation of GIS education into academic programs. The use of a GIS needs to move toward looking at more specific needs. The next step is to take the toolbox approach of ARC/INFO and develop a procedural approach with the toolbox underneath. This would enable the manager to use the software without needing to know every detail of how the software works. The development of another layer on top of the toolbox could help adapt the software to specific natural resource applications.

Communication Using a GIS

The map products from a GIS can help communication with the public, within the Forest Service, and with other agencies. One can show important concepts with map products instead of trying to describe the effects of policies. The GIS products are also useful because of the short amount of time required to produce them compared to old methods.

U.S.D.A. Forest Service, Willamette National Forest, Eugene, Oregon

Interviewed Ken Adee, GIS Coordinator, of the Planning Division. He has worked for the Forest Service for ten years, and has been at the current position for three years.

Mission Statement

A mission statement, specific to the Willamette National Forest, was not available.

Objectives of a GIS

There are several objectives of using a GIS for the Willamette National Forest. Land management involves conflicting uses, such as responding to national, state, and local concerns about preserving Spotted owl habitat, and management of Old Growth ecosystems within the context of fulfilling the legal mandate to harvest a certain level of timber. The level of timber harvest conflicts with the mandate to maintain and protect the forest environment. Emerging issues such as preservation of anadromous fish, the use of other forest products (e.g. yew trees), and travel and access management (what roads are closed, which are open), as well as, long-range forest planning have complicated management of the Forest. The Forest personnel weren't able to adequately manage all of the information needed to respond to issues using manual methods of handling that data. Manual maps are not flexible, and do not allow quick and easy access to information. The more complex the issues, the more the analysis requires multiple resource data layers. Manual methods just weren't adequate. The GIS technology was available to some extent, and was acquired to help address these issues.

Implementation Stage

The Willamette National Forest started with the use of some type of GIS and it has evolved over time. Until recently, the Forest focused on the use of TRI and MOSS, more recently (1991), the emphasis has shifted to the use of MAPS. MAPS comes with MOSS, but the Planning Division doesn't use MOSS as much as before. The Forest collects all kinds of natural resource data on water, wildlife, vegetative, soil, and fisheries resources. The greatest amount of data is for management allocation, such as Spotted owl habitat, general forest, special interest areas, wild and scenic rivers, and other data. Digital elevation models are also used for terrain and administrative boundaries and are an important data layer.

There are many gaps in the data and in other areas there is much duplication of data. The most difficult data to acquire is accurate, precise data for vegetation, i.e. stand conditions, snag densities, down and dead material, Spotted owl habitat, and verified information on species. The Forest personnel would like to have 100% coverage for the entire Forest. Such information requires good field exams and is very time consuming. Currently, varying data definitions and standards complicate acquisition of good data. In other cases, information is in very different formats and difficult to bring together. The Forest is currently working out procedures for updating layers and for data standards.

Some data variables are just very difficult to acquire or change too quickly to capture. Spotted owl locations, of course, are difficult to pinpoint. Most animal species are difficult to locate and so far, attempts to map them have not been successful. It is not impossible, but acquiring such data requires more time, money, and personnel. Most data concerning the Forest is difficult to represent spatially -- there are always differences in the imagery (aerial photography, satellite imagery), and it is difficult to get two different images to agree in all locations.

Reasons for Choosing the GIS Software

MOSS was selected for the Forest due to agency direction from the regional and national office. Other packages were not considered.

Satisfaction and Concerns with the GIS Overall

In general, the resource people are dissatisfied with the current GIS. Personnel, who do not work directly with the GIS, want spatial information and analyses faster. Their expectations of the GIS are very high and they want the products now. For others, as long as the map is attractive, they are satisfied. The GIS funding is there, but there is little organizational support. The Division needs support integrating the GIS with the various resource people. Those who work directly with the GIS want reliability and accuracy of data. In particular, the people on the Forest districts are concerned with the resolution of the data.

It is very difficult to train personnel to use the GIS. It takes a long time to get fully trained on a GIS, especially for using MOSS. One must know SQL (standard query language) commands, mapping analysis language, and how to re-format files. Much of the work is done by temporary employees, and this creates problems in GIS use. It takes at least one to two years to get an employee up to speed on the GIS. It is difficult to get them promotions. They work at the Forest for a couple of years before moving on to other employment. The resulting high turnover is a major hindrance to effective use of the GIS.

Data standards is a big issue. GIS is a tool that helps one get the job done, but it doesn't have a plan that comes with it. There is the need for standards in updating data and such conformity takes time and involves personnel at all levels -- regional, S.O. and district.

Satisfaction and Concerns with the GIS Platform

The Division is totally dissatisfied with the GIS software both MOSS and MAPS. The software lack analytical functionality, are very slow, and use an archaic data structure. In particular, MOSS gives incorrect answers without erring out. For example, asking for the amount of Old Growth or the size of particular forest stands can result in a ridiculously large amount, such as 300,000 acres. This just exacerbates the problem of perception. GIS products may look good but be completely inaccurate. Neither software is user-friendly and the support is inadequate -- problems with the software have not been fixed. The GIS software does link to ORACLE (database) but it is a crude link. The S.O. built their own link that works just as well as any other.

The GIS personnel are very disillusioned with Landsat imagery. It cannot be used for a lot of applications. It is more useful for broad scale mapping and for updating such maps. The Forest is now using SPOT panchromatic imagery for updates.

There has been little up-front cost for the software (all public domain software) but the cost has been very high in using the system. There is the cost of re-doing work, cost in time, and cost in frustration. Therefore, using this software has not been cost-effective. The Division has been constrained in its options in selecting a GIS. The funds exist, but the Division cannot buy another GIS due to Project 615, the national procurement of a Forest Service-wide GIS and other computer resources. This may be the biggest GIS contract ever awarded. The proposal is asking for a lot of functionality from the selected GIS and a positive result is that it is creating competition and driving the technology. The vendors are working on their products so each GIS can do all these things being asked for.

Best Role of a GIS

The best role of a GIS is definitely for modeling and analyses.

Recommendations for Better Utilizations of a GIS

The saying goes "garbage in, garbage out." Products may come out looking very beautiful, and the result is that people believe it is accurate. The focus needs to be on getting accurate data into the GIS. Once this data is in place, there needs to be development of adequate resource models. With the right system, such capabilities exist, especially in raster-based systems.

The perception is that one can implement a GIS and then immediately get results. In reality, it's a multiple year, multi-million dollar process. This inaccurate perception cannot really be helped; GIS personnel have been doing what they can and haven't really known how long it can take to get a GIS implemented, running, and useful.

The issue of perception gets complicated even between the S.O. and the districts. The saying goes "fast, good, cheap, -- pick two!" The S.O. sends out maps to the districts and the S.O. doesn't have the ability to determine if these maps are actually ground true. The maps are verified to match manuscripts, not necessarily assessed with additional field work. Such discrepancies frequently don't show up until analyses are done and then the resulting analyses' maps don't look right. The perception from the districts is that the S.O. should be sending out 100% accurate maps.

Improving the use of GIS technology just takes time. If we stick with it, it will get better. The real issue is information management; GIS is just one tool. It boils down to a procedural organizational issue. On the Willamette, either information management hasn't been practiced or

was done poorly. The traditional way of building a database went like this: have an application, determine a need, determine the data needed, and build a database strictly upon that functional need. This process happens in different divisions repeatedly and simultaneously. The result is multiple sources of information with lots of overlap and duplication of effort with little sharing. This is especially wasteful when trying to maintain all of these databases.

The issue is also one of the politics of information. Making GIS successful requires organizational commitment. It is difficult because people are locked into their functional perspective. They give lip service to the idea of information integration but don't want to commit to data conversion. People don't want their databases cut or to lose control of their databases. Their databases are something they have invested a lot of time and energy into and it's difficult to release control of it in the name of information integration.

There is much disillusionment at the S.O. It is a time of budget reductions, and currently the GIS is multi-funded. If GIS is not meeting expectations (realistic and unrealistic) then there is much resistance to continued investment in GIS. Now, it is more of a battle to convince people of the need for GIS technology and automating data. Actually changing the politics of information and the way the Forest Service has been doing business is unrealistic. The Forest Service cannot stop everything they are doing and redesign how the agency manages information.

Communication Using a GIS

GIS provides graphics that can explain what's going on and aid in communication.

U.S.D.A. Soil Conservation Service, Western National Technical Center, Portland, Oregon

Interviewed Mon Yee, Soil Scientist/GIS specialist for the SCS, Portland, OR. He has been at this present position since 1981 and has used MOSS since 1983 and GRASS since 1990.

Mission Statement

The SCS mission is "...to provide national leadership in the conservation and wise use of soil, water and related resources through a balanced, cooperative program that protects, restores, and improves those resources." More specifically the Western National Technical Center mission is "to provide existing and emerging technology and products needed by western states to facilitate sound soil, water and related resource decisions (SCS In-house Mission Statement n.d., n.p.)."

Objectives of a GIS

The GIS was acquired to access the large amount of natural resource information. Most of the data the SCS deals with is spatial in nature. There was no national guidance or policy to procure a GIS. Mon Yee obtained first generation MOSS software in 1983, to run on a coexisting Data General system to use for spatial analyses.

Implementation Stage

The SCS has had the current GIS for approximately six months (less time than other agencies surveyed). An information needs analysis has been done, and currently the GIS is in the

database building stage. Some previous MOSS files will be converted for GRASS software. One goal is to digitize seventeen different data layers for twenty-six counties in GRASS. Eventually this data will be used for analysis and modeling, and to a lesser extent for spatial database management. Currently, seventeen data layers for six counties in the western U.S., exist for MOSS and have been used for analysis and map products.

Data layers will be updated as needed. Other layers are more difficult to get. Land use is very dynamic and the SCS is hoping to get access to satellite imagery to monitor land use changes. The SCS plans to digitize information on soils, geology, land ownership, transportation, hydrography, land use, land cover, the public land survey system, vegetation, census information, as well as other types.

Reasons for Choosing the GIS Software

The SCS was looking for an inexpensive software that would run on the current UNIX system. GRASS was a public domain software that achieves that goal.

Satisfaction and Concerns with the GIS Overall

The agency is satisfied overall with the GIS. Concerns include the desire for a data acquisition technician and a database manager, and the difficult task of collecting an adequate database that is accurate and cost-effective.

It is also recommended that the SCS have better understanding from upper management, and funding for additional staff positions. In addition, managers do not understand that the biggest cost is for data capture. There is also a gap in understanding from upper management as

to what "spatial data" really is. This lack results in no commitment on their part to fund activities that will lead to an efficient spatial database management system.

Satisfaction and Concerns with the GIS Platform

The agency is relatively satisfied with the hardware and moderately satisfied with the software. The agency would like a workstation for its speed and compactness. GRASS is public domain software and it needs enhancement. Public domain software is designed with a single user in mind. GRASS is not well-suited for natural resource management. Better support for the software is necessary. There is no lead agency to perform maintenance and software enhancement, and it is weak in the area of links to other database systems and software. GRASS could become a more powerful software if it had stronger links to database software such as ORACLE. Support is also weak for the plotter functions within the agency -- the software needs enhancement in this area. The software also needs to be stronger in its analytical capabilities. It has a limited relational database capacity. Possibly the next version of GRASS, version 3.1, will have stronger capabilities.

Best Role of a GIS

The strongest part of a GIS is its analytical and modeling capacities.

Recommendations for Better Utilization of a GIS

To avoid duplication of effort and save costs, spatial digital data transfer standards should

be designed and adhered to. There is also the need for a central clearinghouse for all the digital data layers, all at one standard. This would facilitate the use and exchange of spatial data. The Northwest Land Information System (NWLIS) network, approximately twenty agencies, has attacked the problem of data standard guidelines and eventually other states can learn from this Oregon example.

Agencies should first shop around for the best GIS software available, and then look for hardware for better efficiency and payback in the long run. Fortunately, software vendors have responded so that software will run on just about any hardware set-up. The SCS went backwards, asking what free software would run on their current hardware. To have a truly operational and functional GIS, the investment should include the cost to encode all data and hire all the necessary staff, in addition to hardware and software costs.

Communication Using a GIS

Within the SCS, GIS products have stirred interest. Mon Yee has communicated to other staff what the GIS capabilities are, the data layers of interest, and how they can use such data. The NWLIS is a good forum for support and exchange of information. Eventually the public will be the ultimate benefactor. Agencies can provide the public with better information through GIS graphic products and analyses.

U.S. Geological Survey, Water Resources Division, Portland, Oregon

Interviewed Bruce Fisher, the Project Chief for the BPA/EPA River Reach Study. He has been at the present position for two years and has been using the current GIS for four years.

Mission Statement

The U.S. Geological Survey (USGS) was established by an act of Congress on March 3, 1879, in order to answer the need for a permanent government agency at the federal level to conduct, on a continuing, systematic, and scientific basis, investigations of the "geological structure, mineral resources, and products of the national domain." Although a number of laws and executive orders have expanded and modified the scope of the Survey's responsibilities during its 110-year history, the Survey has remained principally a scientific and technical investigation agency, as contrasted with a developmental or regulatory one. Today the Survey is mandated to assess on-shore and offshore energy and mineral resources; to provide information for society to mitigate the impact of floods, earthquakes, landslides, volcanoes, and droughts; to monitor the Nation's ground- and surface-water supplies; to study the impact of man on the Nation's water resources; and to provide mapped information on the Nation's landscape and land use. The Survey is the principal source of scientific and technical expertise in the earth sciences within the Department of the Interior and the Federal Government. The Survey's activities span a wide range of earth-science research and services in the fields of geology, hydrology, and cartography, and represent the continuing pursuit of the long-standing scientific missions of the Survey (USGS Yearbook 1983, n.p.).

The mission of the Water Resources Division, which supports the mission of the USGS and the U.S. Department of the Interior, is to develop and disseminate scientific knowledge and understanding of the Nation's water resources. The activities carried out by the Water Resources Division fall into three broad categories: (1) resource assessment; (2) research; and (3) coordinating the activities and cataloging the products of numerous other entities involved in water research, data acquisition, or information transfer.

Objectives of a GIS

This Water Resources Division is a data collection and research division. Its expertise is collecting data that it needs to analyze and map hydrologic information. The Division is concerned with surface- and ground-water resources of Oregon and Washington. It is also concerned with water resource issues elsewhere, and there is agency overlap with Oregon Department of Environmental Quality, Oregon Department of Water Resources, and the Bonneville Power Administration.

The agency acquired a GIS to spatially analyze the water resource information it gathers. The GIS can perform statistical analysis, produce map products, develop relationships based on spatial phenomena, and route through the data. Routing is the use of a GIS to spatially move up or down a stream network. This kind of work was once done by hand. With a GIS, staff can accumulate statistical information for analytical output for a report. The Water Resources Division also provides digital data for other agencies.

Implementation Stage

The Water Resources Division has used mainframe ARC/INFO run on SUN workstations and on a PRIME mainframe system for approximately five years. It is used for analysis and modeling, in addition to database management and map products. The Ground Water Group has developed a software interface between the GIS and a ground water model. This interface uses INFO to load the ground water model. Some data is updated weekly, while on other projects there is no updating because other users (other agencies) may update as their needs dictate.

This Division collects digital data for water resources -- surface and ground water, water

quality data, water use patterns, and climatic data. Data that is still desired includes: the public land survey, climatic data such as updated precipitation, solar radiation, evapo-transpiration, and fuller coverage of water rights data. Other data that is desired, but more difficult to portray due to their dynamic nature, are stream flow data and water quality changes.

Reasons for Choosing the GIS Software

In 1985, ARC/INFO was considered to be the superior GIS software. The USGS purchased it in 1987, and the Water Resources Division bought it at a very good price from the USGS. This software is very compatible with the in-house hardware. It possesses good analytical capabilities and good support which contribute to its fine reputation.

Satisfaction and Concerns with the GIS Overall

The Water Resources Division is satisfied with the GIS overall as an analytical tool, as is the USGS. Every office of the Water Resources Division nationwide has a GIS. They find that the GIS database is good. Overall, this Division is concerned with the reliability of answers from the GIS, and the time required to generate GIS products and analyses. Concerns are in the areas of personnel: high turnover of trained staff, difficulty finding trained staff, and communication with upper management. Agency area concerns are the lack of support from upper management, and too few workstations.

Satisfaction and Concerns with the GIS Platform

This Division is satisfied with the platform, yet, ARC/INFO does not work well on PRIME super mini-computers for the high number of users. The platform has weak computational performance. ARC/INFO is not user-friendly and is weak in its statistical capabilities. Attribute data is stored in INFO and it must be accessed into another statistical program. One must develop an interface, which is not the best way to get from point A to point Z.

Best Role of a GIS

Data acquisition requires a lot of time. Once data is in a digital form it is easy to update and revise. When the data layers are built, the GIS is best suited for monitoring. There is always some doubt when it is used for modeling -- the data in the GIS is only as good as the weakest data layer. The final analysis may look good, but will not necessarily be accurate. Many new kinds of questions can be addressed by the GIS. Boolean functions (another GIS analytical operation) allow the GIS to do analyses not easily accomplished by hand.

Recommendations for Better Utilization of a GIS

The source of the data must be accurate, and consistent. One must not assume that data acquired from other divisions or agencies is accurate. One of the big problems in the big picture of GIS use is giving the agencies all the tools inherent in the GIS, but with no direction of how best to take advantage of these tools. It leaves it up to the agency to discover how the tools fit together. It is very difficult for agencies to have all the necessary technical expertise, in-house,

to know best how to adapt the GIS software to specific uses and link it to modeling software. ARC/INFO is a toolbox approach software. Due to its complexity and flexibility, ARC/INFO is not user-friendly. It therefore calls for the development of some standardized "cookbooks" -- commands, steps, and procedural guidelines for standard applications and the expected results. These kinds of procedures can help address the problem of manipulating the data layers to death, which can result in lost time and accuracy. The software vendor could send a sample of a specific application, for example, surface water models, with implementation steps and expected results. There is definitely the need for a standard methodology of specific applications. The vendors could consult with different agencies who have similar roles and concerns, in order to develop specific modules that deal with specific models.

Communication Using a GIS

A GIS is effective at producing visual interpretations of data in the form of map products. At the Water Resources Division, the products are used to communicate within the agency, with other agencies, and with the public. The main emphasis is not on trying to affect natural resource policy, but to use GIS map products for demonstrations, at meetings, and to provide information to other agencies.

State Agencies

Oregon Department of Environmental Quality, Portland, Oregon

Interviewed Doug Terra, Cartographer, of the Water Quality Division, Standards and

Assessments Department. He has been at the current position since June 1988 and has used the current GIS for two years.

Mission Statement

Unlike other agencies, the Oregon Department of Environmental Quality has no jurisdiction over lands, but does have administrative functions over resource use. The OR DEQ deals with environmental problems such as groundwater, surface water, air quality, hazardous waste management, and noise. The OR DEQ has six divisions including hazardous waste, air quality, environmental clean-up, administration, and water quality.

The OR DEQ is involved in several water quality projects. They are in the process of establishing total maximum daily loads (TMDL), a measurement of the total amount of pollution, on waters of the state which have been designated as "water quality limited (OR DEQ 1990, 5-107)." The OR DEQ also "reviews water quality standards contained in Oregon Administrative Rule, Ch. 340, Rule 41 to revise them as necessary, based on updated information, to assure that beneficial uses are protected (OR DEQ 1990, 5-115)." The OR DEQ assists the Columbia River Estuary Study Task Force and the Research Planning Institute in updating the Columbia River Oil Spill Contingency Plan, a document originally produced by DEQ in 1979 (OR DEQ 1990, 5-116). The DEQ is also involved in fulfilling Sections 401 and 404 of the Clean Water Act by requiring all permits to meet state water quality standards. The Clean Water Act requires that an applicant for a federal license or permit involving an activity which causes discharge into waters of the state, including wetlands, obtain a state certification that such a discharge will meet state water quality requirements. This is a 401 certification and includes dredge and fill activities, and hydroelectric activities.

The Oregon DEQ Water Quality Division mission is to "protect the recognized beneficial uses of Oregon's water resources by maintaining and enhancing the quality of its surface and groundwater. In accomplishing this mission, Department staff are directed to use available resources efficiently and effectively (Lilliquist et al. 1989, 3)."

The Oregon Clean Water Strategy is a project coordinated with the EPA, to encourage a comprehensive, geographic approach to improving and protecting water quality. Its goal is to integrate existing water quality programs with new responsibilities specified in the Water Quality Act of 1987, such as non-point source pollution and surface water toxics problems. Its purpose is to enable the DEQ to target limited resources to maximize environmental benefits by dealing with the most serious water quality problems affecting the most valuable resources first (Lilliquist et al. 1989, 35). The strategy will enable the agency to establish priorities for the water quality program, and guide agency decisions over the next several years (OR DEQ 1990, 5-110, 5-113, 5-115).

Objectives of a GIS

The GIS is used for a section-specific need and was acquired because funding was available from the Groundwater Section of the OR DEQ. Within the Water Quality Section, it is used by the Surface Water Standards and Assessments Section for: (1) use for a state-wide non-point source pollution assessment in 1988; and (2) the Oregon Clean Water Strategy, July 1989.

Oregon is the first state to develop a clean water strategy based upon GIS-aided assessment. A goal of GIS use was to bring together diverse information in different formats to enhance proper project management (OR DEQ 1990, 5-110, 5-114). It is used for input into

decision- and policy-making concerning the allocation of limited resources. The OR DEQ uses its GIS generated information to try to influence other state, federal, county and city agencies to follow OR DEQ guidelines. This is the unusual case of a state agency mandating standards to smaller agencies and also to federal agencies.

Implementation Stage

The Water Quality Division has used mainframe and pc ARC/INFO for two years. It is now being considered for the other OR DEQ Divisions. It is used on a project-by-project basis for every stage and type of GIS capability -- building the database, manipulation and analysis of digital spatial and attribute data, modeling, and map products.

Oregon chose to utilize its new ARC/INFO GIS to handle material collected for the Oregon State Clean Water Strategy. In developing the Strategy, existing water quality assessments and lists were combined with information from a variety of other sources using the GIS. All of the information was linked to EPA River Reach Segments and then priorities set (OR DEQ 1990, 5-114, 5-115).

This Division collects data on water resources, hydrology, water quality, climate, vegetation, fishery resources, wetland areas, soils, and air quality. The Division would like more digital data for the public land survey and for wetlands. It is also desired that the GIS be used to integrate reports, for example, a spatial library query where one looks up an area and can see the environmental concerns and data pertaining to that area. Updates are scheduled for every two years for non-point source water pollution, which is the main area of concern of the Division at this point.

Reasons for Choosing the GIS Software

Mainframe and pc ARC/INFO were chosen primarily for inter-agency cooperation and compatibility. It is compatible with the GIS Service Center located at the OR Department of Energy. It also runs on the appropriate hardware at the OR DEQ.

Satisfaction and Concerns with the GIS Overall

The Division is excited and interested in application of a GIS, and finds the GIS products to be very useful. There are several areas of concern. Funding of personnel is difficult to get. The emphasis of using temporary employees exacerbates the problem of finding and keeping trained staff. The cost of data acquisition and pre-processing is a high up-front cost of using a GIS. This includes both converting data to a digital form and converting one digital format to the ARC/INFO compatible digital format. There is some duplication of effort within the agency. It is an issue of funding and communication with upper management. Within the agency, the cost of the GIS platform and GIS personnel is not shared. There are high expectations of the GIS from the Information Services Section of the Division of Management Services. There is concern about the role and importance of the GIS within the big picture of data reliability.

Satisfaction and Concerns with the GIS Platform

The Water Quality Division is not fully satisfied with the platform. There are problems with the hardware in the areas of storage space and speed. ARC/INFO is not user-friendly, and for the high price many problems should have been corrected. Often times, bugs are not fixed

and the vendor gives little hardware advice. The database part of ARC/INFO, INFO is old technology for relational databases, and its links to other databases are weak. pcARC/INFO is also not multi-tasking, and its analytical capabilities need to be strengthened.

Best Role of a GIS

A GIS is especially suited for input to models and output from models. At this point there is no real modeling in a GIS. Spatial and probability models can do overlays and feed into statistical models.

The GIS has enabled this Division to not only answer old questions faster, more accurately, and display the appropriate information clearly, but also to answer new types of questions. The Division is concerned about the role and importance of the GIS within the big picture of environmental data management, and how to address issues of reliability of data and scale problems.

Recommendations for Better Utilization of a GIS

A GIS requires a lot of time and money, not only for data acquisition, but also to fund trained staff, and upper management needs to understand the situation. Building user interfaces that never get used is a problem. Managers do not want to get involved in the daily tasks of GIS use -- they want GIS products. The tool-kit approach of ARC/INFO is a concern because every user must learn every tool in order to know how to use it. There is a steep learning curve for ARC/INFO, and most personnel are weak in the area of designing databases and other computer programming. For the agency, a program should be written where the toolbox is used to create

a standard application program. It would consist of standard menus and procedures. This could avoid the problem of lack of user-friendliness.

Communication Using a GIS

The use of a GIS has improved this Department's ability to communicate and generate support. A GIS integrates people across "turf" boundaries. It communicates effectively to the public, within the agency, and with other agencies.

Oregon Department of Water Resources, Salem, Oregon

Interviewed Mike Ciscell, who has been at the present position for four months. He worked previously at the Idaho Department of Water Resources. The OR Department of Water Resources has used the current GIS software for three years.

Mission Statement

The Oregon Department of Water Resources is mandated to map water rights, points of water diversion, and places of water use throughout the state. This agency supports the Basin Planning Team, whose role is to develop digital data layers and coordinate with various agencies. They coordinate with dialogue concerning plans, in order to eliminate conflicts between agencies, and collect digital data from various agencies. The Oregon Department of Water Resources is concerned with the water ways of Oregon, the quantity of water resources, and where and how water is used.

Objectives of a GIS

This agency acquired a GIS to meet several objectives. The GIS will be used to map water rights into a digital format. It will also be used to update water rights ownership. This involves digitizing tax lot information acquired from other agencies (local and county) and overlaying this information with water rights data. The objective is the ease with which such a water rights system can be updated using a GIS. The GIS will also be used to model water availability. The GIS was not acquired primarily for planning.

Implementation Stage

Approximately 10% of the desired base data layer information has been acquired and converted to a digital format. That 10% has been manipulated for analyses and GIS hard copy products, mostly maps. The GIS is used for database management. It is also used as an analytical tool for water basin planning, and for overlays of water rights with tax lot information.

The agency has used mainframe ARC/INFO for three years and plans to use it for mapping water rights and for water basin planning. This agency plans to update water rights information every six months and update hydrologic information as it becomes available to the agency.

The agency collects data pertaining to water resources, wilderness areas, fishery resources, wetland areas, and water rights. Data that is still desired for some areas are water rights, hydrography, land ownership, and land use and management status. Some data are difficult to represent due to spatial distribution or fluctuation with time. These are tax lot information, parcel ownership which needs updates in a timely fashion, and stream flow information, which changes

throughout the year.

Reasons for Choosing the GIS Software

ARC/INFO has a good reputation, and good support from ESRI, the company that produces it. It is suited for the needs of this agency and is user-friendly. In addition to its high quality of map products, it is capable of a variety of analytical functions.

Satisfaction and Concerns with the GIS Overall

Despite the fact that this agency is in the beginning stages of implementation, the agency is satisfied so far with the GIS overall. Data availability is always a problem, as is the time required to acquire and convert data into an appropriate digital form. Data such as stream flow, water rights, and land ownership all change with time and are difficult to acquire. Therefore, the integrity and completeness of the database is an area this agency is concerned with and working on.

It is also difficult to find staff trained in both natural resource management and with a GIS background. Despite the fact that there is some duplication of effort with other agencies, there is good inter-agency cooperation due to the State Mapping Advisory Counsel (SMAC). Everyone knows that a GIS is an expensive investment and is very time-consuming, especially in the beginning stages of implementation. There is some activity among the regional offices of this agency with little communication, at times, about these activities. Overall, there is good support from and communication with, upper management and between the regional offices.

Satisfaction and Concerns with the GIS Platform

The Oregon Department of Water Resources is satisfied overall with the GIS platform. Concerns include the ability of the VAX mainframe to handle and process large amounts of information quickly. The software does contain some "bugs" - error messages popping up with no description of the problem. Frequently such problems are not fixed until the next software update.

Best Role of a GIS

The GIS is capable of many different functions, and is ideally suited for modeling and analysis. The use of a GIS has enabled the Oregon Department of Water Resources to be able to accomplish many of its original tasks more quickly, and with higher quality, clear output products.

Recommendations for Better Utilization of a GIS

In the area of data acquisition, the data needs to be accurate and up-to-date. A standardized digital data format could help because it would allow attribute information to be transferred between different software programs easily and still be understandable. The issue of quality control could also be addressed by such standard formats and data acquisition standards.

The GIS user community could produce a monthly data clearinghouse documenting agencies' GIS activities. This could help reduce any duplication of effort among different agencies and enhance inter-agency cooperation. Agencies need dedicated GIS personnel, not a

natural resource person who does GIS part-time. Many agencies are under-funded in this aspect.

Communication Using a GIS

A GIS is an effective tool for communicating to the public, other agencies, or within the agency. Its map products are clear. This agency is at a stage of using its GIS as a data entry tool but will emphasize the use of the GIS for communication with the public in the future.

Oregon Department of Energy, State GIS Service Center, Salem, Oregon

Interviewed Scott Smith, the manager for the GIS service center. He has been at the present position for four years and has used the current GIS since Fall 1985.

Mission Statement

The objectives of the GIS Service Center are to: (1) provide GIS work for agencies that do not have their own GIS; (2) to encourage coordination between agencies for cost sharing, to reduce duplication of effort, to be a data broker, for example, for the regional index of GIS use for the Northwest Land Information System Network users group, and to negotiate contracts for GIS work; and (3) to act as a digital map library for statewide data layers, for data that does not necessarily have a particular home in any one agency. For example, elevation data has no home agency. The GIS Service Center is concerned with statewide digital data from all kinds of agencies and groups: governmental, non-governmental, private companies, non-profit groups, and universities. The GIS Service Center collects data on water resources, wildlife habitat, wilderness

areas, fishery resources, vegetation resources, endangered species, wetland areas, soils, and other data.

Objectives of a GIS

The Oregon Department of Energy, and the Department of Land Conservation and Development, began testing and using a new type of computer mapping system in 1983. This system was used to study potential impacts to coastal areas from energy development, and to analyze estuary zoning issues (SMAC 1990, ii). The objectives of GIS use have changed and focused since that early beginning.

Today, resource policy issues are more complex and it has become more important for agencies to have access to complete, current, and accurate geographic information. The new technology has enabled the use of a GIS to respond to such a need and to minimize duplication of effort and expense between different agencies (SMAC 1990, ii).

There are many goals of the State Service Center GIS. Digital base map layers for a statewide digital base map library are being created at the Service Center (SMAC 1990, 3,7). GIS data acquisition at the Service Center will focus on making cooperative projects with other agencies easier. State agencies' decision-makers will have access to base map data from the Service Center, yet, those agencies will have independence in the use of this data (SMAC 1990, 1). Another objective of the GIS is to make sure that this data, which is available to other agencies, is up-to-date, scale-appropriate, and conforms to data standards set up by the SMAC (SMAC 1990, 1,3). This data will be available at scales ranging from 1:100,000 to 1:2,000,000 for layers such as the public land survey grid, transportation, surface hydrology, boundaries, land ownership, terrain, geographic names, soils, wetlands, demographics, land features, land use, and

zoning, among others. Availability will range from 1991-1995, and different agencies will be responsible for input of base data at 1:24,000 or larger scale into the statewide digital base map library (SMAC 1990, 7-8). In time, the installation of an image processing system for the State Service Center GIS will enable users to see mapped data in an actual three-dimensional landscape to improve the utility of the data (SMAC 1990, 13). The State Service Center will provide data base and management system development services. These range from simple digitizing to complex, menu-driven data management systems, provided to other local, state, and federal agencies for a fee, after evaluation of project conformity to SMAC GIS Plan guidelines, objectives, and goals (SMAC 1990, 10,16).

Implementation Stage

In 1983, the OR DOE was involved in an Oregon coastal energy impact program. The Service Center concept was born out of this initial cost-share project. It provided support to Oregon Department of Land Conservation and Development (DLCD), who did not have a GIS. Instead of hiring a consultant, DLCD jumped in and did it. Both agencies were interested in using a GIS for two perspectives: coastal energy development, and coastal zone management of seventeen estuary areas.

Other agencies saw the value of a Service Center and cost sharing. The State Service Center did several large projects that received a great deal of attention. In addition to mapping seventeen estuary areas for DLCD, a statewide non-point source water pollution study was completed for the Oregon Department of Environmental Quality, and a GIS for the Columbia River Gorge National Recreation Area was implemented, among other projects.

The goal of the State Service Center is to help the client build a database, train them to

use the GIS, and then back off and let them take responsibility of the GIS. In some cases, the State Service Center does do some GIS modeling and analysis for agencies. For example, they assisted with modeling and analysis to help the Forest Service develop land use designations for the Columbia River Gorge National Recreation Area. The State Service Center has been involved in all stages of GIS implementation: building databases, inventory, analysis, modeling, and generation of GIS map products, depending upon the needs of clients and at what stage the client takes over GIS use.

For many clients there is a real desire for base layers such as transportation, the public land survey system, elevation, and hydrography. There is also the desire for satellite imagery to be integrated into a state-wide database. Land ownership changes frequently and is difficult to represent spatially. The overwhelming number of zip codes are difficult to represent spatially. The State Service Center would like to see digital data be compiled into a map library.

Reasons for Choosing the GIS Software

The State Service Center uses mainframe, workstation, and pcARC/INFO. ARC/INFO was chosen for several reasons. The software is structured as a set of modules which can be combined. This provides the user with flexibility. A menu can be written to ride over the different tools and how they interact together. ARC/INFO has a good reputation and good support, along with strong analytical capabilities.

Satisfaction and Concerns with the GIS Overall

The Service Center is very satisfied with the GIS overall. Areas of concern include: the

high turnover of trained staff, difficulty finding trained staff at the right price, funding, and the cost of acquiring data. Universities do not teach graduates how to implement and follow through a GIS project. Training is most effective on the job. It takes a year to become fully trained, but often staff turnover aggravates the problem. Funding is always an issue. The State Service Center runs on cost reimbursement, and therefore is impacted by other agencies' funding fluctuations.

Satisfaction and Concerns with the GIS Platform

The State Service Center is satisfied with the GIS platform. Concerns in hardware include: speed and cost. PCs are inherently slow and small, and the Center is phasing out the mainframe system because it is slow and expensive to maintain. Workstations are incredibly fast and store incredible amounts of information, but are expensive.

Areas of software concerns includes the cost and flexibility of the software as it relates to user-friendliness. It does require some time to learn ARC/INFO, but many people do not understand the relationship between flexibility of the software and user-friendliness. The more flexible the software, the more powerful yet complex, and therefore less user-friendly. The approach of ARC/INFO is a toolbox approach, and it performs very well. Tools can be re-arranged for every different set of circumstances and needs. The Service Center prefers to have the flexibility because each project is different with different needs, and thus requires different combinations of tools. The cost of ARC/INFO is high, especially for each workstation it runs on. Each one must have a license based on CPU; one separate individual license must be paid for each CPU.

Best Role of a GIS

The GIS enables managers to answer many new questions in new ways. It has the ability to deal with huge amounts of data. One cannot map and manually log so much information. Managers can now ask new questions not asked before. They are "not doing the same old thing faster, but doing different things."

If GIS were used just for monitoring one would just get a good DBase program, unless it is a huge task such as DLCD tracking down land use change. GIS functions for many different tasks, depending upon who is using it. In the 1990s, several issues will dominate the actions of agencies in Oregon. Air, water, and land pollution will require analytical models in order for agencies to deal with these environmental problems, among others. Agencies need to stop being reactive (monitoring) and become proactive, and a GIS is instrumental for such modeling and analysis.

Recommendations for Better Utilization of a GIS

The source of data needs to be accurate, up-to-date, and with consistent data standards. There is the need to make better use of two technologies: satellite imagery and global positioning systems. This combination can improve the quality of data, and its locational accuracy. Cooperation is not the biggest challenge. Agencies are talking to each other, and database merging is being addressed in the State GIS Plan by the State GIS Administrator. The biggest challenge is data acquisition. Getting data in a timely manner that is accurate, at a proper scale, and in a format that everyone can understand is necessary, and data dictionaries are a must. Agencies can use GIS models to help them manage natural resources within environmental

constraints. Whether or not they do so is dependent upon politics.

Technology has increased dramatically over the past 20 years. At one time, information was organized into data tables which then progressed to two-dimensional maps. Today, one can drape two-dimensional maps onto three-dimensional models. In the future, textures can be changed through animation to produce a true three-dimensional scene. Eventually, the technology will advance to a point where one can actually experience a scene. The focus of GIS use has already moved away from graphics, and more emphasis is being placed on moving attributes. Within the next 5-10 years, GIS use will move away from two-dimensional maps. In the next five years, the technology will enable one to actually see a particular site with its changes resulting from a particular set of policies that are proposed. One will not perceive this with a GIS map but will perceive a scene through a viewer -- technology that is an offshoot of today's flight simulators. In another ten years, one may be able to actually experience the scene through a virtual reality system by putting on a suit and goggles.

Communication Using a GIS

A GIS can help one to visualize data -- a tremendous value. In state government, there is a lot of jargon. To possess the ability to show a GIS map product can help everyone understand issues better. It is an excellent aid to show relationships between datasets. Different agencies can display information, yet, politics still plays a major part in management and policy decisions. Possibly, the use of a GIS can actually work against those who do not have access to the technology. Those without access may not be able to challenge decisions based upon GIS analyses without acquiring their own GIS and the same data upon which such agency decisions were made. This potential problem may deflate the stall tactics often used by environmental

groups until such groups get their own systems. Information access is a valuable commodity. Any special interest group is going to have to gear up if they want to play the game. With 30-60 day deadlines for public and agency review of state and federal initiatives, they cannot check results of state agencies' analyses manually.

The future connection between modeling capabilities and visualization capabilities has enormous implications, and not just for natural resource management. Politicians, or whoever is involved, can experience the scene and different management alternatives without even visiting the site. One can collect the scene digitally right now by satellite imagery. For civilian satellites, the resolution is down to 1/4 acre, and only time is required to get access to defense industry technology. Eventually one must ask: are environmental issues national security issues? If one party can detect that a particular natural resource is scarce through the use of satellite imagery, they could cut supplies off for political reasons.

CHAPTER V

ISSUES IN IMPLEMENTING GIS TECHNOLOGY

Introduction

Chapter I introduced the subject of GIS use for natural resource and environmental management. Chapter II began an investigation of the definition of successful GIS use. This process requires looking at the issues and barriers to effective implementation. The underlying factor to all of the issues, which is rarely mentioned in GIS literature, is the relationship between expectations and perception. More specifically, this thesis establishes that GIS technology has been viewed inaccurately and unrealistic expectations have resulted. The consequence of those unrealistic expectations is dissatisfaction and disillusionment with GIS technology. This may result in abandonment of GIS technology, loss of time, money, and energy.

Perception of GIS technology, as an issue, is important because it underlies many of the other, more recognizable barriers for GIS use. Those barriers must be mitigated. Therefore, perception must change to offset further losses from failures in implementing GIS technology, and for GIS to achieve its full potential as a tool in decision-making.

With that in mind, Chapter I introduced the goals and objectives of this thesis. Chapter II presented a brief background to GIS technology, especially the potential of GIS, to aid an understanding of the remaining chapters, and help establish the definition of successful

GIS use. Chapter III went on to describe a model of acquiring and implementing a GIS. By understanding that process, the reader can understand the issues better. The model can also explain when issues and barriers in the process may arise. This identification is important to help potential GIS users avoid such problems in future implementation.

Chapter III also described the methodology used in researching governmental agencies for this thesis. Establishing the commonality among the agencies' mandates, goals, activities, and spatial data needs allowed the survey results to be useful as a barometer of satisfaction with GIS technology. It is also a means of identifying and describing each manager's description of issues of concern, and how they view the technology. Chapter IV presented the results of that research for each agency surveyed.

The issues identified by the GIS managers can be consolidated. This chapter will define and describe those issues, and present them grouped into fifteen barriers in three different areas: institutional, economic, and technical areas. This delineation is based upon the similarities among the issues within each grouping. For each barrier, the following section will:

1. Describe the barrier
2. Describe where it may occur in the implementation process as outline in Chapter III
3. Characterize the agencies' responses
4. Connect those concerns to the perception issue
5. Make possible recommendations or areas of further research

The purpose is to describe the issues, identify which are most significant, identify where they occur in implementation, and show how they reflect incorrect perception of GIS technology and its use. Describing such current perceptions is a means to changing perception

constructively for better GIS implementation and use.

Issues

Figure 3 presents a matrix of agencies and the concerns of the GIS managers from each. The issues that concern GIS managers can be broken down into institutional, technical, and economic barriers to GIS implementation and use (Dueker 1987, 1361-1365). Certain barriers are more significant to GIS managers than others and patterns arise in their responses. These more significant issues will be discussed in more detail later in this chapter. There is overlap between the different barriers but the following section will group these into five sets of barriers within each of the three areas. Though this breakdown is necessarily artificial, it will help to present the issues in a logical manner to help understand these barriers. Each will have a number representing its position in the matrix in figure 3 for easy reference.

Institutional Barriers

Institutional barriers are those that result from the organizational behavior of governmental agencies. This behavior is essentially the procedures and methods of handling spatial data, of sharing data between departments and among agencies, the ways upper management communicates goals throughout the agency, and characteristics of communication among agency divisions. It also includes the procedures for acquiring and training staff, for educating employees, how the agency is structured with respect to work procedures and work flow among departments and employees. Behavior is also a function of economic characteristics such as agency budgets, funding methods, the way agencies perform cost/benefit

BARRIER		U. S. A. C. E.	U. S. D. E. B. P. A.	U. S. D. I. B. I. A.	U. S. D. I. B. L. M.	U. S. E. P. A.	U. S. F. S. Reg. 6	U. S. F. S. Mt. Hood	U. S. F. S. Col. Riv.	U. S. F. S. Siu- slaw	U. S. F. S. Wil- la mete	U. S. D. A. Soil Cons Serv	U. S. G. S. Water Res.	OR D. E. Q.	OR Dept Wat. Res.	OR Dept En- ery	T O T A L
I-1	Expectations	X			X	X		X	X	X	X	X		X			9
I-2	Naivety	X			X	X	X	X	X	X	X	X	X	X			11
I-3	Cooperation							X			X						2
I-4	GIS Knowledge	X	X		X		X		X		X						6
I-5	GIS Direction	X	X			X	X				X	X	X		X		8
I-6	GIS Politics	X	X								X						3
I-7	Duplication of Effort					X		X			X			X	X		5
I-8	Data Standards		X		X		X	X				X				X	6
I-9	Data Availabil- ity		X							X					X	X	4
I-10	Staff Training	X			X	X	X	X		X	X					X	8
I-11	Find, Keep Staff		X	X			X	X	X	X	X		X	X	X	X	11
T-1	Data Quality		X	X							X		X		X	X	6
T-2	Analyses' Validity				X								X				2
T-3	Satellite, GPS		X					X								X	3
T-4	Software ease of use	X		X	X		X		X	X	X		X	X		X	10
T-5	Software Integrity				X	X		X	X		X			X	X		7
T-6	Software Capabilities	X	X		X	X	X	X		X	X	X	X	X			11
T-7	Hardware Storage		X							X		X		X			4
T-8	Hardware Speed		X		X			X		X		X	X	X	X	X	9
T-9	Hardware Other	X			X			X		X			X				5
T-10	Vendor Support	X									X	X		X			4
T-11	Platform Capabilities	X									X	X		X			4
E-1	Cost GIS overall	X			X						X	X				X	5
E-2	Cost Hardware					X			X							X	3
E-3	Cost Power, Storage		X			X	X	X								X	5
E-4	Cost Staff, Training				X							X		X	X	X	5
E-5	Cost Data Acquisition	X	X	X	X	X	X		X		X	X	X	X	X	X	13
E-6	Cost Sharing	X												X		X	3
E-7	Cost Software-Other										X					X	2

Figure 3: GIS managers' concerns in implementing GIS technology

analyses, and incentives and penalties that affect employees.

Expectations (I-1), Upper Management Naivety (I-2), and GIS Knowledge (I-4)

Description

The barriers of expectations includes: the anticipation of certain services and products from a GIS -- usually from upper management or from other divisions, the expectation soon of a certain amount of analyses or map products and for a certain level of validity for these capabilities and products, high expectations for the GIS to help solve agency problems in the activities they engage in and the resources they manage. Upper management naivety includes: a lack of proper perception of GIS technology including a lack of awareness of the level of funding required for GIS use including software, hardware, staffing, and data acquisition costs, a lack of awareness of the time required for many GIS functions, problems in communication breakdown between upper management and departments or among departments, an unrealistic focus on and demand for map products versus focus on analytical capabilities, and misunderstanding concerning the role of GIS in an agency. Problems concerning GIS knowledge within an agency include, a lack of understanding which is usually gained through study or experience with GIS technology, and a deficiency in education about the costs, benefits, limitations, and capabilities of GIS technology. Problems with the level of GIS knowledge may affect other agency divisions and sections who want GIS products but don't work directly with the GIS. This issue may also be the desire, on the part of GIS managers, for better GIS education all around.

Occurrence in the Implementation Process

As stated in Chapter III, GIS education may be started at several stages in the implementation process. It's not so much when it occurs as having agency personnel educated to the appropriate degree. Education occurs in Stage 1, at a very general level with the objective of demonstrating GIS technology: what it is, how it's used, costs and benefits. More vital is strategic education and training during the implementation stage (Stage 4) of developing the database, and implementing changes in operational procedures and in institutional characteristics such as in work load and flow. It is more important later in implementation to have very detailed training for those using the system, in addition to education of all those who desire to use the GIS products.

Agencies' Responses

These are obviously areas of great concern. Out of fifteen agencies, expectations was mentioned nine times, upper management naivety was mentioned eleven times, and GIS knowledge deficiencies were mentioned six times.

Relation to Perception

Of all of the barriers, these are the ones that pertain most to the perception of GIS technology. Proper perception is essentially becoming aware of, and correctly understanding GIS technology. This can only be gained through study and experience. Antenucci states that there is a "temptation...to buy a system, build a database on the fly, and get started. Many

systems are launched with little planning, little design, and great expectations (Antenucci et al. 1991, 214)." It is obvious in surveying these agencies that proper perception has not yet been gained by most personnel who are involved in GIS use within many agencies.

Recommendations

These three related barriers most likely result from two factors. As stated in earlier chapters, one factor is human nature. It is the desire for a quick and easy answer. With today's pressures on these agencies for both better response time and decision-making, it's easy to understand the natural tendency to jump on the GIS bandwagon with less preparation and thought than is required. It is not even a purposeful omission, only the natural outcome of the stage of maturity for the technology at this time. Secondly, the fast pace of technological change makes it difficult to keep up with such change in both GIS knowledge and GIS application. Just as agencies are understanding the capabilities available in GIS technology and the problems involved in GIS use, the technology changes and issues may also change. That is the very nature of changing technology which is so representative of this information age.

Several recommendations are made by the GIS managers surveyed. The GIS manager from the US Army Corps of Engineers suggests that managers become more involved in GIS use and in GIS conferences. He also suggests a GIS clearinghouse and meetings to of document all other agencies' GIS activities so that all can learn from others' experiences. The GIS manager from BPA states that natural resource professionals need to recognize the capabilities and power of a GIS as a tool, and that it needs to be integrated into the day-to-day work, be accessible, and be easy to use. The GIS manager from the BLM stresses the

importance of viewing GIS as a tool, not as an answer to resource management. Several managers state that upper management needs to focus less on map products and more on GIS analyses. GIS awareness includes not only education about the capabilities of GIS technology, but also the cost, according to the USFS Columbia River Gorge's GIS manager. He adds that overall commitment is required that includes incorporating GIS technology into the day-to-day workings of the agency. The Siuslaw National Forest's GIS manager believes that better understanding begins at the university level with the incorporation of GIS into academic programs for natural resource students.

Changing expectations and perceptions is key to better use of GIS technology. Change does not come easily, especially for those agencies which are larger. A certain degree of tension and disillusionment about GIS technology is necessary to drive change and eliminate some of the barriers examined here. Expectations and perception will be discussed in more detail later in this chapter.

Inter-departmental and Inter-agency Cooperation (I-3), Politics of GIS Use (I-6)

Description

When inter-agency cooperation is mentioned, GIS managers are referring to the lack of coordination toward a common purpose. That purpose may be the goal of sharing data among agencies. It may also include overall GIS direction when several departments or agencies engage in joint GIS projects, such as the Oregon State GIS Plan (mentioned in Chapter IV). The politics of GIS use involves the methods or tactics involved in managing an agency or department, the intrigue and maneuvering within a group of workers, including tension among

users or between different offices engaging in "turf battles" over roles, responsibilities, and ownership of data.

Occurrence in the Implementation Process

Inter-agency cooperation is essential when agencies are involved in a joint GIS project, or when one agency may require spatial data from another in the database development stage of GIS implementation. Increasingly, governmental agencies are engaging in joint projects where each participant contributes finances, personnel, and time toward the common goal of implementing a GIS to benefit all the involved parties. This kind of cooperation is more common as pressures increase and budgets decrease and will be discussed in more detail later in this chapter. Inter-departmental cooperation is similar, and in large agencies may feel similar to dealings between different agencies.

Cooperation among agencies or departments is also vital when only spatial data is acquired and shared between parties. This issue arises at Stage 4, the development stage of implementation, when the database is being built and developed. Cooperation at this point is obviously important since data quality is key to successful GIS use and is the most costly aspect. Cooperation is key in projects that range from agencies who are only sharing data for GIS database development, to multiparticipant GIS projects involving many different users, agencies, and the diverse data their activities requires.

Agencies' Responses

In this survey, these were not barriers that concerned GIS managers most. These

issues are discussed early in this chapter not in order of importance to the surveyed GIS managers, but corresponding to where they appear in figure 3. The barriers of lack of cooperation and the politics of GIS use warranted only a few responses from the surveyed GIS managers. Lack of inter-agency or inter-departmental cooperation was mentioned twice and the politics of GIS use was mentioned three times. As mentioned earlier, unrealistic expectations of GIS use, lack of GIS knowledge, and related issues were of much greater concern. Later in this chapter, it will be demonstrated that other barriers are also of greater concern to the surveyed GIS managers.

Relation to Perception

The lack of cooperation is probably most common between different departments since most of the GIS managers surveyed are involved in single agency GIS projects. These barriers likely result from mis-communication and lack of education about the benefits of cooperation, in addition to institutional characteristics which contribute to such behavior. These institutional characteristics include the fact that all departments or agencies do not take an active role in GIS use unless they are specifically mandated to do so or work directly with the GIS. Institutional change is necessary for these institutional behaviors to change. As stated earlier, institutional change is difficult. People are used to working in the ways they have always worked. Key to successful GIS use is changing institutional procedures so that GIS technology becomes integral to everyday operations. This requires that people perceive their part in GIS use in a new way. This will also be explained in more detail later in this chapter.

Recommendations

Few GIS managers made recommendations on the areas of cooperation and agency politics. The USACE GIS manager states that inter-agency cooperation is not an easy task. It is not within each department's or each individual's job description to participate in GIS meetings between agencies. He goes on to state that if it can be shown to be worthwhile, agencies can get more personnel involved in GIS and better application of a GIS as a planning tool. The Forest Service Region Six GIS manager stated that cooperation can be enhanced by the development of data standards: information definitions that are commonly agreed upon to facilitate the exchange, standardization, and quality of digital data.

Again, the best recommendation to address cooperation and agency politics is education, training, and institutional change. This can take the form of meetings and also task groups who meet regularly who represent different divisions, departments, or agencies. For example, these task groups could be legally mandated with statewide GIS activities and responsibilities directed by one central committee with representatives from many different backgrounds and concerns about GIS use. Task groups can give direction to different departments or agencies regarding GIS roles, responsibilities, duties, and contributing resources of time, personnel, and funding. The essential element of institutional change is the realization that cooperation is necessary and benefits everyone, and that everyone must be involved across departmental and institutional boundaries.

GIS Direction (I-5), Duplication of Effort (I-7)

Description

GIS direction includes a lack of management, supervision, or guidance of an action or operation within or between agencies. It also includes a lack of documentation of GIS activities of different agencies, a lack of a central clearinghouse of available digital data available, agencies not knowing what data they need and how to use it, and a lack of direction in overall GIS use or in the use of the GIS tools. Agency personnel often lack a "clear vision of the role of GIS within the organization (Antenucci et al. 1991, 211)" which may result in inadequate institutional support for GIS use. Lack of a clear and adequate direction of GIS projects may result from a deficiency in institutional changes in procedures which are required to integrate GIS into decision-making and work flow (Antenucci et al. 1991, 213).

Duplication of effort results when different departments or agencies perform the same work done previously or simultaneously by others. It includes both duplication within and between agencies, and may result from miscommunication or lack of communication. It is directly related to lack of appropriate GIS direction. Strong direction from a GIS task team or some other agency-directing body can eliminate duplication of effort. Clear direction results from clear vision, goals, and objectives of GIS use, and when that direction is properly communicated and administered to all involved in the GIS project.

Occurrence in the Implementation Process

The lack of GIS direction can occur at all points in the process. In the past, many

agencies have acquired a GIS with little thought or planning. Within the model for implementation, direction is key at all points but probably most important at the early stages and in developing a final implementation plan (Stage 4: Development). The implementation plan includes the institutional changes, more specifically, new and different operating procedures for GIS use. GIS use will change the way the agency does business, and clear direction must work toward the best use of the technology.

Agencies' Responses

Eight GIS managers mentioned problems in GIS direction, while five mentioned duplication of effort. As stated earlier, these two barriers are closely related. Duplication of effort can result from lack of, or inadequate direction in GIS use. This lack may be on the part of the department, team, or advisory board in charge of GIS implementation.

Relation to Perception

In addition to unrealistic expectations, the lack of direction in implementing a GIS is a main contributor to barriers to effective GIS use. Both are the result of incorrect or even non-existent perceptions of GIS capabilities. Lack of direction is also an institutional problem often inherent to the structure of the agency itself. According to Antenucci, "the extent to which an organization succeeds in altering its procedures and work flow has a direct bearing on whether the technology will be integrated and the organization will reap its benefits (Antenucci et al. 1991, 213)." It seems to follow that institutional changes are necessary for GIS direction to be properly administered and carried out through an agency.

Recommendations

The GIS manager from BPA stated that a GIS needs to become integrated into the day-to-day work of an agency. The GIS manager from the BLM added that the best way to come up with procedural changes is to prototype procedures through use of a pilot study. The manager from EPA's lab states that duplication of effort must be avoided, especially for financial savings. The manager from the SCS believed that to avoid duplication of effort, spatial digital data transfer standards must be designed and adhered to. GIS direction is important, according to the USGS Water Resource GIS manager. It's not just giving agencies the tools inherent to a GIS but giving them direction as to how best adapt the GIS software to particular problems and applications. The OR Dept. of Water Resources GIS manager stated that a monthly data clearinghouse documenting agencies' GIS projects can help reduce duplication of effort among different agencies.

Cooperation between agencies is most often enhanced by user groups and other kinds of inter-agency committees. In Oregon, communication has been enhanced by the State Mapping Advisory Council (SMAC). Formed by executive order, with members appointed by the Governor, its function is to coordinate mapping activities in Oregon. They have developed a GIS plan to "ensure the best use of state financial and personnel resources as a system is built to meet resource management needs of the 1990s." This plan is meant to coordinate mapping activities in Oregon, and to provide a plan and timetable for the development of an integrated GIS (SMAC 1990, 1). The major implementation center is the GIS Service Center (located at Oregon Dept. of Energy). Their goal statement is as follows:

To assure that Oregon's public sector decision-makers and other users have complete, timely, accurate and reliable information to use when addressing problems and making plans for the state's natural resources, human population, economic and recreation activities (SMAC 1990, 1).

These goals are important, since it is expected that by 1995, most state agencies will have some GIS capability (SMAC 1990, 1). The GIS Service Center acts as Data Administrator, service group, trainer, and consultant to help state agencies.

A federal-state coordinating group, the Northwest Land Information System Network (NWLISN), consists of approximately 20 agencies. It addresses the problem of data standard guidelines and cooperation among agencies. This is achieved through one of the NWLIS activities, the development of a computerized index of digital maps and data to encourage sharing and alleviate duplication of effort (SMAC 1990, 6).

User groups and committees are fine for addressing problems in GIS direction but the future may require more drastic means of achieving successful GIS use. Integrating GIS technology into agency activities is directly the result of the quality of GIS direction. GIS needs to be an integral part of agency activities instead of just an outside activity. This requires more than good managers carrying out the usual work. It requires agency managers to rethink agency procedures, and design changes that will integrate GIS into day-to-day operations. According to the Willamette National Forest GIS manager, agencies must change traditional methods of handling information. Instead of building databases simultaneously for different functional needs, agencies need to get everyone to cooperate and share their information and not have turf battles. The idea of institutional change is not enough. This kind of institutional change is difficult. It requires people with a vision for change that transforms and a leadership style that motivates that change despite the institutional behaviors and momentum that discourages change. The difficulty of institutional change will be

discussed later in this chapter.

Data Standards (I-8), Data Availability (I-9)

Description

Data standards represent a criterion or an acknowledged measure of comparison for quantitative or qualitative value. Standards are a way of determining data quality and of defining the characteristics of data. These should be commonly used and accepted as criteria about the accuracy, timeliness, etc., of spatial data to enhance data acquisition and data exchange between agencies. Standards include a data dictionary of how data is defined. It is also important to specify all graphic and non-map data, accuracy, precision, format, and characteristics when planning and acquiring a GIS database. Standards are necessary to provide a higher confidence level to those people making decisions based upon GIS databases and analyses. It also allows data to be shared with knowledge of that data's accuracy and reliability (see duplication of effort).

Data availability is the characteristic of whether data is accessible for use, and at hand. In this section it does not represent the cost of finding adequate data but refers to the existence of actual data sources. The content and accuracy of the GIS database is essential to the success of a GIS, especially since all GIS analyses depend on this data.

Both data standards and availability are directly related to data quality. Data standards are a method of improving data quality. Availability is a characteristic that is measured and assessed for spatial data. Quality is the essential characteristic of the data, its degree of excellence. Data quality will be discussed as a technical issue as well. See the article by

Brian D. Kiernan, "Quality Control Dictates Conversion Success," in GIS World, (Nov. 1991): 90-93.

Occurrence in the Implementation Process

Data standards and availability becomes an issue at Stage 1 of implementation, the information needs analysis. It is at this point that the agency must examine the current spatial data and somehow develop definitions and measurements of data quality. This is the gist of data standards. These issues are again important in Stage 2, developing the specifications for the GIS database, and in Stage 4, development, when the database is being built.

Agencies' Responses

Of the fifteen GIS managers, six mentioned data standards, four mentioned data availability, and seven mentioned data quality. They mentioned these areas as being issues but did not elaborate on the nature of the issues as much as did regarding recommendations.

Relation to Perception

One of the major misconceptions in GIS use is that existing sources of data are accurate and appropriate for inclusion into a GIS database. Data from divergent sources are at different scales, resolutions, degree of precision, degree of accuracy, and have different characteristics. Human nature tends to take the path of least resistance. It is easy to include all kinds of data into a GIS database without really scrutinizing the data. It is difficult to

examine data. Often, information about the base data -- its date of compilation, scale, source and method of derivation, accuracy, generalization and/or transformation procedures used have not been documented. While some agencies may document data quality by visual overlays, more often agencies fail to document data quality at all (Grady 1990, 3). It is therefore difficult to assess the value of such data and determine which data is appropriate for inclusion into a GIS database.

Once such data has been digitized into a GIS database, it is even easier for it to be perceived as accurate. This includes a real blind faith in the source of data. In some cases some may choose to ignore error due to expediency (Grady 1990, 2). GIS produces attractive map products. Attractive products further lull GIS users into a false complacency about the reliability of GIS analyses, GIS products, and the spatial data they are based upon.

Recommendations

Spatial data layers are often available. Some sources are third party vendors and federal, state or local governmental agencies. For more information about data availability, see the articles by Susan Hallen, "Finding, Evaluating and Using Existing Data Sources," in GIS World, (Nov. 1991): 60-63; and by Khagendra Thapa and Robert C. Burtch, "Primary and Secondary Methods of Data Collection in GIS/LIS," in Surveying and Land Information Systems, 51, no. 3, (1991): 162-170.

Several of the GIS managers made recommendations for overcoming these barriers. The GIS manager from the BIA stated that agency staff need to learn to create appropriate, accurate databases. The GIS manager from the BLM added that personnel need to not confuse precision with content accuracy of data. Several GIS managers express the desire for data

standards. The USFS Region Six GIS manager added that standards are needed due to information definitions which get weak with subjective calls in evaluating data quality, and for exchange of digital information. The Mt. Hood GIS manager stated that the agency needs less focus on map products and more on data integrity in addition to understanding other agencies' data standards, data formats, and data definitions to ensure cooperation and avoid duplication. The GIS manager from SCS sees spatial digital data transfer standards as a method to avoid duplication of effort and save costs. He adds the need for a central clearinghouse for all digital data layers at one standard. The issue of data standards is being addressed. The USGS National Committee for Digital Cartographic Data Standards (NCDCCDS) has developed proposed Spatial Data Transfer Specification (which have been submitted to the National Institute of Standards and Technology).

Another method of improving data quality and preventing misleading spatial data, in addition to standards, is the practice of including data lineage with spatial data. Grady quotes the Working Group II (from the NCDCCDS) on data set quality "lineage includes the original source material and all the processes and transformations leading to the final product. This information is required for a user to evaluate fitness and it is required by a producer to maintain and update the data (Grady 1990, 2)." Data lineage is often overseen by a database administrator, to "attest to data integrity" and to verify that the data adheres to established standards (Grady 1990, 3-4).

Data quality can be checked one of two ways -- front end checking and deferred checking. Front end checking is the traditional method. Through it, an agency will "define a data dictionary which can apply rules to transactions before any new data are entered into the database, preventing updates that would conflict with existing data (Grady 1990, 4)." Some argue that this method slows down the already laborious effort of data collection. This is the

best method, according to Grady, to assure that data lineage is documented correctly. Deferred checking is performed by scanning the database after entries are made. It is a good supplement to front end checking and can flag any data that lack lineage documentation or that conflict with other data.

Through data lineage, source data must be scrutinized according to recognized cartographic principles to control error (Grady 1990, 4). For example, information about the data's scale, its source and method of derivation, its accuracy, and the generalization and/or transformation procedures that were used must be examined. The temporal component is also important to data lineage. The compilation date of source materials, publication date of source materials, dates of the original survey, and the date of revisions must be included.

Data lineage should also include the legislative mandate that led to that particular data collection (Grady 1990, 4). According to Chrisman, "data is collected and maintained in response to a social need as expressed by the legal and political system (Chrisman 1987, 1369)." There are risks to not including data lineage, and these techniques should be included in building a database, to ascertain data quality, be part of a data quality report, and know what issues drove data collection.

As mentioned earlier, the Oregon GIS Service Center is the focus of activities meant to facilitate cooperation and coordination among different kinds of agencies (federal and local governments, neighboring states and private industry) to ensure better GIS use. The goal is to establish a plan to develop a "timely, accurate, reliable GIS database that can be accessed and shared by all agencies in the GIS network (SMAC 1990, 3)." The plan addresses data standards and compatibility issues, evaluation of other GIS activities and degree to which such projects agree with SMAC GIS plan goals, establishment of different agencies' responsibilities and roles toward this statewide GIS, provide a framework and direction for statewide GIS

activities, define the GIS Service Center's responsibilities, develop a public access policy, and develop a GIS training guide, and address other issues (SMAC 1990, 2,10-17).

For the specific task of addressing data standards and data availability, the plan's strategies are meant to provide a framework to allow the user community to catalog where data exists, where data are needed, the level of data quality, and what agencies are responsible for data creation and maintenance (SMAC 1990, 3). The GIS Plan also includes the development of a data dictionary. The Plan describes dictionaries as follows:

A data element dictionary describes the contents of data layers, such as data coding schemes and format. It provides users with a key to a given data set. Dictionaries must be built within each agency, and, eventually, between agencies. A dictionary needs standards, documentation, and cross references between federal and state agencies to be effective (SMAC 1990, 3).

The plan also includes standards for base map layers (data capture, accuracy, scale, coordinate system), transfer formats (to allow sharing, reduce reformatting), documentation about spatial data (i.e. data quality), and digital mapping standards (location ties, scale, legend, source, projection, name of compiling agency) (SMAC 1990, 5). The SMAC GIS Plan is an example of a method for addressing problems of data quality.

Staff Training (I-10), Keep and Find Staff (I-11)

Description

Concerns about staff training include the difficulty of in-house staff training while they attend to other duties. It may include the lack of funds to send staff to seminars or classes. It

also includes the time involved in training and keeping up with changes in technology.

Concerns about finding and keeping staff include finding staff who can program, have both knowledge of GIS and natural resources, or having to use contractors instead of agency personnel. It may also include the high turnover of trained staff, the lack of in-house expertise in modifying software, and a deficiency on the part of universities who educate potential employees. Staffing, as an issue, is not merely an institutional issue. Its economic aspects will be discussed later in this chapter.

Occurrence in the Implementation Process

Staffing becomes an issue at three points in the implementation process. Early in the process, those who are preparing an economic feasibility report must make very clear to management the full staffing costs involved in a GIS. These costs include training current staff and hiring additional staff. One aspect not readily recognized is that many staff must perform all of their usual duties in addition to new GIS duties. When the final implementation plan is being developed staffing requirements must be realistic and generous. Staffing is a huge cost. A firm commitment must be gained from the accounting and budgeting divisions to follow through with such staffing requirements. This commitment must be reflected in continued financial and institutional support for broad-based training and hiring over the long term.

Agencies' Responses

This is one of the most commonly mentioned issues. Of the fifteen GIS managers,

eight mentioned staff training and eleven mentioned finding and keeping adequately trained staff. It is not known whether these are issues for all of the agencies represented, only that they were mentioned by most of the GIS managers.

Relation to Perception

Staffing problems are often a result of incorrect perception. An agency fails to recognize the need for continued staffing of current manual activities in addition to the need for new staff for automated activities. Possibly they have the unrealistic perception that a GIS will save time right away and therefore there is no need for additional staff.

Recommendations

Many of the GIS managers had comments regarding this area. The BIA manager stated that there is a need for deeper staffing -- consistent numbers of personnel to cover the loss of trained personnel due to turnover. The Mt. Hood National Forest GIS manager saw GIS as an incredible opportunity for personnel to cross traditional functional and organizational lines in the future. The Siuslaw National Forest GIS manager believed that GIS needs to be better incorporated into university academic programs for those desiring to go into the natural resources fields.

Again, the key emphasis should be on realistic expectations regarding staffing requirements. The cost of implementing a system consists mainly of the cost of developing the database and the time it takes to accomplish that task. This requires not only additional training for current staff but also additional staff. A database administrator is a must as are

GIS technicians and other positions specifically created for the new system.

Technical Barriers

Data Quality (T-1), GIS Analyses Quality and Validity (T-2)

Description

Data quality is a measure of the data's accuracy, precision, timeliness, appropriateness, and format. How does data quality as a technical issue differ from data quality as an institutional issue? As an institutional issue it is a result of the procedures and behaviors of agencies. As a technical issue, it is a reflection of the capabilities of GIS technology. Once data is encoded into a digital format, it is difficult to assess its quality. One would have to go back to the source data to determine quality. This is a weakness inherent in the technology at this point in time, as well as an institutional issue.

Concern over the validity of GIS analyses may include not only the soundness of analyses, or the quality of the underlying data, but also the cost and time involved in making analyses accurate. This economic problem will be discussed later under costs.

Just as it is difficult to assess data quality once spatial data is entered into the GIS database, it is also difficult to assess the reliability of the analyses based on that data. For each operation performed on that data, the amount of error is multiplied. Often the validity is a function of a weakness in the software. This will be discussed later in this chapter. These related issues of the quality of data and of GIS analyses are important because the content and accuracy of the GIS database are essential to the success of GIS in better managing natural

resources.

Occurrence in the Implementation Process

At earlier stages, issues of quality stem not only from technical problems of pre-processing data, but also from institutional problems of poor data collection mentioned earlier. The technical aspects of the issues of data quality, and the validity of analyses based on that data, become important in the development (Stage 4) and operation stages (Stage 5) of GIS implementation. It is at that time that spatial data is encoded into the GIS database and different operations, analyses, and modeling may be performed on that database.

Agencies' Responses

Of the fifteen agencies, six mention data quality and two mention the validity of GIS analyses as technical issues. The GIS manager from USGS Water Resources stated that lost time and accuracy may result from "manipulating data layers to death." The Willamette National Forest GIS manager stated that Forest districts are concerned with the resolution of GIS data and that it is difficult to determine if GIS data is "ground true," that is, accurate to the actual forest conditions. Possibly, more concern was not expressed over these issues because these agencies are still in the early stages of GIS implementation. At later stages, after database development is more or less complete, these issues become more important.

Relation to Perception

Converting poor data into a digital format will not result in better information upon which to base management decisions. In addition, the use of GIS technology creates further problems in this area by creating the false perception that GIS queries, analyses, and modeling are accurate and reliable. The problems inherent in overlaying maps is compromised further by automation because GIS users are less likely to be aware of such compromises in creating GIS overlay map products and analyses.

Recommendations

It is an artificial delineation to separate the technical aspect of data quality from the institutional and economic aspects. As discussed regarding the institutional aspect of data quality, i.e. data standards and accessibility, one method to increase user confidence in the reliability of the data is data lineage.

Maps, by their very nature, represent areas of uniformity. The problem is that most natural factors, such as soils, vary along a continuum. Therefore, source maps, such as a soils map, have a certain degree of inherent error, both in positional accuracy and in homogeneity. At some point a soil scientist surveying the soils of an area decided that a particular type of soil has made a transition to another type. This is a judgement call and not easy to quantify. When such generalized information (see Chapter II) is encoded into a GIS database, it may be combined and manipulated with other kinds of data representing different natural phenomenon -- each with a certain degree of error. This is especially true in a raster-based GIS where a raster cell must be given a value representing the dominant characteristic of that

cell when, in actuality, that cell represents a parcel of ground with varying characteristics. The problem is further exacerbated when different source maps of different scales are used. Maps are often enlarged or reduced to meet a common scale resulting in further generalization.

The implication for environmental management is that resource managers are developing policies and decisions concerning the land. Often such decisions are based on knowledge of several factors about that land and how such factors combine. When there is such emphasis on the GIS database, the inherent generalization of different data layers, the different methods of compilation, and the original format and scale, may lead to very inaccurate overlays and deceptive results from GIS-performed analyses. Managers synthesize different maps representing different characteristics of the land (such as vegetation, soil type, erosion potential) to determine ecological response units (Bailey n.d., 14). They desire that these units "reflect differences in potential response to management and resource productivity (Bailey n.d., 15)." Due to the potential inaccuracies present, the value of overlaying such maps for decision-making should always be questioned.

The errors in GIS data can be addressed in several ways. First, it should be recognized that such error exists and expectations of data quality and validity of GIS operations changed accordingly. Secondly, in converting source materials to digital data, extra care should be taken, especially when changing the scale of source material. Another method is for the software to actually document a statistical degree of computational error for each data layer and for each level of data manipulation. This can accompany each layer or analyses map in the legend. It can also take the form of a "shadow map" of thematic error generated by each GIS process (Berry 1987, 1410). The validity of GIS analyses can also be tested against field measurements. "Detailed studies should be conducted with actual resource data to determine how well ecological maps produced with the overlay approach represent the

distribution of natural resources (Bailey n.d., 16)." This is especially important in using GIS operations to determine ecological response units. Errors in determining the characteristics of the land or its resources may lead to disastrous consequences for planning and implementing policy decisions.

Using a GIS to perform old agency activities, as well as new kinds of analyses can lead to a false confidence in GIS results. Managers need to be aware of errors and pursue methods of improving data quality and the validity of GIS analyses. For more detailed information on assessing error, see these articles: Walsh, Lightfoot, and Butler's article "Recognition and Assessment of Error in Geographic Information Systems," in Photogrammetric Engineering and Remote Sensing, 53, no. 10, 1423-1430; Michael Blakemore's article "Generalisation and Error in Spatial Data Bases," in Cartographica, 21, no. 2/3, (1984): 131-139; and Douglas A. Mead, "Assessing Data Quality in Geographic Information Systems," in his Remote Sensing for Resource Management, (1982): 51-62.

Satellite Data, Global Positioning Systems (T-3)

Description

Remotely sensed data and global positioning systems (GPS) are two separate technologies mentioned in Chapter II, the brief background of GIS technology, and are combined here because both are satellite technologies. When GIS managers were interviewed they were asked to comment on these areas. More specifically, whether they felt that such technology was being used adequately. In this case, remotely sensed data is referring to satellite imagery, primarily from the U.S. Landsat satellites or the French SPOT (System

Probatoire d'Observation de la Terre) satellites.

The Landsat 5 satellite (operational in 1983) and SPOT satellites provide imagery complementary to each other. Landsat 5 has two types of sensors, the multispectral scanner, with data in four spectral bands (visible green, visible red and two reflected infrared bands) at 80-meter resolution, and the thematic mapper with six spectral bands with 30-meter resolution and a thermal infrared band with 120-meter resolution. SPOT has sensors capable of 10-meter resolution with black and white panchromatic images, and 20-meter resolution for three-band multispectral images. The resolution of SPOT is better than Landsat's, but has a more limited spectral coverage and smaller area per scene (Driscoll 1990, 79). Other countries have satellites that have sensors appropriate for remote sensing information appropriate for input into a GIS, but most of their data is not available or used in this country.

Satellite imagery is used as an external source of data for input into GIS databases, usually as a secondary source in combination with aerial photography and field work. Both Landsat and SPOT data can be timely and cost-efficient when data needs do not require extremely high resolution levels. It is especially important for small scale maps of land variables such as water bodies, vegetation, landforms, and other characteristics.

Initially designed by the U.S. Department of Defense, the NAVSTAR Global Positioning System is a set of orbiting satellites (not yet fully operation but will eventually have a total of 24 satellites) that can make positioning on earth possible to within millimeters of accuracy. Positions on the earth are calculated by measuring the distances to the satellites. The GPS receiver decodes the timing signals from whatever satellites are in view and knowing their location, computes the latitude, longitude, altitude, and time. When all 24 satellites come on line, the system will be very accurate, within millimeters for those systems that track up to four satellites (Stutheit 1989, 29).

Occurrence in the Implementation Process

The use of satellite imagery and GPS occurs at the development (Stage 4) and operation stages (Stage 5) of implementation. It is at this time that the GIS database is being built. Satellite imagery and GPS are important sources of data.

Agencies' Responses

Of fifteen agencies, three mentioned satellite data and global positioning systems. One would conclude from the little response that this area was not as much concern to the GIS managers as other areas.

Relation to Perception

The use of both these technologies can lead to greater confidence in the quality of the data. Satellite imagery must be used cautiously and appropriately due to the subjective nature of interpretation. For that reason, Landsat data and other similar imagery are good secondary data for correlation with other kinds of data. Being aware of the advantages and drawbacks of satellite imagery is important to successful use as input into a GIS database.

Recommendations

Due to the very nature of satellite imagery, it can give information about environmental change, including the rate of change. Monitoring such change is an important

activity for all the agencies interviewed. Despite problems of resolution, the integration of satellite imagery with GIS technology is significant for that reason. The future may bring satellite imagery with resolutions down to 15-20 meters. Military reconnaissance satellites have sensors with a very high resolution of 1 meter. It is most likely that image data will be available for all areas of the world at 20 meters.

The advantage of using GPS is that data can be collected in the field and its positional accuracy can be computed quickly and correctly. The information on coordinates, elevation, and time can be imputed into a GIS database quickly and effectively with no manual conversion or entry necessary. GPS receivers are amazing. They can be hand-held and battery powered, therefore portable and very appropriate for field work. Some GPS receivers can even convert the data for direct input into GIS software such as ARC/INFO. GPS is expensive technology (up to \$70,000 for a multi-channel, dual frequency system that provides millimeter accuracy), but there are companies who will contract out GPS work. Land survey data are some of the most important data to a GIS. With GPS' ability to locate exact locations, the future applications will be incredible, giving anyone the ability to know exactly where they are, any place on earth.

Software Ease of Use (T-4), Integrity (T-5), and Capabilities (T-6)

Description

The ease of using GIS software refers to the potential trade-off between user-friendliness and power and flexibility of a GIS program. User-friendliness refers to the user interface. Concerns in this area may include the desire for pull-down menus, or automation of

a set of commands to allow individuals with little GIS expertise to use the system. Systems that are easier to use allow many users and this promotes GIS knowledge. Ease of use is also an economic issue. If a great amount of training is required for staff to be able to use the system, then it can add significantly to costs. This aspect will be discussed in the cost of staffing and training, later in this chapter.

Concerns over software integrity include "bugs" in the software or the fact that software anomalies are not corrected until the next software update. This is often a function of the stability of the company that developed the software and whether that company will still be around tomorrow.

Concerns about software capabilities relate to its functionality. "Functionality refers to the capabilities of systems to perform the functions involved in a GIS (Woodcock, Sham, and Shaw n.d., 312)." These abilities include data acquisition functions, pre-processing functions, data management functions, manipulation, analysis, modeling functions, product generation functions, links to databases, links to other software such as statistical software, and the ability to convert between raster and vector formats. Concern over functionality occurs more frequently with public domain software.

Occurrence in the Implementation Process

Technical problems with GIS software occur at several points in the implementation process: first, when an agency is trying to select a system by evaluating one system against another; secondly, when GIS software is first used in a pilot project, which may take place at almost any stage in the process; and finally, when the system gets up and running (Stage 5: Operation). The Information Needs Assessment and the Specifications for the System form

the basis for evaluating different software programs. With over 50 choices of software available, selection is difficult. The selection must be based upon which software best fits long-term functional requirements as determined in Stages 1 (Concept), 2 (Design), and 3 (Acquisition) of the implementation process.

Agencies' Responses

Of the fifteen GIS managers, ten mentioned the issue of the ease of using the GIS software, seven mentioned software integrity, and eleven mentioned software capabilities (see Figure 3). These are important issues to these GIS managers.

Relation to Perception

Many perceive GIS technology as a quick-fix and often select a GIS with little prior experience. This is often a problem with any new technology and will be discussed in more detail later. Agencies must be aware of the costs and limitations of different GIS software. They must also know that different systems are not all appropriate to fit every agency's needs.

Recommendations

Agencies must pick the most appropriate system for desired use. Selection criteria include the desired scope and scale of the system, the kinds of analyses required of that system, the kinds of data that will be used, the desired applications programs that may be added, and the number of users. Due to the general rule of functionality being inversely

proportional to ease of use, a high number of personnel interfacing with the GIS may require a system that sacrifices capabilities for user-friendliness. Getting a more functional software may require much more funding for training. These needs must all be identified in the Information Needs Analysis process (Stage 1 of the implementation model) and in the specifications for the GIS database and system characteristics (Stage 2 of the implementation model). Each issue should be anticipated one step earlier in the implementation process than where the barrier might potentially become a problem.

Agencies must also select a system that will still be around tomorrow. GIS technology is changing so fast that products are changing and some vendors may go out of business. This is more true for commercial software although public domain software is not immune to changes. Source codes allow agency personnel to adapt GIS software. In some ways public domain software has advantages. While the source code for commercial systems is not usually available, public domain software source codes are usually available so that users are not left out in the cold if the software vendor doesn't survive in the GIS market. Public domain software tends to be based on standard hardware and hardware repairs are more easily accomplished and available (Woodcock, Sham, and Shaw n.d., 313).

Agencies must realize that each software program has limitations. For example, the limit of functionality is usually opposite of the software's data structure, ie the greatest limitations of a vector-based system are in raster-processing functions and vice versa (Woodcock, Sham, and Shaw n.d., 312). Agencies must also realize that you get what you pay for. Public domain software is less expensive but may result in higher costs later. The Willamette National Forest GIS manager states that there has been little up-front cost for the Forest's public domain software, but the cost has been very high in using the system. There has been the cost of re-doing work, cost in time, and cost in frustration.

Software programs that were once state-of-the-art may not keep up with changes in technology and in the GIS market. One example is the story of MOSS. MOSS was an early system, and has its roots all the way back to 1976, when a group of resource managers in the U.S. Fish and Wildlife Service formed a group called the Western Energy and Land Use Team (WELUT). They wanted "to apply new technologies to the problem of minimizing the ecological damage of coal, oil-shale, oil, geothermal and other energy development projects (Parker n.d., 70)." MOSS was developed and first used by offices of the BLM, USFS, Soil Conservation Service, and one USFWS project -- the National Wetlands Inventory in St. Petersburg, Fla. Since then, SCS has adopted GRASS, another public domain software developed by the US Army Corp of Engineers, as has the National Park Service. The BLM formally adopted MOSS in 1985, (see Chapter IV for the Western Oregon Digital Database project) and the Forest Service still uses MOSS, at least until the national procurement. MOSS was an early system and at one time considered one of the better choices among the limited options available. Today many GIS users express dissatisfaction with it and many commercial software packages are considered to be better. Sometimes, private industry can respond more quickly to changing technology and market demands.

Artificial intelligence, or expert systems, will continue to play a role in dealing with the issues of ease of use of software. Expert systems solve problems that would normally require an expert's interpretation and can improve the overall application and performance of a GIS (Wilkinson and Fisher 1987, 66-67). It works by means of a computer model of human reasoning. Applications in the future include: extracting useful information from satellite imagery, scanning and editing data from non-digital maps, assessing data quality and reliability, performing automated name placement, and performing automated map generalization (Robinson and Frank 1987, 1435, 1439). Expert systems can also produce high

quality maps and graphs by incorporating rules of cartographic design. Expert systems can help automate extraction of geomorphological features from digital elevations models for land-cover classification and monitoring, speed searches through large geographic databases, and create intelligent user interfaces and database queries (Ripple and Ulshoefer 1987, 1431). This interface would improve data access and retrieval without requiring the user to be aware of the physical data structure (Wilkinson and Frank 1987, 68) and guide an inexperienced user through the use of a GIS (Ripple and Ulshoefer 1987, 1431). Expert systems can also perform the computationally difficult procedure of vectorizing raster images. The future trend is toward more use of artificial intelligence tools such as expert systems. A more extensive description of the role of knowledge-based systems is provided by Wilkinson and Fisher, 1987; Ripple and Ulshoefer, 1987; and Robinson and Frank, 1987.

A deeper issue in selecting GIS software is that different vendors have GIS software with different command and query languages. This makes it difficult to compare different GIS platforms when trying to evaluate and select them. It also makes it difficult to share data among different GIS databases and among different agencies and to integrate different software with GIS software, such as modeling software or standard databases. Somehow, vendors and GIS customers need to address this gap between dissimilar systems. There are likely people out there who would try to address this issue but at a high consulting fee. Possible some kind of national direction to address this issue could be developed. One interesting phenomenon is that for some reason, change has come more slowly to software than to hardware improvements.

Hardware Storage (T-7), Speed (T-8), Other (T-9)

Description

Hardware concerns include those about the processor (micro, mini, or mainframe), the workstation (mechanism by which the user accesses the database), digital display devices, input/output peripheral devices, and networking devices.

GIS databases have massive storage requirements. For example, a complete database containing all 54,000 7.5 minute quadrangle maps covering the lower 49 states would require 10 to the 14 bits of data for a ground resolution of 1.7 meters (Berry 1987, 1409). The storage capacity of the hardware will determine the size limitations of GIS databases. Storage capability is provided by magnetic or optical disc, or magnetic tape.

Processor memory is related to storage. It is usually expressed in megabytes (or "megs" as popularly called). It is comparable to a PC environment where a machine with a 386 co-processor is said to have 2 megs of RAM expandable to 8 megs. It is the available memory to run software programs and access data. It allows complex GIS capabilities and multiple users to access and manipulate the GIS database.

The speed of the hardware usually refers to the speed of the CPU whether it be in a PC environment, workstation, or mainframe computer. It is the speed at which the hardware allows the software to perform its functions. Concerns in this area may include multiple users slowing down mainframe systems, especially if a central system is used for all kinds of uses in addition to GIS uses.

Other hardware components include a variety of peripheral devices such as printers, plotters, other hard copy devices, scanners, and GPS receivers. Other concerns include the

lack of compactness of some systems, the output rate from plotters, not having enough workstations, the characteristics of the GIS interface, and lack of capability for the types of graphic and tabular output desired.

Occurrence in the Implementation Process

Hardware problems do not usually arise until well into implementation. It is usually when the GIS is operating that limitations in hardware use arise. Hardware issues need to be addressed early in the process when describing the specifications for the system characteristics in Stage 2.

Agencies' Responses

Four GIS managers expressed concerns over storage capabilities, nine expressed concern over processing speed, and five mentioned other hardware concerns. The Mt. Hood National Forest GIS manager mentioned the problem of competition of many users for one system. He also mentioned that MOSS was written for machines with 64K of RAM which makes the system slow today. Even the availability of new hardware does not ensure more processing speed. The Siuslaw National Forest GIS Manager mentioned several problems with speed, power, and plotter output during peak-use times. He expresses the desire for total conversion to workstations. The USGS Water Resources GIS manager also mentioned problems with storage space and speed. The OR DOE GIS Service Center's GIS manager mentions the inherent limitations of PCs in processing speed. The SCS GIS manager also expressed the desire for the speed and compactness in workstations. The OR Dept. Water

Resources GIS manager mentioned concerns over the ability of the mainframe to handle and process large amounts of information quickly.

Relation to Perception

Agencies desiring to implement a GIS must be just as aware of hardware capabilities as software. There is the tendency for agencies to concentrate on software choices. Hardware choices are just as important as are all of the factors that should be considered in this investment.

Recommendations

In comparing PC, workstation, and mainframe systems, each is a successive step up in scale. At one time, each step up resulted in decreased response time. This is no longer true. More and more software operates well on the workstation (mini) with good processing speeds, storage, ability to allow multiple users, and to run complex applications programs. Optical discs, in series with such systems, make it possible to store vast amounts of digital data.

The most important view an agency should take is not to concentrate on whether to get a PC, workstation, or mainframe system but to examine the hardware alternatives for the best fit for storage, processing speed, number of users that can be accommodated, characteristics of the user interface (i.e. menu-driven systems which have automated command sequences to allow use of the GIS without the user having to learn command languages, see expert systems), and degree to which the system is distributed (i.e. number of workstations, how workstations are linked, and how each may access a central GIS database). These needs

should all have been determined and documented in the implementation process as a result of the Information Needs Analysis, the Economic Feasibility Document, and the document of Specifications for GIS Database and System Characteristics. It is also important to select hardware with the best future adaptability and potential for the manufacturers to stay in business and support their hardware products. The GIS database is meant to last a long time and hardware choices must reflect this realization.

Hardware capability is not the most critical issue. Rapid developments in hardware will result in many changes. Processing power will continue to grow. Prices for main memory will decrease. The access time of hard discs will increase slowly. The capacity of hard discs will grow and prices will decrease, and communications networks will proliferate (Frank, Egenhofer, and Kuhn 1991, 1433). These technological developments will help relax these barriers and allow GIS managers to concentrate on other barriers to effective implementation.

Vendor Support (T-10) GIS Platform Capabilities (T-11)

Description

These two issues have been combined for discussion here. The issue of vendor support is very much related to the hardware issues just discussed. Vendors include both software or hardware sellers. Support includes sound documentation for software use, the availability of technical advice available to customers, training provided by vendors, the response to customers' requests addressing software problems and updates, and the support potential of vendor products, ie the risk that the vendor may not be able to support customers

into the future if they go out of business or change to new products without supporting old ones. Concerns with platform capabilities includes dissatisfaction with a GIS platform or frustration because the platform is not appropriate for desired GIS applications.

Occurrence in the Implementation Process

Dissatisfaction with vendor support and GIS platform capabilities usually arises after the system is up and running in the final stages of implementation. Again, the characteristics and track record of vendors is another capability that must be demonstrated when vendors respond to the invitation for bids in the acquisition stage (Stage 3) of implementation.

Agencies' Responses

Of the fifteen GIS managers surveyed, four mentioned concerns about vendor support, and four expressed dissatisfaction with the GIS platform capabilities. The other GIS managers did not indicate problems nor specify which hardware they use. One GIS manager mentioned the fact that the manufacturer of their hardware no longer will support developments on the particular machine that was bought, a SUN 386i workstation. This is because that manufacturer has produced, and is emphasizing, newer models. The OR Dept. Water Resources GIS manager stated that vendors do not correct technical problems with the GIS software until the next software update.

Several GIS managers have expressed dissatisfaction with the GIS overall. The Willamette National Forest GIS manager stated that many agency personnel and the GIS division are dissatisfied with the GIS platform, especially the software (MOSS). The GIS

manager from SCS adds that the vendor selection process that the agency went through did not allow selection of the most appropriate GIS. The OR DEQ is not fully satisfied with its GIS platform capabilities.

Relation to Perception

As mentioned earlier, human nature or institutional pressures leads agencies to dive quickly into GIS acquisition with little planning. Getting adequate vendor support and acquiring the most appropriate GIS platform are a function of careful thought, consultation, and planning. Agencies must be aware of this tendency.

Recommendations

Vendor responsibilities and expectations must be documented in detail in Stage 3 (acquisition) of the implementation process. The vendor's responsibilities should include documentation, technical support, maintenance, and in some cases, training. These terms should be put into writing before the contract award and vendors who are unwilling to undergo this process should be avoided.

Selecting the most appropriate GIS is a function of carefully reviewing all the steps outlined in the implementation process. It is difficult to select the best choice. No one platform will meet every desired functional capability. Emphasis should not be given to one area over another and one cannot isolate the different components of a system; they all work together. Pilot projects are very significant to selecting the best system. Such projects allow an agency to foresee any possible problems before investing in a new system.

Economic Barriers

Dividing different GIS implementation issues into separate institutional, technical, and economic components is not always meaningful -- the division is somewhat artificial. Since the issues are so interrelated, the recommendations for the following economic issues will come at the end of this section. The same recommendations can cover all of these cost-related issues.

Cost GIS Overall (E-1)

Description

Concerns over the cost of GIS technology overall include the continual need to spend money for GIS maintenance, updates, database development and staff. It may also include the high cost of the desired GIS that the agency wanted but could not afford. An agency may have acquired an inappropriate GIS for their needs. Often agencies award the contract to what they perceive as the lowest bidder without adequate emphasis, in their cost/benefit and acquisition methods, to the long-term cost/benefits and capabilities of different systems. This is due to procurement rules that require awarding the contract to the lowest bidder together with inadequately detailed platform specifications. This is not the best approach; it doesn't allow sufficiently for differences in the capabilities of different GIS platforms, or between firms in quality of the product, service, and support.

Occurrence in the Implementation Process

The overall cost of a GIS can become an issue at several points. First, during development of an economic feasibility study (Stage 1), an agency not only must assess the available funding for a GIS, but must also estimate its cost. During the design stage (Stage 2), a firm financial commitment must be obtained from the agency's budgeting office. During the acquisition stage (Stage 3), those systems that best meet agency technical specifications may be financially out of reach. Additional expenditures due to other factors, such as training, re-doing work or updating the system will occur at the operation stage. Sustained funding problems can occur at all points, and is a particular problem during future operation.

Agencies' Responses

Of the fifteen GIS managers surveyed, five mentioned the high cost of their preferred GIS. The Willamette National Forest GIS manager described the many costs that have come up in overall GIS use: in time, frustration, and re-doing work. The OR DOE State GIS Service Center GIS manager explains that the Center runs on cost reimbursement where other agencies pay for the Center's services in addition to the GIS platform costs. This makes the Center's funding inconsistent due to the fluctuation of other agencies' funding.

Relation to Perception

Part of the issue here is that many agencies do not understand how important consistent, long-term funding is to the success of GIS use. Agencies are also unaware of the

costs involved in continued staffing, training, software and hardware updates and maintenance, database development, and other factors. How agencies may overcome this barrier will be discussed at the end of this section on economic barriers.

Cost Hardware (E-2), Cost Processing Speed, Cost Storage (E-3)

Description

The cost of hardware includes all of the components associated with a GIS. These include the computer -- mainframe, workstation, or PC, the display terminals, input devices such as digitizers and scanners, output devices such as plotters and printers, networking components, and others. The cost of processing speed is the cost of that hardware that can process data faster, usually a workstation. Storage costs are usually in the form of high-capacity magnetic and optical discs, as well as, the hard-drive storage capabilities of the more expensive workstations.

Occurrence in the Implementation Process

Hardware costs arise in buying, installing, and upgrading the hardware. This occurs at Stage 3 (acquisition), Stage 4 (development) and stage 5 (operation). At the acquisition stage (Stage 3), initial costs of purchase arise. A payment plan may extend the costs into later stages. Installation costs arise in the development stage (Stage 4), and maintenance costs arise regularly as the system goes into operation (Stages 5-6).

Agencies' Responses

Of the fifteen GIS managers surveyed, three mentioned the cost of hardware, the cost of hardware speed, and the cost of storage. The EPA lab GIS manager mentioned the high cost of hardware in terms of CPU, storage, and high quality plotters. The Mt. Hood National Forest GIS manager also mentioned the cost of GIS hardware. The OR DOE State GIS Service Center GIS manager added that workstations are fast and store large amounts of data, but are very expensive. Obviously these hardware costs did not concern the GIS manager to the extent that other costs concern them.

Relation to Perception

Just as in the cost of the overall GIS system, wrong perceptions about costs involved in hardware will result in dissatisfaction with the hardware aspects of a GIS when adequate storage and speed is not affordable. Agencies must properly assess the various capabilities of different platforms, as well as, the costs and choose what is most appropriate within their budget.

Cost Staffing and Training (E-4)

Description

The cost associated with staffing includes training and sending staff to classes, workshops, seminars, conferences. It also includes hiring consultants, systems analysts to help

with specific application programs, new staff, such as a database administrator, a GIS implementation manager, and others. Staffing and training are expensive aspects of GIS implementation due to the scarcity and high wage rates of GIS specialists. Database development and staffing costs much more than the GIS platform, and agencies need to plan for these costs.

Occurrence in the Implementation Process

Staffing and training costs are an issue at every stage of implementation. These costs must be accounted for in the economic feasibility plan (Stage 1, in the implementation plan), and in gaining a firm financial commitment from the funding source (Stage 2), during development of the system when staff are initially trained or hired (Stage 4), and throughout the lifetime of the system (Stages 5 and 6).

Agencies' Responses

Of the fifteen GIS managers surveyed, five mentioned the cost of training and staffing as a problem. Some agencies, such as the BLM office surveyed, use contractors already trained in data acquisition skills, due to the high cost of training agency personnel. Other agencies, such as the OR DEQ use temporary employees because it is difficult to fund permanent positions. According to the OR DEQ GIS manager, this adds to the problem of finding and keeping trained staff. He adds that one source of this funding problem is that other agency divisions, who use GIS products, do not contribute to the cost of staffing. The OR DOE State GIS Service Center GIS manager added that it is difficult to find funding,

especially for trained staff. It is possible that the other agencies either have problems in this area, or are in an early implementation stage and have not yet experienced staffing problems.

Relation to Perception

Agencies do not properly assess the costs involved in GIS use. Since data acquisition, building and maintaining the GIS database is the bulk of the cost, it follows that staffing costs will also be high since staff perform that work. In addition, staff cannot just let their normal duties slide while being trained. Additional funds must be made available for new staff to replace them, for training (seminars, classes, conferences, etc.), and for hiring new staff. This funding must be sustained over the entire implementation process and use of the GIS.

Cost Data Acquisition (E-5) Cost Sharing Data (E-6)

Description

The cost of data acquisition includes the cost in money and time to get accurate, up-to-date data for a GIS database. This cost covers both data acquisition, pre-processing of data and the cost of checking and making data reliable. Concern over the cost of sharing data is caused by users of GIS products who may not contribute toward funding the costs involved in using a GIS. These may be other divisions or other agencies.

Occurrence in the Implementation Process

The cost of acquiring data must first be assessed in the economic feasibility study at the beginning of the process. This is based upon the information needs analysis, since costs are dependent upon the amount, quality, detail, accuracy, and precision of the desired data, in addition to the degree to which such data is available. These costs can be further detailed based upon the documented specifications for a GIS database. The actual expenditure begins with the development of the database (Stage 4) and continues throughout use of the GIS.

Agencies' Responses

Of the fifteen GIS managers surveyed, thirteen mentioned the cost of data acquisition. This area generated the most response of any issue. The GIS manager from the USACE, stated that when one division pays for database development, it's difficult to find additional funding and have other divisions participate in cost-sharing. BPA's GIS manager stated that the biggest cost of GIS implementation is data acquisition. The USFS Columbia River Gorge GIS manager added that data acquisition and pre-processing are the most cost- and time-intensive stages of GIS implementation. The USFS Siuslaw National Forest's GIS manager added that more detailed data and field checking of GIS data for accuracy and precision are very costly. The BLM GIS manager mentioned the high cost of not only acquiring data but making sure it is reliable. Only three GIS managers mentioned the cost of sharing data.

Relation to Perception

Like all of the other costs, incorrect perception is at the root of this problem. Data acquisition can be up to 90% of the cost of GIS use. Jumping into implementation without really investigating the real costs can have consequences, especially when these costs are underestimated and not planned for.

Cost Software (E-7)

Description

Software costs include the up-front cost of buying the software program, for updates, for buying a separate license for each CPU, and hidden costs like security and monitoring the software copies, and maintaining software integrity.

Occurrence in the Implementation Process

Not only is there an up-front cost of GIS software at Stage 3 of implementation, but also other costs. New software may be acquired for specific applications and for other functions to increase productivity and enhance GIS capabilities. Pull-down menus and other intelligent user interfaces may be developed, software updates may cost additional money, and other costs may arise.

Agencies' Responses

Of the fifteen GIS managers surveyed, only two mentioned the cost of software. The USFS Willamette National Forest GIS manager made an interesting comment. He stated that MOSS has not been cost effective because of hidden costs due to deficiencies in the software itself. These costs include time, frustration, and the cost of re-doing work. The OR DOE State GIS Service Center GIS manager also mentioned the high cost of the GIS software.

Relation to Perception

Agencies have incorrectly perceived the cost of the software as the major cost of implementing a GIS. Agencies are not becoming more aware that software costs probably only account for approximately 10% of the total costs.

Recommendations for Economic Barriers

Recommendations to overcome all of these economic barriers will be presented here. The GIS manager from the USACE recommended leasing of hardware to allow access to the latest technology while helping deal with equipment depreciation. He also adds that all divisions of an agency are consumers of GIS products and should participate in cost sharing. He also recommends automated methods (i.e. artificial intelligence and expert systems) of data capture to deal with the high cost of data acquisition. The BIA GIS manager recommended contracting out data acquisition work if it exceeds 80 hours to deal with the cost, especially the cost of staff time.

Developing GIS databases with desired accuracy, precision, resolution, and content is very expensive. For all of the costs involved in GIS use, hardware, software, staffing, training, and building the database, several recommendations can be made to deal more effectively with the funding issue. These recommendations all involve changes in institutional procedures and behavior. Developing new funding and cooperation strategies requires change from the traditional approach to database development to new ways of managing information.

As mentioned by some of the GIS managers interviewed, funding issues can be addressed by cost-sharing. What form can cost-sharing take? It can take the form of multiparticipant GIS projects, a cooperative effort among several, often diverse, organizations such as governmental agencies, public utilities, and other private organizations toward common goals for GIS use.

Usually, participants come together into this legal agreement based mostly on geography. Different organizations desire to work together toward a corporate GIS for their area. The participants share the costs and the benefits of working together. Because such an agreement cuts down on duplication of effort, it also cuts down on the cost of database development, resulting in large savings for all involved (Montgomery 1990b, 62). Multiparticipant projects not only address economic barriers, but also institutional barriers in the areas of data acquisition, cooperation, GIS knowledge, and building unity in the direction, purpose and goals of overall GIS use.

Before participants can come together with a written legal agreement, they must first participate in a feasibility study, just as in the implementation process outlined in Chapter III. Once a study is completed, a more detailed contractual agreement can be written. This document will outline the responsibilities of the participants, define data standards to enhance cooperation and sharing of data, designate ownership of data, define the costs and allocate the

costs equitably, describe administrative details, define the steering organization or committee, determine a schedule for goals, and address issues before they occur (Montgomery 1990b, 64).

Participants must belong to an area with geographic boundaries, all must possess the ability to fund their portion of the responsibilities, all must be apolitical on projects, and all must demonstrate the ability to cooperate. Data-sharing agreements also describe the ownership of data, the rights of access to that data, it prevents distribution to those not paying for the GIS database, and they describe responsibilities concerning the maintenance of the data. Typically, one of the agencies acts as the lead agency in the endeavor (Montgomery 1990b, 64).

How each participant contributes toward the cost must be investigated and decided early. Each is paying for a GIS base map for their area, in addition to, the maintenance of that data. They are also paying for that data to meet standards of quality that all the participants have decided upon, as well as access to that data. In order to provide consistent, long-term funding, a cooperative GIS can be funded through several avenues. These include enterprise funds, general obligation bonds, other kinds of bonds, sales tax, dedicated fund loans, lump sum payments, user fees, improvement district funds, special assessment funds, and the traditional method of ongoing joint operation costs. To ensure equity, each participant pays only the costs in proportion to the benefits they realize (Montgomery 1990c, 80-81).

Multiparticipant GIS projects are often driven by an executive committee which has general oversight of the project in addition to a technical team that actually implements the project. A project manager communicates the technical committee's recommendations to the executive committee and facilitates communication from the executive committee back to the technical committee. The project manager looks for possible warning signs on the part of the participants of trouble for the project. These include: insufficient project commitment, lack of vision by committee members, inadequate levels of technical expertise, lack of commitment to

maintenance of data, reluctance to spend money and time on an implementation plan, attempting too much too soon, ineffective communication among participants, and hidden agendas. The project managers' responsibilities may include: building consensus among participants, facilitating communication among participants, learning as much as possible about GIS technology, representing participants fairly, executing the implementation plan, focusing on goals, and realizing the extent of the project (Montgomery 1990d, 105-106).

Agencies behave a lot like individuals. Each has an interest in reaping the most benefits with as little contribution as possible towards projects. The biggest challenge for these partnerships is that "investment in the multipurpose system is not in the interest of individuals and individual agencies. These short term interests are better met by single purpose systems. This must be offset by new and better institutional and individual incentives (Dueker 1987, 1364)" to get agencies to behave in ways that will benefit GIS use in the long run.

One multiparticipant GIS project is the case of Oregon, and the State Mapping Advisory Council. Created by executive action, its members are appointed by the governor. Their function is to coordinate mapping activities in Oregon. They are analogous to the executive committee described in the paragraph above. Its function includes the development of a GIS Plan to "provide the structure to ensure the best use of state financial and personnel resources as we build a system to meet the resource management needs of the 1990s (SMAC 1990, ii)." The Oregon State GIS Service Center, located in the Oregon Department of Energy, is the main implementation tool of SMAC and analogous to the technical committee described earlier. The GIS Plan includes, as one of its goals, not only better coordination between agencies (mentioned earlier in this chapter) but also cost-sharing. Custodial agencies are each responsible for certain data toward a statewide digital base map (SMAC 1990, 16).

Services that the GIS Service Center provides are cost reimbursed. The Center provides services from "digitizing, to complex, menu-driven data management systems" to local, state, and federal agencies (SMAC 1990, 16). Not only is the cost shared among agencies, but the framework is set up to best develop a quality GIS database, to develop data conformed to agreed standards, and to ensure that the data can be shared among all the different users. Multiparticipant projects can cut down on the disillusioned casualties that result from over-budget GIS projects whose start-up times take years. It can even prevent total abandonment of multi-million dollar projects. They are worth the administrative trouble of pursuing.

Legal Issues

One issue not discussed in this thesis is that of access and privacy. Public agencies are required, by law, to release raw data to the public. At the same time, an individual's right to privacy must be protected. For more discussion of these legal issues see: Phillip Parent's article "Geographic Information Systems: Issues Arising from the Proliferation of Information," in URISA Journal, 1, no. 1, (Fall 1989): 17-26. Also see Howard Roitman's "Legal Issues in Providing Public Access to an AMS: Case Studies and Variances," in URISA Journal, 2, no. 1, (Spring 1990): 38-46. Also see the section in GIS World call "GIS and the Law," which is included in every issue.

Conclusion

Overall Pattern of Responses

Looking back at Figure 3, several areas of concern stand out: (1) the high expectations and lack of direction for GIS use (especially from upper management of agencies); (2) finding, training and keeping qualified staff; (3) dissatisfaction with software capabilities and ease of use; and (4) the high cost of acquiring high-quality data and building the GIS database. Is there a pattern that can be explained in these responses? What is the cause of this dissatisfaction? What issues need further research?

A pattern does emerge from the survey results as presented in Figure 3. The areas that are mentioned most often represent two phenomena. First, certain concerns represent areas not easily quantifiable in terms of costs, or agencies were not aware of the nature and extent of the commitment required for these areas in time, money, staffing and expertise. One example is the large amount of resources required to build and maintain a GIS database to the degree of quality that these agencies desire. This is a significant concern demonstrated by the large corresponding response from the survey participants.

Second, certain barriers, not mentioned often by the survey participants may not be areas of great concern. The agencies were either aware of the nature of the resources necessary and adequately planned for this cost, or they have not reached a stage of implementation where that issue may arise. An example of the first case is that the cost of GIS software is not often mentioned. This could be surprising since programs such as ARC/INFO range \$2,500 - \$88,000 and support costs for MOSS are over \$5000 per year. Maybe it is because these represent a more easily quantifiable cost -- a one-time expenditure

that agencies are aware of and can plan for. An example of the second case is that data quality and the validity of GIS analyses were not mentioned to the extent one might expect. Further research can help one understand these patterns, possibly through additional interviews. These are issues that will become of greater concern as agencies move farther along in the GIS implementation process. Regardless of the pattern, the cause of many of these barriers can be traced to the perception and resulting expectations for GIS use.

The Honeymoon is Over

GIS managers are concerned about the many complex issues that are involved in GIS use. Even more alarming are the many barriers they mentioned to the future success of GIS technology and how these issues are related to the way the technology is perceived. Like other new technologies, the honeymoon is over for GIS. The dazzle of new technology, in addition to the human tendency to want quick fixes, encouraged agencies to dive into acquisition too quickly and with little experience, thought, planning, or direction.

Many have likened this to a first stage, after the introduction of a new technology, when it is viewed as a panacea technology. At this point, people regard it with awe, seeing limitless potential. There was danger in that first stage with so many pushing GIS without fully scrutinizing it. Many of those forward-thinking, risk-takers are now experiencing frustration and disillusionment. As has been discussed throughout this thesis, they are not experiencing the benefits they dreamed of: projects are over-budget while dragging behind schedules, and hidden costs have reared their ugly head. Beautiful map products are presented -- lulling users into thinking such maps are reliable, threatening repercussions from faulty decisions based on such data. Negative consequences could include legal consequences when

decisions concerning public lands are based on GIS data and analyses, and could be challenged in court. This is why the issues of data quality and the validity of GIS analyses may become increasingly important to GIS users.

The honeymoon is over and GIS users have aired legitimate concerns. The future use of GIS technology may be jeopardized. Unsuccessful implementation may result in much frustration causing so much lost time and money that GIS projects may be abandoned with a resulting backlash against GIS technology (and GIS gurus!). Overextending the capabilities of a new technology will result in frustration when it is found that it doesn't meet expectations. At the end of the panacea -- the honeymoon -- a change is required on behalf of the users.

Change Expectations Instead of Divorce

All new technology goes through a cycle and GIS technology is no exception. When expectations are not met in a relationship these expectations need to change concerning how one views their partner instead of abandoning the relationship. So it is that users need to reassess their relationship with GIS technology, change expectations, learn from others' mistakes and make expectations match reality. Don't divorce the technology, change perception of it instead.

There are potential positive results from changing expectations and perceptions. If an agency's expectations of the level of funding, time and effort required for GIS implementation and use are realistic, appropriate levels of resources (money, staffing, institutional support) are more likely to be allocated, resulting in a better chance for successful GIS use. On the other hand GIS acquisition and use may be realistically limited to fit within budget and resource constraints with accompanying realistic expectations.

Changing the perceptions of GIS technology is closely linked with transforming the very nature of the governmental agencies discussed throughout this thesis. One point that must be understood is that not all agencies create the environment necessary for successful GIS use. Sustained commitment, staffing, and funding are essential. Unfortunately, the management in these agencies does not always have that commitment and, as mentioned earlier, private industry often responds more quickly to demand and to change than do governmental agencies. In other cases, if sustained support is not possible, either an agency must consider participating in a multiparticipant GIS project, or investing in the scale of system appropriate to the level of resource commitment they can make. In some cases, an agency may not be able to afford investing in a GIS at all.

As has been explained, GIS technology is capable of much more than automating previous activities. It can improve the quality of the work done by agencies and perform analyses not previously possible. There must be emphasis on information management focusing on integrating a GIS with other systems and types of data. As stated by the USFS Willamette National Forest's GIS manager, the use of GIS is a procedural, organizational issue. The traditional ways of handling information, whether it be in a GIS database or other form, need to be changed if GIS technology is to be used most effectively. GIS will never meet its potential if it is used only to automate the old ways of handling spatial data.

Institutional Changes Required

Organizations need to adapt to new technology as well as demand that new technology adapt to agencies. This requires a new kind of perception and institutional change. New institutional structures and procedures are required for the best GIS use. Traditional views and

procedures were designed for manual methods of handling spatial data. Agencies cannot use old institutional procedures for automated spatial data handling. Buying new technology without accompanied institutional change will not result in the quick fix that has been so frequently sought through GIS implementation. Agencies must change institutional characteristics. Leaders in GIS use must establish new ways of achieving very different goals for how GIS technology can aid in decision-making and in fulfilling agency responsibilities.

Institutional Change is Difficult

The biggest challenge is in changing perception. All other challenges are tied to this. The biggest obstacle to changing perception is the resistance to change within organizations. While technology is rapidly changing, agencies are slow to react and even resistant to change by their very nature.

Any discipline is organized around a set of views, methods and procedures. The discipline of natural resource management and environmental planning has established procedures, definitions of what practices are carried out, and job definitions for those who work in the field. These were developed within an institutional environment that did not include GIS technology. The drawback of established practices is that change is difficult and not enthusiastically embraced. Drastic change requires institutions, such as the agencies discussed throughout this thesis, to completely change the established ways of doing things. The more entrenched these established procedures, the more difficult and uncomfortable the change. As stated by the Willamette National Forest's GIS manager, this kind of drastic change is necessary for GIS technology to be used to the fullest potential and incorporated into agency activities.

Some Deeper Questions Regarding Geographic Information Systems

GIS technology is complex. A GIS consists of the people using the system, the procedures they use in managing information, the institutions' organizational characteristics, the data involved in the system, the software used to manage, manipulate, and analyze that data, and the hardware upon which this occurs. The complexity of this relatively new technology must be understood and perceived correctly, as should the costs and benefits of its use. A successful GIS project is one that receives long-term support and commitment through institutional changes, financial support, adequate staffing, and regular assessment and review of the system's use and whether it is helping fulfill agency goals. As has been mentioned in Chapter I, there are some deeper questions one can ask:

1. Does new technology result in better decision-making?

New technology will not necessarily result in better decision-making. As explained earlier, institutional change is required to fully integrate GIS technology into the activities of agencies. That kind of change is uncomfortable and difficult for agencies. The extent to which GIS can result in better decision-making relies in part upon the success of institutional change and institutional response to technical developments in GIS use. Even if GIS technology can become fully integrated into institutional procedures, a deeper issue arises. The desire for new technology, as a decision-making tool, has its roots in the frontier mentality that is so much a part of the American culture. It is the human desire to subdue the land, to extract resources, to achieve quick technological fixes to over-exploitation problems and efficiency and practicality. In the quest for new ways of squeezing every ounce of practicality

out of natural resource management, a very subtle yet serious consequence may result. They may believe that any resource problem created by them can be fixed through the use of information and analysis. The information is managed rather than the actual landscape. Those working in natural resource management and related fields may be neglecting consideration of what is moral and right in the name of efficiency and practicality in the decision-making process.

2. Does accurate data actually result in better policy decisions?

More accurate data could result in better policy decisions if such decisions were solely based upon GIS data. The process of policy development is complex and GIS analyses will only play a small role in what is a largely political process. One may ask, "Is accurate data really the bottom line for policy-making, or is the data always manipulated to serve political ends in natural resource management?"

3. Will inaccurate perceptions of GIS lead to disillusionment and abandonment of the technology?

Inaccurate perceptions can lead to abandonment or under-utilization of GIS technology by some agencies, and more serious consequences may come about. The loss of time and money that results from pursuing an under-utilized GIS can damage the public image of agencies, shakes the public's confidence in these agencies as stewards of the public's resources, hurts the national economy and results in lost opportunities for the use of GIS technology.

4. Will the relationship between GIS and users change to a more realistic one?

It is not known how much perceptions of GIS will change. Due to human nature and the nature of true innovation, changes in GIS use will respond to those who exert the most pressure for change. As explained earlier, institutions have difficulty changing. Real innovation and change usually comes from those outside the established GIS user community -- more specifically the field of GIS applications for natural resource management. Insiders usually cannot see beyond the limits of the traditional ways of doing business; they cannot question their specialty. Outsiders are free from the framework and "how it's done" and can challenge the traditional procedures. The biggest problem is that their maverick ideas are not widely received. (See Richard de Neufville and Jennifer Croissant, "A Policy for Technology Leadership." URISA Journal, 2.2 [1990]: 7-15).

5. Is there a point of diminishing returns where additional funds no longer result in more accurate data or better decisions?

There may be a point of diminishing returns in GIS implementation that agencies are poorly equipped to recognize. Further research is needed to help them recognize and understand the relationship between expenditures and data quality. The source of funding is not inexhaustible for GIS use. In fact, with current economic conditions, funding is very limited. Data quality can be viewed in one of two ways: (1) In the future, agencies will become more concerned about data quality and the validity of GIS analyses; and (2) GIS users also have the potential to respond in a very different way, given the financial constraints for data quality. The focus may shift away from accuracy. Often, decision-making is more

interested in the speed of answers and the focus of GIS use may shift to speed and efficiency in communicating geographic information and making decisions. Continued research in the GIS field can investigate these trends and help GIS users anticipate consequent changes.

6. Can new technological advances relax institutional and economic constraints?

One area of the technological barriers must be addressed for future relaxation of other barriers. Software capabilities and software ease of use apparently are not advancing at the desired rate. This is evidenced by the level of concern from the surveyed GIS managers. The GIS software used by the survey participants requires highly trained GIS operators, does not integrate well with other databases, and has slower response time than desired. There is some hope. Capabilities have improved through recent upgrades of GIS software such as ARC/INFO 6.0. Modules of this software allow visualization of the database, integrate raster and vector data, and make available a menu for standard applications. Hardware, developed in the mid-1980s, had speeds around four million instructions per second (4 MIPS). Today, many systems use 28-MIP machines and the most recent hardware is capable of 60-100 MIPS. These advances create new opportunities for specialized application programs and true 3-dimensional modeling. These require enormous computational speed (Michael Miller, CH2MHill, Corvallis OR. Personal interview. 9 March 1992). The same rapid technological changes that led to the development of GIS technology (Chapter II) could lead to even more radical change. Today's GIS may not be the GIS of the future. Another software can replace the current software or a completely different approach to handling geographic data may be in store for the future. In essence, both technology and institutions must change together, and

since technological advance is inevitable, the pressure is for institutional change.

Technological and institutional changes work together for better use of GIS technology.

A definition of successful GIS use may be merely evaluating whether the system is performing what people want it to do. If GIS technology is not meeting expectations, either expectations will change or the pressures will cause change in GIS technology. The answers to these questions depend upon whether or not institutions can respond to the fast rate of technological change and change their thinking to best incorporate GIS into agencies' behavioral framework. To not simply replace old methods and ways of solving problems but think in an entirely new way will prevent GIS failure. Future successful implementation of this technology will be largely dependent upon the degree to which perceptions can be corrected to result in new institutional behaviors, procedures, and methods. These kinds of changes must not ignore the moral issues at the core of why we manage natural resources. These issues involve the use of technology at the expense of deep scrutiny of the morality of decisions and whether more speed and efficiency is compatible with good stewardship of natural resources and environmental characteristics.

The nature of change requires that there be some form of leadership. Just as there are task groups for GIS use, i.e. the Oregon State Mapping Advisory Council, so there can be groups who have the goal to encourage development of new ideas. They can focus on keeping up with new ideas and being at the forefront of change. For this to happen they must be willing to let go of views and methods traditionally held by GIS users. This change must occur soon.

As demonstrated throughout this thesis, the field of GIS use is complex and constantly changing. What at first seem to be merely technological problems are actually institutional issues. Institutional behavior is a direct reflection of how society views environmental

management. As noted, the real issue of today is not the need for more accurate data and more efficient resource management. Instead, it is the need to examine the ethical basis for natural resource management and to change human and organizational behavior as technology changes. There is a unique opportunity for GIS to be a unifying technology that brings together all kinds of information -- spatial and non-spatial to help managers have the geographic information necessary for better decision-making. This opportunity will be realized through changes in the underlying beliefs and behaviors of those working in the field of GIS use for environmental applications.

APPENDIX

GIS STUDY: INTERVIEW QUESTIONNAIRE

QUESTION: Is GIS being used to its fullest potential for multiple biogeographic applications (wildlife, wetlands, forest) by governmental agencies in the Willamette Valley; How can the use of GIS technology be improved for natural resource applications.

Department/Division _____
 Name/Position _____
 Address/Phone _____

How long at present position _____

How long using this GIS _____

Level of position

- ☐ head administrator, district ranger, lead person
☐ middle management, GIS analyst, system manager
☐ technician

Level of agency

- ☐ state ☐ inter-governmental
☐ regional ☐ federal ☐ other _____

1. What are the objectives of this agency/department that involve GIS; what natural resource problems and issues do you address?

2. Which types of land does this agency have jurisdiction over in terms of ownership, land cover, uses?

3. For what types of natural resources does this agency compile data?

- | | |
|---|--|
| ☐ water resources | ☐ vegetation resources |
| ☐ wildlife habitat | ☐ timber stand conditions |
| ☐ wilderness areas | ☐ endangered species |
| ☐ fisheries | ☐ wetland areas |
| ☐ other (describe) | ☐ soils |

4. How does a GIS help fulfill agency objectives; why did your agency acquire a GIS?

5. How long has this department used this GIS?

Where is the project on the implementation curve?
 ___building database ___using software only for
 database management
 ___manipulation of data layers
 for analysis ___output of desired map products

- 6a. Which GIS software programs does the department utilize?

- 6b. Is this a prototype or full-usage project?

- 6c. Is the department going to use the GIS for inventory and database management only, or also for analysis and modeling?

7. Why was this particular program(s) chosen?

___cost	___user-friendly	___short start-up
___already used	___inter-agency	___analytical
___by agency	___cooperation	___capabilities
___suited for	___support from	___special
___particular use	___software co.	___permission
___reputation	___experimental	___mandated by
		agency
___other_____		

- 8a. What data variables are involved in this project (see attached list)?
- 8b. What is the source of the data (see attached list)?
- 8c. What data is not on this list but is desired? What data do you most wish were readily available?

- 8d. Do you have data variables that are too dynamic or difficult to represent spatially?

- 8e. How often do you plan to update?

- 9a. Is the department/agency satisfied with the GIS system for database management and its ability to answer analytical resource use questions (differentiate between dissatisfaction with GIS overall vs GIS platform)?

- 9b. If not, why?

- | | | |
|---|---|---|
| ☐ high expectations of GIS | ☐ problems outside of use of GIS | ☐ reliability of answers |
| ☐ speed of answers to upper management | ☐ cost | |
| ☐ PERSONNEL | | |
| ☐ high turnover of trained staff | ☐ duplication of effort | |
| ☐ difficult to find trained staff | ☐ funding | |
| ☐ difficult to train in-house | ☐ little support from upper management | |
| ☐ staff lack ability to adapt software for specific uses | ☐ not enough workstations | |
| ☐ communication within department | ☐ little inter-agency cooperation | |
| ☐ communication with upper management | ☐ need direction from inter-agency committee | |
| ☐ DATABASE | | |
| ☐ lack of appropriate information to answer questions | | |
| ☐ lack adequate database | | |
| ☐ data acquisition standards not appropriate | | |
| ☐ data changes with time | | |
| ☐ cost of acquiring data | | |

__other__

10. Can you answer questions that you could not answer before without GIS?

- 11a. Is the department/agency satisfied with the platform (hardware and software)?

- 11b. If not, why?

__HARDWARE

- __data input
- __editing
- __manipulation
- __storage
- __output
- __hard copy output devices
- __not high quality
- __other

__SOFTWARE

- __not user-friendly
- __lack support from software co.
- __links to other database systems(r-base,...)
- __links to remote sensing, Landsat
- __GIS used only for database management
- __cost
- __plotting
- __power, speed
- __not multi-tasking
- __ease of updating data
- __spatial
- __attribute
- __analytical capabilities

__other__

12. Do you think GIS is best suited just for monitoring or also for modeling and analysis?

13. Do you have any recommendations for better applications of GIS for natural resource management?

source of data accurate, up-to-date, consistent

- avoid duplication of effort

- need more specific links between modeling and software

- need more specific links between modeling and ability to transfer current database to different

software

better understanding from upper management

more staffing, better trained staff

- information needs assessment for kinds of data needed,

potential questions

user-friendliness

ease of database merging

— other

[illegible]

14. What other deficiencies do you perceive with GIS as a natural resource management tool?

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is no handwriting or other markings on the paper.

15. Do you have any further comments for better utilization of GIS as a analytical tool for natural resource management?

16. Do you think using a GIS has improved your ability to communicate effectively with the public and gain support and concensus?

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