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GEODATABASE DESIGN FOR RESOURCE
AND LAND MANAGEMENT GIS:
MISSOULA FIELD OFFICE BLM CASE STUDY,
MISSOULA, MONTANA

By

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Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Geography, GIS and Cartography

The University of Montana
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GEODATABASE DESIGN FOR RESOURCE
AND LAND MANAGEMENT GIS:

Chairperson: Dr. Paul Wilson

The Bureau of Land Management (BLM) is in the process of improving their geographic information system (GIS). The main intention is to upgrade their data and present their employees with the geospatial means necessary to accomplish their resource and land management responsibilities.

Environmental Systems Research Institute (ESRI®) designed the geodatabase model, which provides multiple advantages in organization, management, and maintenance of geographic data. The geodatabase model implements advanced relationships between geospatial features and database tables, creates platforms available in organization and editing, and instills GIS functionality to ensure data integrity.

The main goal of this work is to investigate the daily, annual, and future geospatial objectives of the Missoula Field Office BLM from the ground up, and design a geodatabase model based on the individual resource specialist's needs. It is intended that this model can be used to as the basis to allow an all encompassing geodatabase model to be build that would serve BLM field offices throughout the United States. Six resource disciplines are investigated according to their GIS needs. In order to accomplish this work, the current GIS condition is assessed, regulations and policies are examined, and GIS aspirations are considered.

Within the six resource disciplines examined, thirty-three feature classes, eleven object classes, ten relationship classes, fifty-one domains and three subtypes were created to establish this geodatabase design. This geodatabase design will prove successful for the Missoula Field Office to document, organize, edit, manage, and analyze their many geospatial requirements. The model developed will aid the Missoula Field Office BLM to adequately fulfill their land management data responsibilities, and assist their GIS demands as a federal agency.

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CHAPTER ONE **INTRODUCTION**

Overview

The Bureau of Land Management (BLM) is a land management agency in the Department of Interior, United States Government. The agency was established in 1946 through the consolidation of two governmental agencies, the General Land Office and the U.S. Grazing Service. The BLM is responsible for carrying out a variety of programs for the management and conservation of resources on 258 million surface acres and 700 million acres of subsurface lands.¹ Their mission is to sustain the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations.² Dean Stepanek, BLM Montana state director in 1986, had this to say about the mission of the BLM,

“As the Nation’s principle conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation.³”

The Bureau sustains the health of public lands through scientific investigation of soil, air, water, historic and cultural entities, and plant and animal habitat. The agency reviews changes in these resources over time due to natural or human disturbance, which

¹ U.S. Bureau of Land Management. *About the BLM*. Washington D. C: Government Printing Office, On-line. Available from Internet, http://www.blm.gov/wo/st/en/info/About_BLM.html, accessed 29 October 2007.

² U.S. Bureau of Land Management. 2003. *Frequently Asked Questions*. Washington D.C: Government Printing Office. On-line. Available from Internet, <http://www.blm.gov/nhp/faqs/faqs1.htm#1>, accessed 10 January 2007.

³ U.S. Bureau of Land Management. *Garnet Resource Area Resource Management Plan*. Government Printing Office, 1986, inside cover.

are then evaluated and addressed accordingly.⁴ Modern methods of data collection and analysis are utilized to ensure the lands current state of health, and when lands are found unhealthy, appropriate measures are taken to improve their condition.

The BLM sustains the diversity of land through implementing land use plans, which recognize the unique nature of individual management areas and which incorporate the knowledge and experience of local communities and stakeholders in designing balanced and effective management approaches.⁵ They manage a vast array of landscapes including: forest lands, grasslands, desert, arctic tundra, and high-mountain landscapes, commanding a large range of land management practices to meet their diverse needs.

The Bureau has the responsibility to develop revenue based on the productivity of their public lands for the economic benefit of local communities, states, and the nation. They manage public lands for multiple uses including; livestock grazing, timber production, and energy and mineral resource production. Revenues generated from these activities are critical in ensuring future management practices, and assisting local communities in managing resources. For instance, in fiscal year 2004, grazing fees, recreational use fees, timber sales, mineral leasing and production, and other activities generated 3.2 billion dollars, of which 1.6 billion was transferred to the states. State and local communities benefit from these payments including firefighting, police protection, construction of vital infrastructures, and search and rescue operations.⁶

⁴ U.S. Bureau of Land Management: *Public Rewards from Public Lands*: Washington DC: Government Printing Office, 2004-2005, 3.

⁵ BLM, *Public Rewards from Public Lands*, 3.

⁶ BLM, *Public Rewards from Public Lands*, 4.

The National Environmental Policy Act (NEPA) requires federal agencies, including the BLM, to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and by considering the reasonable alternatives to those actions. To meet this requirement, federal agencies must prepare an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). The Environmental Protection Agency and the public, and other interested parties review and comment on EAs and EISs to ensure that they comply with NEPA requirements.⁷ Figure 1 describes the basic concept of the NEPA process.

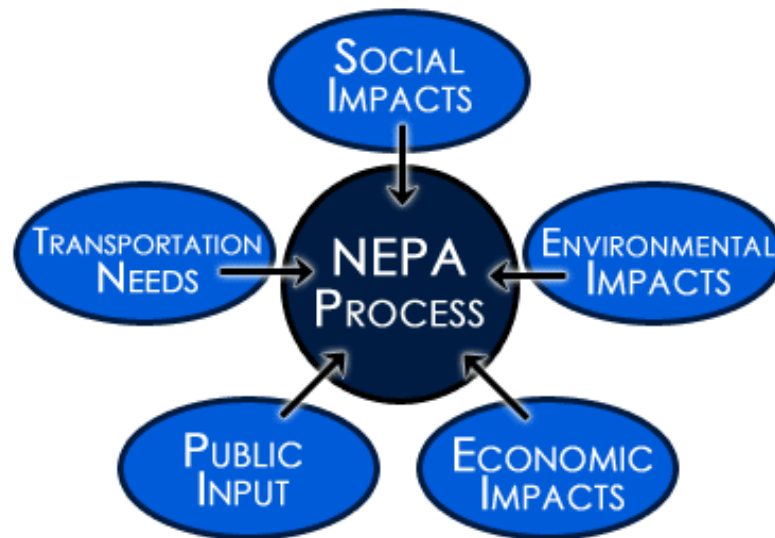


Figure 1, The NEPA Process.⁸

Resource specialists within the BLM work in conjunction with one another to investigate the environmental, social, and economic impacts of the proposed action. This process also requires them to evaluate transportation needs. Once completed, the public may look at the proposal, and interject their personal concerns or reassurances. The

⁷ Environmental Protection Agency (EPA). 2007. *National Environmental Policy Act (NEPA)*. Washington D.C: Government Printing Office, On-line. Available from Internet, <http://www.epa.gov/compliance/nepa/index.html>, accessed 5 November 2007.

⁸ Idaho Transportation Department. 2007. Boise, ID. On-line. Available from Internet, <http://itd.idaho.gov/Projects/images/nepa.gif>.

NEPA process is sometimes repeated multiple times, ensuring all parties come to a common understanding and agreement to a proposed action.

A large amount of geospatial data is required in order to meet NEPA requirements and formulate intelligent land management decisions. Geographic data is essential to organize, manage, and evaluate the many geographic components present on public lands. These components include: wildlife habitat, cultural and historic entities, vegetative habitat, mining information, infrastructure, aquatic habitat, riparian habitat, natural hydrology, topography, etc. Most of the BLM data is geographically sensitive material, and its availability is necessary to support accurate analytical assessments.

Resource and land management organizations meet their geospatial demands using Geographic Information Systems (GIS) as their primary database manager and geographic mapping tool. Employing a GIS can accomplish many of the demands placed on land management data. In resource GIS, the purpose is to provide a spatial framework to support decisions for the intelligent management of the earth's natural resources.⁹

GIS has evolved immensely since its inception in the 1960s. Due to this rapid growth, many organizations have not been able to keep up with this ever-increasing technology. Primarily, this is due to inadequate funding, training, and the frequency of GIS software upgrades to newer formats. Although older technology has proven successful, the newer systems encompass increased analytical capability and functionality, making it beneficial for these organizations to adopt.

In many cases, technology is acquired by organizations without the appropriate research, design, and implementation plans required for a successful system. An organization may observe the benefits of a GIS by other sources, assuming the GIS will

⁹ Zeiler, Michael. *Modeling Our World*. Redlands, California: ESRI Press, 1999. 2.

demonstrate success once acquired. This is a common mistake, and the end result creates many data management problems. For maximum performance, the organization needs to understand the functional capabilities of its GIS, and the delicate process of data design needed to reach their organizational goals. GIS data design is a critical element necessary for foundation of any GIS system. Once created, the hundreds of geospatial processes may be used for further analytical capability.

The BLM is not immune to the problematic challenges faced by most GIS users. Many problems can spawn from an unorganized or ill-planned GIS such as structural flaws, incompatible formats, incomplete data, unnecessary duplication, and inaccurate editing, any of which may result in the inadequate use of the system's advanced functionality. GIS is not always utilized to its full potential, and in many cases, utilized only for its cartographic capabilities.

When data is not organized properly, a variety of problems may occur. For example, when GIS data is fragmented into a number of locations, a great deal of time may be spent in retrieving and interpreting its characteristics. This lack of organization can lead users to adopt their own organizational structure for data, placing the data in the design of project areas and project types, by years, by departments, or even by the names of individuals. In some cases, there may be no particular organizational structure at all. Unorganized data leads to a lower processing speed and decreased worker efficiency. When data is organized properly, maximum processing speed is achieved and worker efficiency is enhanced. Establishing the structure and developing the data's organization and relationships are an important step in planning an efficient GIS.

When a map is created within a GIS, the map file is basically a template with geographic entities called layers linked to the map. A layer references geographic data stored in a data source and defines how it is displayed. Once layers are established in a particular directory location, relocating them will disrupt these links, and the layers will not display on the map. A systematic approach is needed to organize the data in the most intuitive and proficient data structure to ensure maximum productivity.

The evolution of GIS technology has brought with it a variety of GIS file formats. Selecting the appropriate GIS format depends on organizational requirements and format availability during the time period it was created. Within the last couple decades, formats have changed from coverages, to shapefiles, to feature classes.

Unfortunately, many agencies and organizations use shapefiles as their GIS platform, which is the older GIS data storage format developed in 2000. Shapefiles are effective for basic vector GIS storage, yet lack many of the new capabilities associated with more advanced technologies currently available. The newer, more efficient GIS technologies contain multiple advantages over these older formats, including a variety of database and mapping functionalizes that will be discussed in detail in the following chapter.

It is difficult for resource specialists to keep up with the latest GIS concepts, technologies, and evolutions, while continuing to execute their primary responsibilities. As GIS evolves, the latest versions have consistently added further dynamic functions and database capabilities, making it difficult for resource specialists to stay abreast of this knowledge. Another misconception is that GIS may be simple and effortless, and more a product of technical support. This is an unfortunate approach to an extremely complex

and dynamic profession. GIS is based on geography, although natural sciences and a multiple array of occupations contribute to the knowledge of the GIS Specialist. It is extremely important for GIS Specialist to attend training periodically, and study other disciplines to ultimately grasp the overall capabilities present in GIS. This may simply entail conducting online course work, or assisting alternate specialist in the field to gather further information.

Data design is vital in creating a proficient and successful GIS. If not designed properly, data may be incomplete and incapable of performing relevant organizational and functional tasks. Incomplete data may only contain spatial coordinates of the geographic feature and lack any significant attribute data. For example, there may be five similar polygons comprising a single project or area of interest, yet they may be contained in five separate GIS files. These polygon files may even lack the specific resource data needed for documentation or analysis.

The fundamental idea behind GIS is to associate tabular data with spatial representations. If geospatial data is lacking tabular attribute data, this will likely generate difficulty in documenting relevant resource data for labeling, classifying and conducting analysis and queries. Data must be designed with extreme consideration based on the desired needs of the GIS and resource specialists.

These problems and concerns can be addressed, corrected, and improved by employing an updated GIS, while concentrating mainly on the data needs and design elements to ensure its potential success. This effort would allow the BLM to organize all of their data in a more proficient manner, and use their spatial data in the most efficient way.

Due to the large amount of data collection needed to meet the goals and internal scope of the BLM, a complete GIS architecture is too large of a project for a master's thesis. Instead, a case study that examines the most critical needs of one field office would represent a more acceptable scope for this thesis. It is the intention that this case study will produce a model for designing and managing spatial data, which ultimately can be adopted by other field offices throughout the BLM.

Purpose Statement

An updated GIS is desired by the BLM Missoula Field Office to support their natural resource and land management practices. The Missoula Field Office offers an ideal setting for a representative case study, because of its wide range of environmental diversity, numerous recreational activities, cultural and historic qualities, and various land management activities. This thesis will comprehensively design geodatabase data for six resource specialists under the Environmental Systems Research Institute's (ESRI®) platform based on the resource discipline's responsibilities.

The design of this geodatabase has been the result of a cooperative effort between the individual resource specialists and the author of this thesis, who has been employed by the Missoula Field Office as a GIS Technician for four years. The author possesses a comprehensive understanding of the Bureau's GIS data, and is familiar with the current natural resource and land management practices. He has worked extensively in data enhancement, including the creation of new data and its design and organization, essentially improving the geoprocessing capabilities of the data. In addition, the author has accompanied multiple specialists in field operations, adding a hands-on experience and understanding of their geospatial needs.

It is the purpose of this thesis to conduct a case study involving the Missoula Field Office of the BLM to create a geodatabase design that can be used as a model by all BLM field offices for organizing the data needed to accomplish their geospatial responsibilities.

The overriding objective of this thesis is to develop and design geographic data in a proficient manner to assist the needs and responsibilities of BLM resource specialists.

The intention is to organize the geospatial data of the Missoula Field Office into a functional geodatabase, ultimately providing a functioning GIS. An integrated and comprehensive GIS is needed that contains the ability to assist resource and land management professionals in the BLM in obtaining their resource goals. To achieve this goal, several subsidiary objectives will be set.

Subsidiary Objectives:

- Set up spatial reference system.¹⁰
This stage describes the current spatial reference system currently in use by the Montana/Dakotas BLM Region, while explaining the spatial reference system parameters, including the coordinate system, the datum, the ellipsoid, and data precision.
- Investigate responsibilities and tasks of six resource disciplines.¹¹
This stage studies the responsibilities and tasks of each resource specialty using their job descriptions, daily and annual responsibilities, and future objectives.
- Identify GIS data layers needed to reach these goals of the resource disciplines.
This objective involves organizing the spatial data of each resource discipline into concrete GIS data elements such as feature classes (points, lines, polygons), or tables (object classes).
- Design and formalize the relationships that exist internally within the GIS data.
This stage dissects the data even further into the suitable geodatabase details such as the relationships between feature classes and tables.
- Develop schema.
Schema is the structure of the data, which establishes the organization, based on the relationships between data and advanced functionality.
- Review results.
This stage creates a design diagram model to illustrate the flow of the entire GIS system.

¹⁰ The spatial reference system describes the coordinate system, datum, ellipsoid, data precision and other pertinent information used in mapping.

¹¹ The resource disciplines are described on page 12 of this document.

Designing the geodatabase will ultimately help document, organize, edit, manage, and analyze the Missoula Field Office's geospatial data. Once completed, this model will provide a potential GIS resource not only for the six resource disciplines studied, but for other resource disciplines in the Missoula Field Office, and for other BLM field offices throughout the nation.

Scope

The Missoula Field Office, which is part of the Montana/Dakota Region encompassing Montana, North Dakota, and South Dakota, is the focus of this thesis. The state office is located in Billings, Montana while eleven field offices are distributed throughout the three states (Figure 2). North and South Dakota contain one field office each, while Montana contains nine.¹²



Figure 2, Montana/Dakotas Region.

The Missoula Field Office is located in western Montana and is responsible for the natural resources and management of 146,423 acres of BLM lands in nine counties

¹² U.S. Bureau of Land Management. *Montana/Dakotas*. Washington D. C: Government Printing Office. On-line. Available from Internet, <http://www.blm.gov/mt/st/en.html>, accessed 1 February 2007.

including: Lincoln, Flathead, Sanders, Lake, Mineral, Missoula, Powell, Granite, and Ravalli counties (Figure 3).

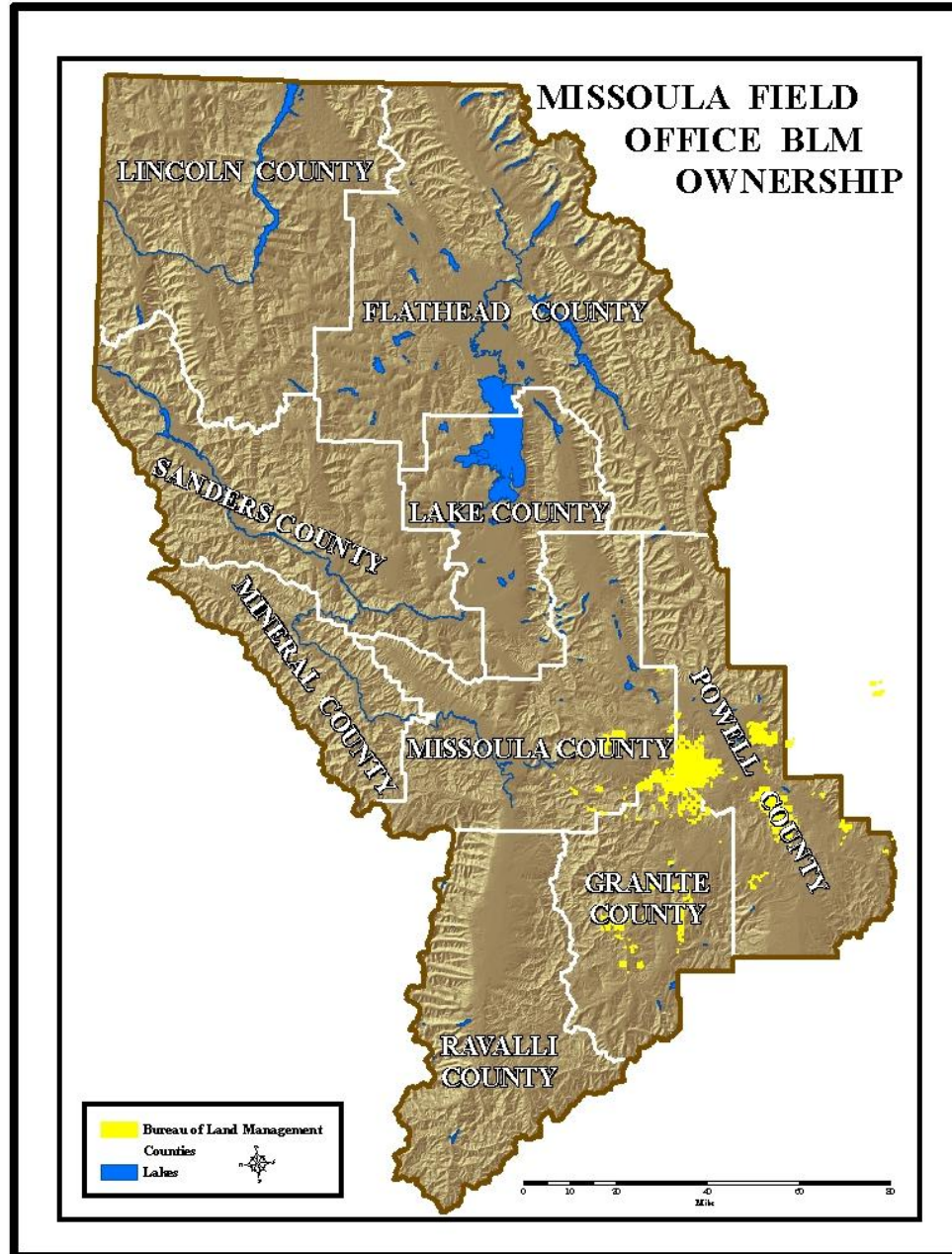


Figure 3, Missoula Field Office Lands.

The majority of BLM lands are located in Missoula, Powell and Granite Counties. Most of these are surface lands, while the BLM holdings of the remaining counties

consist mainly of subsurface mineral lands. Figure 3 only displays the Missoula Field Office surface lands; there are large amounts of subsurface mineral land ownership not illustrated.

The Missoula Field Office is broken down in to two primary departments: Non-renewable and Renewable Resources. Underneath these departments lie the individual resource disciplines, which are defined according to their special interests. Non-Renewable Resources contain archaeology, engineering, geology, lands, and recreation. Renewable Resources include rangelands, weeds, forestry, wildlife, fisheries, and hydrology.

Resource specialists work as interdisciplinary teams, to ensure all characteristics of the environment are carefully examined and the best possible land management practices developed. A resource specialist is someone with the expertise within a particular resource to conduct scientific examinations and make educated decisions. For example, a wildlife biologist is responsible for collecting, analyzing and managing terrestrial wildlife data. There may be one or many resource specialists within each discipline depending on the magnitude of the responsibility. Missoula Field Office employs approximately twenty seasonal employees to assist them in their many land management responsibilities.

The responsibilities, tasks, processes, methods, and monitoring techniques used in resource and land management practices needed to assist the Missoula Field Office are all located in the Garnet Resource Management Plan. The Garnet Resource Management Plan is a document that provides a comprehensive framework for managing the public lands and for allocating resources and land management criteria for the Garnet Resource

Area.¹³ This document is designed to provide a single source of information for the resource specialists, managers, and the public by drawing information together from both the Garnet Resource Plan and Environmental Impact Statement.¹⁴

The Garnet Resource Management Plan has been used as the primary document of reference in this thesis. Techniques are further examined by other sources as has been necessary to illustrate and/or describe additional details.

Chapter Review

This chapter introduced the BLM as a conservation agency; it described the general responsibilities and procedures practiced by the BLM in land management that concern GIS. It addressed need for improving the existing GIS systems through the development of a well-organized geodatabase and outlined the purpose and scope of this project as a case study. It described the study area, and identified the basic geographical components of the BLM within the Montana/Dakotas Region. The internal organization of the BLM field offices into resource disciplines was described.

¹³ The Garnet Resource Area refers to all of the Missoula Field Office surface lands in Missoula, Powell, and Granite counties.

¹⁴ BLM, *Garnet Resource Area Management Plan*, 1.

CHAPTER TWO

GEOGRAPHIC INFORMATION SYSTEMS

Introduction

This chapter will discuss the technology necessary to accomplish this work. This incorporates the study of GIS concepts and the latest GIS technology concerning geodatabases. First, the author will discuss the basic components and concepts of GIS, then illustrate the advanced functionality of the newer geodatabase model. The purpose is to acquaint the reader with the terminology, concepts, processes, and methods associated with GIS that are used throughout the remainder of this document.

GIS Concepts

GIS is a well-organized collection of computer hardware, software, skilled users, and geographic data designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically reference information.¹⁵ The foundation of GIS is based in the science of geography. The examination of natural and man-made environments begins with the consideration of the basic ways to represent features in the world.¹⁶ The basic components of GIS consist of descriptive mapping elements, filing structure, projection, and tabular attribute data. The GIS integrates seemingly disparate information quickly and visually, facilitating communication, collaboration, and ultimately decision making.¹⁷

¹⁵ Zeiler, *Modeling Our World*: 45.

¹⁶ Department of Health and Human Services, Center for Disease Control and Prevention. *Interactive Atlas of Reproductive Health: GIS Concepts*. Atlanta, GA. Available from the Internet, <http://www.cdc.gov/reproductivehealth/GISAtlas/concepts.htm>, accessed 19, November 2007

¹⁷ Tomlinson, Roger. *Thinking About GIS: Geographic Information System Planning for Managers*. 3rd ed. Redlands, California: ESRI Press, 2007, xv.

GIS data is comprised of themes or layers used to display similar features such as roads, rivers, cities, lakes, ownership, etc. Thematic mapping layers are descriptive representations of real-world characteristics of the earth's surface. GIS classifies geographic data in two basic categories; vector and raster formats. Vector data is comprised of geospatial features using points, lines, and polygons. They share the basic concept using nodes containing x and y coordinates to represent and display natural and man-made features.

Points represent discrete features of a specific location such as bird nests, natural springs, fish barriers, and gates. Points generally are used to identify locations of objects instead of shapes. Lines are used to represent linear features such as trails, riparian habitat, and road restrictions. Polygons represent enclosed areas such as restoration projects, livestock grazing allotments, wildlife habitat, or area restrictions. Vector data contains the geographic coordinates and descriptive information regarding the feature and is stored in a spatial database.

Raster data is used to display aerial imagery, elevation, slope, aspect, or any spatial data using pixels or cells in a grid to describe geographic information. Two examples of raster data are ortho-imagery and digital elevation models (DEM). Multi-spectral ortho-imagery uses bands of red, green, and blue values, encompassing all colors of the electro-magnetic spectrum, very similar to the modern digital photograph. Each individual cell is assigned a red-green-blue (RGB) value using the numbers 0-255 in any combination. Digital elevation models (DEM) are raster-based data, which assign elevation information to pixels. DEMs are the basis for a wide variety of geographic

analysis including; slope analysis, aspect analysis, contour creation, view shed analysis, hill shades, etc.

Although raster data is an important data structure in GIS, and opens up a vast number of displaying and geospatial processing advantages, this format will not be investigated for this particular project. Most raster analysis projects throughout the BLM are contracted out to external organizations. Many resource specialists will primarily use raster imagery as the background on a map display or for navigational purposes, although the author has promoted the varied use of DEM data, and incorporated its use in a variety of resource analyses.

Map projections are mathematical formula transforming feature locations from the earth's curved surface to a map's flat surface.¹⁸ Projections are arbitrary designations for spatial data with the purpose of providing a common basis for communication about a particular place or area on the earth's surface. Choosing a map projection is a crucial step in map design, and should be made depending on the goals of the organization.

There are a variety of projections to choose from based on the desired spatial properties of the organization. A projection will display a desired spatial property accurately yet alter other spatial characteristics. Common and desired spatial properties used in map-making include: direction, area, distance, and shape. A map's purpose determines which projection is required to establish the appropriate projection.

Different organizations use different projections depending on their desired display. GIS data is often shared within organizations and agencies using different projections or different spatial reference systems. This makes it important to understand their parameters, functionality, and displaying qualities. Choosing a projection ultimately

¹⁸ MacDonald, Andrew. *Building a Geodatabase*. ESRI: Redlands, California, 1999. 466.

depends on the purpose of map, and the display qualities necessary to meet the organization's geographic objectives.

Datums are another important aspect in georeferencing spatial features and displaying geographic information. The datum is the reference point of a measurement system, usually a system of coordinate positions on a surface (a horizontal datum) or heights above or below a surface (a vertical datum). The datum is used to establish locations on the spheroid; it is used as the starting point to correct local variations in elevation and horizontal position.¹⁹ The North American Datum of 1983 is a widely used datum, located in North America, and used as the geographic foundation for this project.

Geographic Information Systems use spatial databases which link spatial features to non-spatial elements within a database. These databases contain the capability to execute analysis, queries, and a wide variety of geoprocessing functions and have the potential to modify geographic features. The functionality of GIS allows analysis between different databases, geographic features, and non-spatial tables.

Geographic features in a GIS are made up of coordinates that define points, lines, and polygons. A point consists of one pair of x and y coordinates, a line is made up of a string of coordinates that are vectored together, and a polygon will have coordinates that define the shape, area, and perimeter of the area in question. Tabular or attribute data contains descriptive information that can be linked to geographic features. For example, descriptive data for a gate layer includes: name, gate type, gate closure dates, gate key type. This information can be linked or joined to geographic features, such as a point,

¹⁹ Environmental Systems Research Institute. 2007. *ArcGIS 9.2 Webhelp Topic*. Redlands, California. Available from Internet, http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=81&pid=78&topicname=About_the_geoid,_ellipsoid,_spheroid_and_datum,_and_how_they_are_related. Accessed 26 July 2008.

identifying their geographic location. When developing an overall database design, it is imperative to investigate the structure, purpose, and goal of the organization, and to design the structure and individual database components accordingly.

Many queries are performed based on spatial or descriptive attributes. A query is a question asked within a GIS to analyze the data, and receive results. The two types of queries are spatial and attribute queries. Spatial queries ask questions based on location, and include processes that select subsets of the study area based on spatial characteristics. Using gates as an example, a spatial query may be, 'Display all gates located in the Hoodoos Watershed Assessment Area.' This will select all of the gates (point file), which fall within the Hoodoos Watershed Area (polygon).

The second type of query is the attribute query, which is the process of identifying a subset based on questions concerning associated attributes. Using the gate example again, an attribute query is, 'Display all gates that have a closure date of September 1st to November 15th.' This query will cause the computer to search through the database in the 'date closures' field, and selects the attributes containing 9/1-11/15. This would allow an employee to identify what gates are due to be locked on September 1st.²⁰

Spatial databases are a driving force in an effective GIS providing the ability to store, analyze and manage spatial data. Developing the appropriate GIS layers and associated attributes will establish the analyzing capability of the system. Data is stored as records organized into rows, and fields in to columns. Every field will contain one kind of information conforms to definitions that have been applied to it such as is the data text, integers, decimal numbers, dates, or whatever? Records represent the different individual features in a layer while fields document the associated attributes. Identifying

²⁰ Tomlinson, *Thinking About GIS*, 215.

the goals of the GIS is the first step in determining which attribute data to collect. For instance, the gate name, closure dates, and key type represent the fields, located at the top of the database, while individual gates represent the records, located on the right.

Geodatabase Model

Environmental System Research Institute's (ESRI®) is the world leader in GIS mapping software products. ESRI® is responsible for a wide range of cutting edge technologies and innovative GIS functionality. Most governmental agencies and educational institutions use ESRI® mapping software ensuring them a strong place in today's GIS community.

Environmental System Research Institute's latest GIS mapping software package is ArcMap, version 9.2. ArcMap 9.2 introduced the file geodatabase as their latest GIS format. A geodatabase model is a new data model allowing smarter features to be made in the GIS dataset by endowing them with natural behaviors and allowing relationships to be defined among features.²¹ The geodatabase model contains many benefits over prior GIS data formats:

- A uniform repository of geographic data in a central database
- Increased accuracy in data entry and editing using validation rules
- Data objects are more intuitive instead of generic features
- Features have a richer context by relating to other features
- Better mapping products by adding intelligent behavior
- Dynamic features in a map display by custom queries or analytical tools
- Better defined feature shapes using many options
- Continuous features by accommodating large sets
- Edit data simultaneously²²

A geodatabase is a geographic database hosted inside a relational database management system providing services for managing geographic data, such as; advanced

²¹ Zeiler, *Modeling Our World*, 5.

²² Zeiler, *Modeling Our World*, 7.

editing features, validation rules, spatial database relationships, and topological associations.²³ Geodatabases organize geographic data in an efficient manner and allow multiple geographic functions within and between data.

The defining structural components of a geodatabase are found in the data formats. The three types of data formats found in a geodatabase are feature classes, object classes, and raster datasets. The feature class contains geographic coordinates with descriptive tabular data. Feature classes are homogenous collections of common features having the same spatial representation, such as points, lines, polygons, and a common set of attribute columns.²⁴ For example, an archaeological point is a point feature class, describing features discovered in the field by x and y coordinates. This feature class contains descriptive information about objects such as the type of feature discovered, its age, and its condition. The spatial and descriptive data are both stored in the feature class's attribute table. The feature class is very similar to the prior shapefile format.

Object classes are an important evolutionary component untapped from the standard shapefile format, and are used to organize and manage data in the geodatabase model. Feature classes organize all data in to one data layer, including the geographical coordinates and associated tabular data. Object classes are tables that store similar topical data, but they may be separated from the original feature class. For instance, you may have three types of topical data such as stream information, riparian habitat, and stream morphology, all based on the geographical coordinates of a stream segment. One way to organize these different data elements is to have a stream feature class to contain

²³ MacDonald, *Building a Geodatabase*, 464.

²⁴ Environmental Systems Research Institute. 2007. *ArcGIS 9.2 Webhelp Topic*. Redlands, California. Available from Internet, *Elements of Geographic Information*. http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Elements_of_geographic_information, accessed 3, December 2007..

the geographic coordinates and basic stream data. Riparian habitat and stream morphology can contain two separate object classes to house their topical information. These can then be linked to the stream segment features in the stream feature class. Managing data in this manner provides advanced organizational techniques, and allows for categorizes data to be included based on similar topical information. Raster datasets are commonly used for representing and managing imagery, digital elevation models (DEMs), and numerous other geographic data. They can also represent point, line and polygon features but are less efficient at this than vector datasets.²⁵ Raster files are much larger than vector files, and in the past, this has presented problems concerning storage, speed, and maintenance. The prior personal geodatabase that had been based on Microsoft Access had a size limitation of two gigabytes. The newer file geodatabase has corrected this issue and contains an unlimited amount of storage space.

The geodatabase model implements smarter behaviors into features, making them realistic to the real-world scenarios and easier to edit and manage. These advanced geodatabase features include attribute domains, subtypes, relationship classes, topology, geometric networks, and versioning. The author will not discuss all of the features, instead focus on the advanced tools needed solely for this project. These include feature datasets, feature classes, object classes, attribute domains, subtypes, relationship classes, and topology rules. These advanced characteristics were developed to help manage, edit, store, and create relationships between GIS features.

An attribute domain is used to establish allowable data in an attribute table. Domains provide a specification for valid values of a field including value domains, lists

²⁵ ESRI. *Elements of Geographic Information*.

of values, and standard classifications.²⁶ All domains have a name, description, and applied attribute. There are two different types of attribute domains: coded value and range domains.

A coded value domain can apply to any type of attribute such as text, numeric, date, etc. Coded domains specify a valid set of values for an attribute.²⁷ Domains are created for field types to limit the input of data insuring data consistency. For example, bar, Powder River, and wire are the three types of gates on BLM lands. A coded attribute domain is created to ensure only these three selections are available when entering data.

Range domains are used to specify a valid range of values for a numeric attribute. For example, in the stream feature class within the Hydrology discipline, there are numeric codes to represent channel material. These codes range from 0-7 and are attached to stream channel definitions. In this case, a range domain of 0-7 is created to ensure consistency within the database. In this field, if an eight were created in the attributes, the system would warn that this characteristic is not allowed.

Editing spatial databases is highly subject to human error. A misspelled word, spaces before or after characters, or using the wrong characters are all common mistakes in editing large databases. These mistakes will affect any queries or analyses focusing on those attribute values. Coded and range domains are tremendously useful in establishing data integrity and ensuring database consistency.

Although all objects in a feature class or object class must have the same behavior and attributes, not all objects need to share the same default values and validation rules.²⁸

²⁶ Arctur, David and Michael Zeiler. *Designing Geodatabase: Case Studies in GIS Data Modeling*. ESRI: Redlands, California, 2004, 11.

²⁷ MacDonald, *Building a Geodatabase*, 131.

²⁸ MacDonald, *Building a Geodatabase*, 468.

Attributes may be grouped in to subtypes using coded values defining special rules. Subtypes allow grouping of different domains without having to create another feature class. Subtypes ultimately enhance performance and manageability of any GIS system, by using different attribute domains within the identical attribute field.²⁹

Building relationship classes, between tables, is another way to organize data in a more proficient and effective manner. Relationships can be created between feature classes, feature classes and nonspatial tables, or two nonspatial tables. Relationships connect objects in a geodatabase. Spatial objects are stored in the geodatabase under feature classes, and non-spatial tables are stored in tables. The relationships between the two are housed in relationship classes.³⁰

The purpose of a relationship class is to link datasets between interrelated data using unique identifiers. The unique identifier is used to link two data types, using an identical field found in both database tables. Benefits in relationships include easy access to related data, effective data storage, and quicker data edits and performance.

Simple and composite are two types of relationship classes. Both relationship classes contain an origin table and a destination table. In a simple relationship, the tables are independent of one another, while in a composite relationship the origin table controls the destination table. In a composite relationship, if an object were deleted from the origin table, that object also will be deleted in the destination table. This project only requires simple relationship classes.

Cardinality in relationship classes is important when defining associations between datasets. A relationship's cardinality specifies the number of objects in the

²⁹ Arctur, *Designing Geodatabase*, 14.

³⁰ MacDonald, *Building a Geodatabase*, 147.

origin class in relation to the number of objects in the destination class. A relationship class may have one of three cardinalities.³¹ These include one-to-one (1-1), one-to-many (1-M), and many-to-many (M-M) relationship class.³² Figure 4 displays these relationship classes. Note: The asterisk represents many.

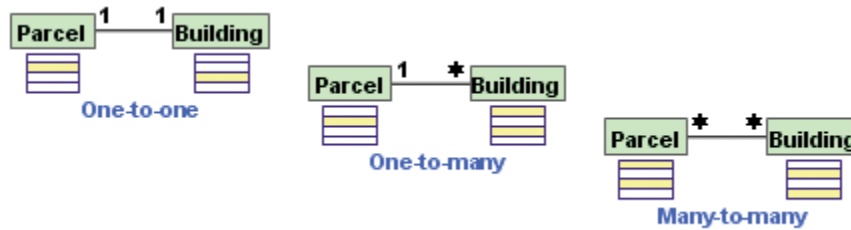


Figure 4, Relationship Classes.

The one-to-one and one-to-many relationships are implemented in this project, and ideally suited for the diverse functions crucial in resource management. A one-to-one relationship class links identical fields from one table to another, and permits one feature description for each table. This functionality allows data to be categorized according to data substance and topic. A one-to-one relationship groups data from a single geospatial feature, and prevents over-sized feature classes and databases.

The one-to-many relationship class permits the documentation of multiple records in the destination table. Until recently, a single geospatial feature did not possess the capability of multiple recordings. Instead, additional feature classes had to be created, or they were added to one feature class, creating an absurdly large and cumbersome database. The one-to-many relationship class is ideally suited for monitoring, permitting a single feature to be documented numerous times on separate occasions.

³¹ Environmental Systems Research Institute. 2007. *ArcGIS 9.2 Relationship Class Properties*. Redlands, California. Available from Internet, http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=2117&pid=2113&topicname=Relationship_class_properties, accessed 18, January 2008.

³² ESRI. *ArcGIS 9.2 Relationship Class Properties*.

Topology is another advanced feature to be examined in this project. Topology is the arrangement for how point, line, and polygon features share geometry. A topological association means that some parts of a feature's shape share the same location and different feature classes in a feature dataset often share geometry between them.³³

The benefits of topology include:

- Constraining how features share geometry. For example, adjacent polygons such as parcels have shared edges; street centerlines and census blocks share geometry; adjacent soil polygons share edges; etc.
- Definition and enforcement of data integrity rules (e.g., no gaps should exist between polygons; there should be no overlapping features; and so on).
- Supporting topological relationship queries and navigation (e.g., to navigate feature adjacency and connectivity).
- Supporting sophisticated editing tools (tools that enforce the topological constraints of the data model).
- Constructing features from unstructured geometry (e.g., to construct polygons from lines).³⁴

Topology defines validation rules within the design format to ensure data integrity. Topology rules enable less error, follow guidelines, and provide data integrity. Figure 5 contains examples of topology with their integrity rules and associated feature types.³⁵

³³ MacDonald, *Building a Geodatabase*, 468.

³⁴ Environmental Systems Research Institute. 2007. *ArcGIS 9.2 An Overview of Topology*. Redlands, California, Available from Internet, http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_topology_in_ArcGIS, accessed 18, January 2008.

³⁵ Environmental Systems Research Institute. 2007. *ArcGIS 9.2 Topology in ArcGIS*. Redlands, California. Available from Internet, http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Topology_in_ArcGIS. Accessed 29, November 2007.













 <p>Points</p>	 <p>Points on points</p>	 <p>Points on lines</p> <p><i>Must be covered by endpoint of Point must be covered by line</i></p>	 <p>Points on polygons</p> <p><i>Must be properly inside polygons Must be covered by boundary of</i></p>
 <p>Lines</p> <p><i>Must not have dangles Must not have pseudo-nodes Must not overlap Must not self overlap Must not intersect Must not self intersect Must not intersect or touch interior Must be single part</i></p>	 <p>Lines on points</p> <p><i>Endpoint must be covered by</i></p>	 <p>Lines on lines</p> <p><i>Must not overlap with Must be covered by feature class of</i></p>	 <p>Lines on polygons</p> <p><i>Must be covered by boundary of</i></p>
 <p>Polygons</p> <p><i>Must not overlap Must not have gaps</i></p>	 <p>Polygons on points</p> <p><i>Contains point</i></p>	 <p>Polygons on lines</p> <p><i>Boundary must be covered by</i></p>	 <p>Polygons on polygons</p> <p><i>Must be covered by feature class of Must be covered by Must not overlap with Must cover each other Area boundary must be covered by boundary of Tessellate</i></p>

Figure 5, Topology Rules.

Chapter Review

The purpose of this chapter was to familiarize the reader with the GIS concepts, terminology, and methods that are involved in this work. This chapter presents the basic concepts associated with GIS, and the advanced functionality of the newer ESRI® geodatabase model. Organization and structure, descriptive mapping elements, projections, tabular attribute data, relationship classes, and topology rules are a few GIS components discussed in this chapter. The following chapter discusses the methodology required to design the geodatabase model produced as the result of this research. The conceptual and logical designs concepts are the focus of this section.

CHAPTER THREE

METHODOLOGY

Introduction

The fundamental principles behind planning a successful GIS are based on an attempt to discover its real purpose, and decide what output and information is needed.³⁶ The research and design of a geodatabase is a critical stage in ensuring its effectiveness and proficiency. If designed incorrectly, the organization's GIS will not function to its full potential, essentially creating problems for the user.

To harvest a GIS's full potential requires coordination, understanding, collaboration, and an enterprise view of GIS management.³⁷ Roger Tomlinson is a pioneer in GIS design since its inception and is considered one of the fathers of GIS. He said it best, "Like a good roadmap, an overview of the method lets you know where you are going."³⁸

One key component for a successful GIS is the people involved in researching, organizing, and designing the system. To be effective, the organization must work in conjunction with GIS specialists to determine the necessary elements, and geographic data needs. The GIS specialist is essential in understanding the functional capabilities of GIS, while the resource specialists are necessary to establish the agency's geospatial needs. It is imperative the GIS Specialist understands the job responsibilities, as well as the methods and techniques used to accomplish these objectives. The resource specialist on the other hand, needs to understand the basic concepts of GIS to communicate their needs accurately.

³⁶ Tomlinson, *Thinking About GIS*, xiii.

³⁷ Tomlinson, *Thinking About GIS*, xiii.

³⁸ Tomlinson, *Thinking About GIS*, 7.

The author of this thesis has worked extensively on multiple GIS projects with the various resource specialists, and assisted them on numerous field assignments. The author has a background in Environmental Science, and repeatedly inquired on the methods, techniques, and basic understanding of the multiple disciplines. In the past four years, the goal has been to develop a comprehensive understanding of the scientific background of the Missoula Field Office's practices. As a result, numerous discussions and informal interviews about each discipline took place on various occasions.

The design of a geodatabase is critical, and if done correctly, will ensure an efficient and valuable GIS for any organization. A well-designed geodatabase will ultimately help document, organize, edit, manage, and analyze the Missoula Field Office's geospatial data.

Approach

This thesis will concentrate on the GIS design in the most recent geodatabase format, using all of its pertaining technical functionality. The main priority is to design a proficient GIS system based on the needs and responsibilities of the resource specialists.

As mentioned previously, the Missoula Field Office is broken down in to two primary departments, Renewable and Non-Renewable Resources. Within these resources, disciplines are used to categorize the individual sciences or special interests. There are a total of 11 resource disciplines, while only six were chosen to for this study. These include: Archaeology, fisheries, hydrology, range, recreation, and wildlife resources.

Purposeful sampling was used to select these six resource disciplines to maximize and increase the effectiveness of this design. Purposeful sampling is a non-random method of sampling where the researcher selects information-rich cases for in depth study. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research.³⁹

These six disciplines were chosen for their heightened need for data design, geospatial data requirements, monitoring needs, and overall size. The research and design of all eleven disciplines would constitute a massive undertaking, too large for this type of study. These six disciplines adequately illustrate the inner workings of the BLM, and in some cases, share similar responsibilities to the remaining five disciplines. All eleven disciplines share parallel methods and techniques, and utilize familiar goals and responsibilities. The six resource disciplines are suitable for this project because they dictate the projected size of this project, and contain universal techniques and practices utilized by all disciplines.

The remaining disciplines include: Lands and reality, engineering, geology, weeds, and forestry resources. Various factors influenced the decision not to use these disciplines. Lands and reality is strictly structured by the state office, and contains the majority of data standards, limiting its design potential. Engineering was not selected because of its different subject matter and lack of GIS use. Geology seemed to require the least amount of attention due to the slow change in geologic features over time. The weeds discipline is transitioning between specialists, which limited the correspondence

³⁹ Zint, Dr. Michaela. *Purposeful Sample*. My Environmental Education Evaluation Assistant (MEERA). Available from Internet, <http://meera.snre.umich.edu/links-resources/ploneglossary.2007-10-17.0963842348/ploneglossarydefinition.2007-11-06.1964294990>, accessed 26 July 2008.

necessary for this project. And forestry was too large, almost warranting its own separate design study.

The spatial reference system utilized by the Missoula Field Office will have to be defined before the design steps are implemented. These mapping elements include the Albers Equal Area Conic projection used by the BLM for all of their mapping, and the NAD83 datum. The parameters of the projection include the central meridian, and two standard parallels. These are locations needed to create the custom projection utilized by the Missoula Field Office. The datum will also be discussed in this step. These terms were discussed in detail in the GIS section of chapter two.

The methods and techniques used to design geodatabases were developed by ESRI®, and are examined in this project. The methodology for this project incorporates ESRI's design techniques and applies them to Missoula Field Office's geospatial data needs. In some instances, ESRI's design methods and techniques are not appropriate for this design, in which case design modifications have been implemented to accommodate the specific interests of this design.

The ESRI® geodatabase design contains three phases: conceptual, logical, and physical. The conceptual phase examines the research component, the logical phase illustrates the design elements, and the physical phase discusses the implementation of the geodatabase design. This project will not physically implement a geodatabase; therefore only the conceptual and logical steps will be accomplished. This work concentrates solely on identifying the agency's needs and requirements, and designing the geodatabase components necessary for a successful land management based system. The conceptual and logical design phases include:

Conceptual Design

- 1) Model the User's View of Data
- 2) Define Geographic Data Entities
- 3) Identify Representation of Entities

Logical Design

- 1) Match to the Geodatabase Model
- 2) Organize into Geographic Datasets
- 3) Diagram Geodatabase Model⁴⁰

Data developed in a geodatabase will guarantee advantages over the previous GIS formats used by the Missoula Field Office. Organizing the data will allow for easy access and functionality and will improve user efficiency. Data will also contain relationships between datasets, be user-friendly, and retain integrity through establishing topology rules. Design is the process in which goals are defined, while alternatives are identified, analyzed, and evaluated.⁴¹ The development of an effective and comprehensive geodatabase will assist the resource specialists greatly in documenting, organizing, maintaining, and analyzing their data in an efficient and effective geodatabase structure.

Conceptual Phase

Conceptual design is the research phase of designing a geodatabase model. This phase helps identify and characterize all data requirements. Resource disciplines are analyzed and their data needs assessed based on agency requirements and responsibilities.

Resource specialists and the author have worked closely with one another to determine what GIS elements are necessary. An abundance of correspondence has taken place between the resource and the GIS specialist. The GIS specialist has worked closely with the specialist when producing GIS projects, and also in field operations.

⁴⁰ Zeiler, *Modeling Our World*, 184.

⁴¹ Zeiler, *Modeling Our World*, 182.

There is also a large amount of training between these specialists. In the past four years, GIS training has occurred on a number of occasions. Advanced GIS education assists the resource specialist in understanding the capabilities of GIS, helping the specialists determine their geospatial needs. The GIS specialist has also been proactive in improving his general knowledge concerning various land management practices with the aim of gathering natural resource knowledge and improving the overall efficiency of the GIS. He has attended numerous meetings on a regular basis that discussed the methods and techniques used by all Missoula Field Office personnel. Moreover, he has taken advanced training when applicable, and heightened his land management knowledge.

When the GIS and resource specialists work well together, both parties welcome the final result at the same time, gaining a sense of ownership of the product. The GIS and resource specialists will also develop an invaluable knowledge of each other's profession, and of the geodatabase design itself.⁴² A productive and efficient GIS requires a healthy and eager relationship between these specialists to improve the knowledge in all areas of expertise. If this does not occur, the final product will less likely be accepted.

The final result of this phase produces the main geodatabase datasets. These main datasets consist of feature classes and object classes, which were identified based on the needs of the resource disciplines and potential GIS functionality. The data was assimilated into one category identifying its geographic component such as the type of feature class (point, line, or polygon) or object class (table). Relationships and advanced functionality were considered throughout this process, yet finalized in the logical phase.

⁴² Zeiler, *Modeling Our World*, 183.

The spatial reference system was defined before the design steps were initiated. The Montana/Dakotas BLM defines the current spatial reference system. The Montana/Dakotas Albers Equal Area Conic projection that is used by the BLM encompasses North Dakota, South Dakota, and Montana, covering the entire geographic area of these three states.

1) Model the User's View of Data

This step in the conceptual phase studies the needs and responsibilities of each resource specialist. This is basically a needs assessment, the foundation of any effective geodatabase model. A needs assessment is the process required to evaluate the needs and requirements of the GIS system. The resource disciplines were studied and evaluated by using their job descriptions, daily and annual responsibilities, agency requirements, regulation management, mapping products, and operational guidelines.

Resource specialists are responsible for documenting multiple data types, using multiple data sets. Data requirements were addressed to identify geographic data needs. Data needs include: resource inventory, federal regulations, habitat identification, man-made structures, environmental structures, topography, resource monitoring, health conditions, diversity conditions, treatment projects, etc. Existing data records were major contributing factors important to the detail of the design. Within the Missoula Field Office, there is a wealth of geospatial data located in a number of locations, including hardcopy-filing methods. This data may be entered in to a GIS system rather easily capturing this critical historical data.

Essentially, the agency's responsibilities and actions determine the GIS data and geodatabase schema required. If geographic responsibilities and data are overlooked, the

system will be incomplete and will not function to its full potential. The research process is the most crucial by identifying the ingredients necessary for the system to work by examining the responsibilities of the agency or organization.

2) Define Geographic Data Entities

The purpose of this stage of the conceptual phase is to identify and group the key geographic entities required to accomplish job tasks and responsibilities. For instance, the wildlife biologist may want to document bird survey routes for monitoring, furthermore recognizing the need for a road feature delineating the bird routes, and actual monitoring data. This step converts the need (bird monitoring), into established actual geographic elements (bird route layer), and object classes (bird monitoring data).

Defining the geographic data entities requires a transformation from the ideas and needs into the creation of concrete feature classes or object classes.

Defining the geographic entities involves identifying and describing the objects necessary for the specialists to accomplish their work. The result will identify the GIS data in their individual entities, and establish objects or tables required to capture their geospatial data needs. The outcome provides the individual data entities, and the following stage analyzes these data categories in further detail. Multiple datasets were identified for each discipline, without exploring the intricacies of the data further. The object is to roughly organize the data into categories, making sure that every element of their needs are met.

3) Identify Representation of Entities

The geographic entities are broken down further in this stage to represent points, lines, polygons, or tables (object classes). The objective of this phase is to determine

how data is grouped and represented in the geodatabase model by classifying entities according to their type of representation.⁴³ As with the previous steps, this step is established during the discussions between the GIS and resource specialists.

Some entities will contain a geometric representation with corresponding attributes, while others will be represented by alphanumeric information only, or photographs. The detailed aspects of the relationships are introduced in the following sections, such as their attributes, connective components, etc. This section considers the following: whether the features are represented on a map, whether the feature shape is needed for analysis, whether cartographic illustration through relationships can be preformed, and whether textual attributes of the feature will be displayed on the computer screen.

These three stages are developed simultaneously for each resource discipline, and included in the conceptual section under each resource discipline. The conceptual research section begins by researching a discipline's responsibilities, and concludes with a list of the basic GIS datasets necessary to reach their goals.

Logical Phase

The logical phase illustrates the complexity of the geodatabase including all design elements required to establish a productive system. All design elements are based on the previously determined data needs described in the conceptual phase of design. The logical phase illustrates data specifications, structure, relational properties, and topology rules. This phase requires the development of representation specifications, relationships, and ultimately, geodatabase elements and their properties.⁴⁴ It identifies

⁴³ Zeiler, *Modeling Our World*, 190.

⁴⁴ Arctur, *Designing Geodatabase*, 8.

the tabular data, gives data definitions, identifies relationships, and accounts for topology. The logical phase basically takes the data researched in the conceptual design and plugs it in to a geodatabase model.

The responsibilities, tasks, and obligations for each resource discipline are further discussed and broken down in to their individual database components in this phase. Data types, record length, field descriptions, subsets, domains, relationships, and topological relationships are examined in further detailed, requiring additional evaluation of the data.

The geodatabase infrastructure is identified, documented, and defined down to its finest detail within the logical phase. Feature classes, feature class attribute tables, stand-alone tables (object classes), subsets, domains, and relationship classes are all documented, which identify all necessary components to build a complete geodatabase. Subsets, domains, and relationship classes are also designed within this phase. Relationships and topologies are considered throughout the conceptual phase, and defined in the logical phase for each resource discipline. Topology rules are identified at this time, which will assign integrity rules between datasets.

1) Match to the Geodatabase Model

The focus now turns from understanding the user requirements to developing an efficient and effective database schema. Schema refers to the structure or design of a geodatabase. The expertise of the GIS specialist in geodatabase modeling, GIS functionality, and analytical capabilities is critical in this phase. Understanding these GIS components is essential in designing the data in the most proficient and effective manner.

This stage assesses all previously determined categories of data one at a time, examining all required data, and their descriptions. This step identifies attribute fields, data types, field descriptions, character size, associated domains, and sub-types. Results of this stage are descriptive tables for each layer or table organized by resource discipline. The data elements are dissected in greater detail, and the fields and records for each database will be created and described.

This stage is an extremely lengthy one, and requires both the GIS and resource specialists. The GIS specialist is responsible for the details and functionality of the geodatabase design, while the resource specialist assists in communicating what data is necessary for each determined dataset.

2) Organize Geodatabase Structure

The feature classes are divided into feature datasets within this step. Feature datasets are organized according to data similarities and assigned integrity rules based on topological relationships. Topology rules are defined, and each dataset will address these integrity rules following the discipline's section of this paper. Relationships are also defined within this section, illustrating the relationship type, cardinality, and key fields in origin and destination tables. Results of this stage outline the feature datasets, relationship classes and their descriptions, and topological definitions.

3) Create Geodatabase Model Diagram

This stage develops a model in the form of a flow diagram to help users visualize the data properties and relationships between data sets. Such a diagram will allow the reader to better interpret vast amounts of information created by displaying the data and

associated relationships. Due to the intricacy of this work, a visual representation is necessary to illustrate the datasets, relationships, and organizational structure and flow.

A comprehensive and complete architecture of the Missoula Field Office's geographic data in a geodatabase structure would assist in organizing, identifying, documenting, displaying, and analyzing resource and land management data in a systematic manner. The results will capture the geographic elements necessary to assist the resource disciplines, and they will contain the personalized geodatabase functionality needed. Fortunately, the lack of data standards and paucity of digital data currently possessed by the Missoula Field Office allowed the author the freedom to design this system with only minor limitations.

Chapter Review

The methodology used to accomplish this work has been established in this chapter. First, six resource disciplines were chosen using a purposeful sample. The reasons these resource disciplines were articulated and the reasons the remaining five were not chosen were discussed.

This chapter outlined the sequential steps necessary to develop a successful geodatabase design for the six resource disciplines. The first three steps were used to develop the conceptual model, to classify features based on an understanding of the data required to support the organization's functions, and to decide upon their spatial representation (point, line, polygon, or table). The last three steps were then used to develop the logical data model that matches the conceptual model to actual ArcMap geographic datasets.⁴⁵ This chapter also discussed the importance of database design,

⁴⁵ Zeiler, *Modeling Our World*, 184.

distinguished the facets involved in design, and identified the procedure needed to accomplish this work. The next chapter will illustrate the geodatabase model.

CHAPTER FOUR **GEODATABASE DESIGN**

Introduction

Chapter Four outlines the spatial reference system currently in use by the Montana/Dakotas BLM, identifies base map data, researches the GIS needs of the six chosen resource disciplines, and identifies the appropriate data that will be inserted into the geodatabase model. The spatial reference is predetermined from the Montana/Dakotas BLM projection. The conceptual design phase addresses the research conducted, and the logical design phase illustrates the resulting geodatabase design.

Spatial reference and scale will be discussed within this chapter. Spatial reference is an important concept in establishing the geometric foundation for any mapping product. It is essential to research and choose the appropriate projection and datum before any geographic mapping elements are produced.

Base map data is another important component in geodatabase design, and will be addressed in this chapter. Base map data provides the essential locational information necessary for geographic reference, data support, and additional analytical ability.

Following the base map section, the chosen six resource disciplines including archaeology, fisheries, hydrology, rangeland, recreation, and wildlife will be discussed in great detail. Within each resource discipline, the conceptual and logical design phases of the geodatabase creation are identified and discussed.

The results of this chapter will consist of a geodatabase design describing all details of this work. Geodatabase design is the foundation for all functional activities with a GIS including: creating expressive maps, retrieving information, and performing

spatial analysis.⁴⁶ It is anticipated that if this geodatabase design were to prove successful for the Missoula Field Office, other BLM offices or resource agencies could adopt many of its components.

SPATIAL REFERENCE

Before a geodatabase can be designed for the Missoula Field Office, the basic spatial geometry of the geodatabase must be reviewed. The spatial reference is the geographic information including the projection or coordinate system, and datum that the agency uses for mapping display. These geographic mapping elements will be addressed in this section.

The Montana/Dakotas BLM Region has chosen the Albers Equal Area Conic Projection (Albers) as their principal projection. Projections inevitably lose some spatial properties when the image of the earth is transferred from a sphere to a flat surface. However, one or more properties can be retained as they are on the globe depending on the characteristics of the specific projection.

A resource and land management agency prefers emphasizing the importance of area as the primary spatial property. Equal area projections portray the area of a map proportionate to the actual area of the earth's surface. The projection requires a central meridian, two standard parallels, and latitude of origin.

Figure 6 illustrates the standard parallels for North America. Notice how the standard parallels are centrally located in the northern and south halves of North America. Distortion in this area is minimized in the region between the standard parallels and most accurate in the areas between these parallels. The Albers projection is more appropriate for areas extending from east-to-west, than areas extending north-to-south.

⁴⁶ Zeiler, *Modeling Our World*, 181.

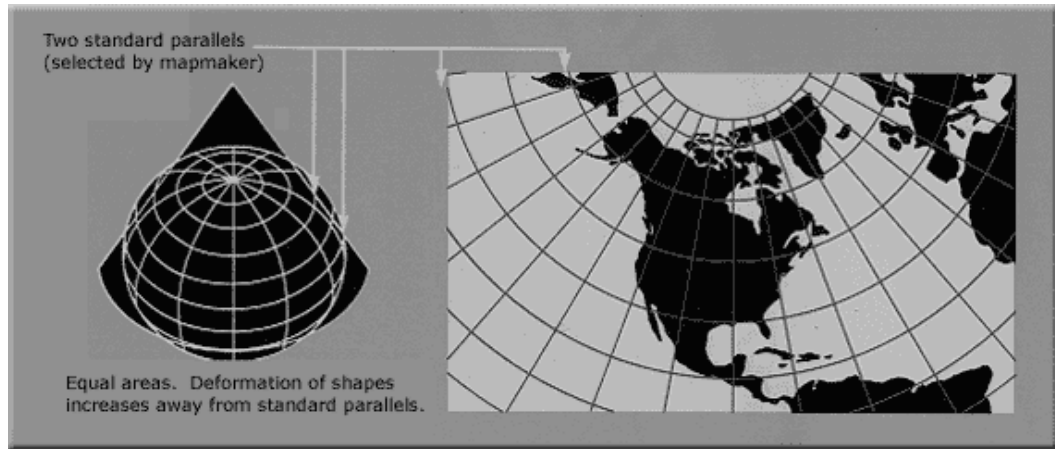


Figure 6, Albers Equal Area Projection.⁴⁷

The central meridian is the longitude line in the middle of the area of interest. Standard parallel one is located in the middle of the northern half of the area of interest. Standard parallel two is located in the middle of the southern half. The latitude of origin is selected from the center most latitude. The Montana/Dakotas BLM selected the following parameters to incorporate North Dakota, South Dakota, and Montana into one projection that would work for the entire region (Table 1).

Table 1, BLM Albers Projection.

Central Meridian	-106
Standard Parallel 1	43.5
Standard Parallel 2	48
Latitude of Origin	42.5
Datum	NAD 83

Generally, equal-area projections are not created on such a massive scale, because distortion occurs on the outer edges of the area. The larger the area, the more distortion is present. This is predominately evident when viewing cartographic products in western Montana and eastern North and South Dakota when the above projection is used. The

⁴⁷ U.S Geological Survey. *Map projections*. Washington D.C. On-line. Available from Internet, <http://erg.usgs.gov/isb/pubs/MapProjections/graphics/albers.gif>, accessed 23 December 2007.

BLM Albers projection distorts western Montana in a clockwise direction approximately five degrees. This distortion can be corrected in ArcMap by adjusting the cartographic display five degrees to the west.

The Montana/Dakotas BLM Region has opted to standardize all geospatial data in the three-state Albers Equal Area projection for various purposes. Their data is comprised of seamless datasets, encompassing the extent of Montana, South Dakota, and North Dakota. The Missoula Field Office also contains, or is in the process of obtaining, seamless datasets for its entire resource area. When the data is contained in the same projected coordinate system, the datasets can be mosaiced with little or no edge-match errors.

The datum chosen for best results is the North American Datum 1983 (NAD83). NAD83 is the survey conducted for North America in 1983. This datum is necessary to account for the irregular shape of the earth's surface, or geode. The resource specialists collect and work with their data at a large scale of approximately at the 1:24,000. This scale translates to one map unit represents 24,000 units on the ground.

The next section will discuss the base map data used by all resource disciplines necessary to reference their specialized geospatial data. This data is either collected from the BLM, or obtained from external sources.

BASE MAP DATA

Conceptual Phase

This geodatabase will contain a collection of base map layers used by all resource disciplines to orient geospatial elements on a map, associate specialized data with surrounding features and geographic elements, and provide all maps with additional

analytical capabilities. Base map data varies in every GIS system depending on the objectives of the organization. Base map data may include things such as infrastructure, management boundaries, land survey data, and natural environmental features. Land management organizations utilize major geographic features such as roads, rivers, elevation, and watersheds. They also use man-made boundaries such as ownership, county boundaries, and the Public Land Survey System (PLSS).

The base map data for this project may be obtained directly from the Missoula Field Office, the state office, or external sources. The layers needed are all contained in shapefile format, and will need to be upgraded to feature classes. The layers may also contain basic fields and attributes, or a complex database. In the case where they contain large and extensive amounts of data, they will be down-sized to contain the essential data elements necessary for this design.

The base map data included in this project provides orientation, contains direct relationships to the object classes, is essential to establish topology, or necessary to perform analytical functions. Some basic locational data will also be added for reference purposes. The base map data chosen for this project includes: roads, streams, Public Land Survey System (PLSS) information, ownership boundaries, watershed boundaries, contours, cities, and county boundaries. As this geodatabase evolves, other base map information may be added as needed.

Roads are a vital dataset necessary to the BLM, or any land management organization by providing access, supplying direction, connecting land management resources, and regulating activities. The Bureau's transportation system represents one of the most critical assets to the accomplishment of the BLM's mission to manage public

lands. BLM roads are the infrastructure of BLM lands that allow the access needed to support all public and commercial activities.⁴⁸

The Missoula Field Office's Lands and Realty discipline developed a shapefile road layer, which is adequate for this project with only minor manipulation. The roads layer contains remote BLM lands and the state and federal highways linking the BLM's scattered lands.

This road layer will be updated to a feature class, and used to create specialized layers such as the road restriction feature class in the recreation discipline, and the Bird Route feature class in the Wildlife discipline. The roads will also be used to develop topology between other feature classes.

Rivers and streams are a vital component to land management objectives. Streams are used as reference material for orientation purposes, focal points for analysis within the fisheries and hydrology disciplines, and used for multiple evaluations and analyses by many other resource disciplines.

The United States Geological Survey (USGS) has completed a valuable stream shapefile layer called the National Hydrology Dataset (NHD). The NHD contains accuracy that is appropriate for the scale of 1:24,000, which makes it ideally suited for Missoula Field Office. This stream layer can be upgraded to a feature class and utilized to create three object classes within this design, including a fish presence table in the fisheries discipline, and riparian habitat and stream morphology in the hydrology feature dataset. This layer will also be used to develop topology for a number of datasets. These layers will be linked using the National Hydrographic Dataset identification number

⁴⁸ U.S. Bureau of Land Management: *Highlights Report: Asset Management Program*. Washington D.C: Government Printing Office, 2006.

(NHDID). The NHDID identifies stream segments from one junction of the stream to another. The NHD layer contains a massive attribute database, which will be scaled down for the design purposes of this project.

The Geographic Coordinate Data Base (GCDB) is a collection of geographic information representing the Public Land Survey System (PLSS) derived from surveys conducted by the United States. The GCDB data layers are frequently utilized by the BLM for orientation. The GCDB grid is computed from BLM survey records (official survey plats and field notes), local survey records and geodetic control information. A number of Federal agencies, local governments and private companies use the GCDB data as the foundation for their geographic orientation and points of reference.⁴⁹

The boundaries of the GCDB are based on the township and range survey method. The township is the largest component and named in accordance with a principal meridian and a baseline. For example, T9N and R3E is a reference to Township 9 north of the baseline, and Range 3 east of the principal meridian. Each township contains 36 sections, approximately one square mile each. This layer will not be used to create feature classes or tables, instead assist in referencing the Missoula Field Office's resource data.

Land ownership is an important geographic component used by the Missoula Field Office for a number of reasons. Ownership is used to accommodate partnerships on projects with parties that share similar land management goals and objectives.

Ownership also assists specialists in obtaining right-of-ways, access to areas, and is useful in dictating multiple land management activities. The Missoula Field Office's

⁴⁹ U.S. Bureau of Land Management: *Geographic Coordinate Database (GCDB)*. Washington D. C: Government Printing Office, On-line. Available from Internet, <http://www.blm.gov/wo/st/en/prog/more/gcdb.html>, accessed 31 July 2008.

Lands and Realty discipline has created and maintained an ownership layer. It is fairly basic ownership layer that contains a handful of useful field categories.

The Missoula Field Office conducts environmental assessments based on a watershed management scale. A Watershed is a physical landscape defined by its elevated ridges with one outlet for water to flow. Watersheds support a variety of resources, uses, activities, and values, where everything is linked in such a way that eventually all things are affected by everything else in the watershed.

Watershed management is a concept of approaching land management activities by recognizing the interconnectivity of all natural resources in a watershed. It uses the watershed as the bases for evaluating and planning all activities, and considers the effects of their assessments on additional environmental elements.⁵⁰ The Missoula Field Office contains a basic watershed shapefile containing the BLM lands. The watershed layer will prove useful when analyzing data for many management activities.

Contours are another important geographical component utilized by the Missoula Field Office. Contours provide a map with topography data by connecting line features of similar elevations. Contours are created in Spatial Analysis, a raster based extension in ESRI's ArcMap 9.2 software. Contours are developed using a Digital Elevation Model (DEM), and running a fairly simple process in either the 3D Analyst or Spatial Analyst extensions. A simple focal statistics resampling was used to filter the DEM before contour analysis was performed. The focal statistic method of resampling smoothes the DEM, in turn producing smoother contour lines.

⁵⁰ U.S. Bureau of Land Management: Department of the Interior. *Soil, Water, and Watershed Management*: Washington D. C: Government Printing Office, On-line. Available from Internet, <http://www.blm.gov/ca/st/en/fo/eaglelake/watershed.html>, accessed 31, July 2008.

The author has created a 100-foot contour layer encompassing the three counties that contain the Missoula Field Office surface lands. The 30-meter resolution DEM was gathered from Montana's Natural Resource Information System (NRIS), but it was originally created by the USGS. The DEM contains elevation pixels at a 30 by 30-meter square area. Please refer to chapter two in the Geographic Information Systems section for more details. This layer will be used strictly for elevation display, and the 100-foot intervals will be labeled to assist the user.

Cities are another geographic entity used in many base map data schemes. Cities and towns reference the map-reader with geographic locations relative to other resource data. NRIS has provided a downloadable city point shapefile, which was created by the USGS. This layer will be used for its geographic point location and ability to label city's names.

The Missoula Field Office also uses counties for geographic referencing. A county polygon shapefile is available from NRIS created by the United States Census Bureau. This shapefile will be used primarily for map display and county labeling.

Nine base map layers will be used in this project to supply locational data for orientation, support resource data, label reference material, and ultimately provide a spatial foundation for cartographic display. These nine feature classes include: Roads, streams, township data, section data, watershed boundaries, contours, cities and counties.

Logical Phase

The intent of the logical phase is place the previously determined base map data in to the geodatabase model. These layers will contain Microsoft Excel tables to

illustrate their design elements, and definitions to explain the important components necessary to fulfill this project’s objectives.

Base Map Feature Dataset

Nine base map feature classes were designed within this project to orient geospatial elements of a map, associate relational data created in the design, and provide resources with analytical ability. The Base Map feature dataset will include things such as infrastructure, management boundaries, land survey data, and natural environmental features.

Road Feature Class

The road layer is a line feature class, which provides access, supplies direction, connects land management resources, and regulates activities on BLM lands. This layer will primarily be used for display, and route numbers labels will be placed on each road. Topology rules will also be created between roads and the gate layer to ensure the gate layer’s data integrity. This geographic coordinates of this road layer were also used to create the road restriction feature class located in the recreation feature dataset (Table 2).

Table 2, Road Feature Class.

Road Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
RdName	Text	30	. . .	Name of the Road
rt_fam_num	Short Integer	6	. . .	Route Identification Number
rt_type	Text	3	. . .	Inventory Date

The Road Name (RdName) identifies the name of the road if applicable. Many BLM roads only contain route numbers, not names, although county, state and federal roads will need this information for labeling purposes. The road layer contains a data standard adopted by the Montana/Dakotas region, identifying their roads using route

numbers. The route numbers are identified by a 6-digit numerical code, beginning with the two-digit county code, and the remaining four are categorized in the order of their creation. For example: The first BLM road created in Powell county is 280001. The 28 identifies the road's location is in Powell County, and the 0001 indicates it was the first road created.

The important elements for this design were taken from the original road database. For the purpose of this project, only the geographic location of roads and the BLM route numbers are needed for this design.

Stream Feature Class

Streams will be used as reference material for orientation purposes, focal points for analysis within the fisheries and hydrology disciplines, and supply multiple evaluations and analyses for most resource disciplines. The streams will be used for basic map display, and their names will be labeled for orientation. This stream layer will help create the fish presence layer in the fisheries feature dataset and the riparian feature class located in the hydrology feature dataset (Table 3).

Table 3. Stream Feature Class.

Stream Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
StrOrder	Text	6	StrOrder	Order of Stream Size
GNIS_Name	Text	65	. . .	Stream Name
ReachCode	Short Integer	14	. . .	Stream Segment Number
Length	Short Integer	2	. . .	Length of Stream Segment

The Stream Order (StrOrder) field identifies the size of the stream, which may be used to display the different sizes on a map. The Stream Order (StrOrder) domain contains the options of (1) High, (2) Medium, and (3) Low. High refers to a larger stream

segment, and low refers to a smaller stream segment. The GNIS_Name field contains the stream name, and allows the ability to label these stream names on a map. The ReachCode field contains a 14-digit identification number, which will be utilized in the future to design further feature classes.

Ownership Feature Class

Ownership layers are an important asset in land management in providing partnerships on projects with the locations and names of neighboring agencies and organizations. Ownership assists specialists in obtaining right-of-ways, access to areas, and is useful in dictating multiple land management activities (Table 4).

Table 4, Ownership Feature Class.

Ownership Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
OwnName	Short Integer	30	. . .	Ownership Name
OwnNum	Short Integer	2	. . .	Ownership Code

The Ownership Name (OwnName) field identifies the owner of the land. This layer will be used for map display, and will assist the resource specialist in identifying BLM lands. The Ownership Number (OwnNum) contains the ownership 2-digit codes. The codes are randomly assigned to land ownerships, and used to reference Red Green Blue (RGB) values. The BLM’s ownership code is 10, which contains the RGB values for the yellow color used to standardize all BLM maps.

Watershed Feature Class

The watershed feature class contains the watershed boundaries necessary for the BLM to conduct analysis based on a watershed management scale. Watershed boundaries are used as a basis for evaluating and planning all activities, by considering

the effects of all environmental components as interconnected natural resources. The watershed boundary feature class is important for display purposes, using its geographic location and labeling capability. The watershed feature class also adds analytical ability using other specialized GIS data (Table 5).

Table 5, Watershed Feature Class.

Watershed Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
WSName	Short Integer	30	. . .	Watershed Name
WSNum	Short Integer	2	. . .	Watershed Number
Acre	Short Integer	6	. . .	Acres of Watershed

The Watershed Name (WSName) field allows this layer to be labeled, and its geographic location assists the resource specialist in making land management decisions.

The Watershed Number (WSNum) field gives a numeric identifier to each watershed.

The Acre field will give the actual acreage of the watershed.

Contour Feature Class

The contour feature class illustrates the terrain on a map by using interconnected linear features with shared elevations. Contours assist resource specialist in understanding the topography of an area, in navigating from place to place, and in conducting analysis. This layer will be used for map display and labeling capabilities (Table 6).

Table 6, Contour Feature Class.

Contour Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
Contour	Short Integer	5	. . .	Continuous Elevation Line

The contour feature class was created from a 30-meter DEM using 3D Analyst, an extension of ESRI's ArcMap 9.2. The Contour field contains the contour intervals specified by the software. The contour interval of 100 feet seems to produce the best results for the Missoula Field Office. These intervals can be labeled according to their elevation. As this geodatabase design evolves, a 40-foot contour is recommended by the author to use in the case of larger scale mapping and analysis. The 40-foot contours offer a wide array of analytical ability and orientation in large scale mapping products.

Township Feature Class

The township feature class contains the coordinates of the Township and Range survey. The township is the largest component and is named in accordance with a principal meridian and a baseline. The township polygons, combined with the next feature class, the section polygons, work together to give accurate geographic locations (Table 7).

Table 7, Township Feature Class.

Township Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
tier_no	Short Integer	2	. . .	Township Number
tier_dir_c	Short Integer	1	. . .	Township Direction
range_no	Short Integer	2	. . .	Range Number
range_dir	Short Integer	1	. . .	Range Direction

The township is named in accordance with a principal meridian and a baseline. The Township (tier_no) field identifies the number derived from the baseline, and the Township Direction (tier_dir_c) field identifies the north or south direction from the baseline. The Range Number (range_no) field identifies the number from the principle meridian, while the Range Direction (range_dir) field identifies east or west direction

from the baseline. The primary function of this layer is to illustrate the township area, while labeling them in their entirety. The four fields presented above can be combined in ArcMap’s label system to read T9N R3E.

Section Feature Class

The section feature class is a polygon layer used to combine with the township layer to display the complete survey system. Within each township, there are 36 sections that are approximately one square mile, or 640 acres in size. The sections can further be broken down into half sections or quarter sections. Additionally, quarter sections can be broken into half-quarter sections or quarter-quarter sections. This project only requires mapping to the section level, to accommodate the township and range polygons (Table 8). Many governmental agencies in the United States still rely heavily on the PLSS for orientational purposes.

Table 8, Section Feature Class.

Section Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
sec_	Short Integer	2	. . .	Section Number

The Section Number (sec_) field contains the section numbers 1 through 36. The layer will be used for display purposes, including the section number. The township feature class and section class will both provide the necessary survey data to assist resource specialist in locating specific areas of interest.

County Feature Class.

The Missoula Field Office is responsible for sub-surface minerals in nine counties. The core BLM lands with surface lands span over a three county area. All

nine counties will be used as base map data for this project. The county feature class is a polygon layer, (Table 9)

Table 9, County Feature Class.

County Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
CntyName	Text	30	. . .	County Name

The components of the county feature class necessary for this project include their geographic boundaries, and their county names. The County Name (CntyName) field contains the names of the counties, which will be used for display.

City Feature Class

The city feature class is a basic point layer used to identify the locations of cities, in addition to labeling their names on the map (Table 10). Cities are strictly used for orientation and navigational purposes.

Table 10. City Feature Class.

City Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
CityName	Text	30	. . .	City Name

The City Name field contains the names of cities used for map display. This layer is another feature used to orient the resource specialist, and support other reference data necessary for the base map's display.

Base map data is important in any GIS because it orients geospatial elements on a map, and supports other specialized data. It will provide each discipline with additional information that will enhance its analytical abilities such as the use of elevation and

watershed data for analytical reasons. Base map data provides orientation, navigation, geospatial analysis, and assists in decision-making for land management practices.

It is suggested and recommended that other base map data be added to this design as it evolves over time. Other raster datasets that are found useful in base map information may include satellite imagery, hillshade, slope, and aspect. Satellite imagery can be extremely useful for reference material, for conducting on-screen digitizing, for locating features, and for verifying data accuracy and integrity. Hillshade, slope and aspect are all created from DEM data. Hillshade is primarily used for esthetic elevation display, and hillshade and aspect are utilized for a wide variety of analytical processes. They were not addressed in this design because they were not relevant to the objectives of this thesis.

Base map data has the potential to be converted in to layer files. A layer file is a collection of similar geographic features for display on a map. A layer file references geographic data stored in a data source, such as a feature classes, and defines how they shall be displayed.⁵¹ Ultimately, layer files instill consistency and save large amounts of time, energy, and frustration in cartographic map creation.

Many of these base map layers contain a universal cartographic standard, and this standard would only have to be created once in ArcMap 9.2, and then saved out as a layer files. For most of these layers, the datasets are finalized, with no need for updates. The concept of layer files may be used with in-house cartographic mapping products, or downloaded in to data collection devices.

Layer files standardize symbology, and save large amounts of time and energy in map creation, without the need to research database components, manipulate data for

⁵¹ MacDonald, *Building a Geodatabase*, 465.

advanced display, or create label qualities. There would be no need to manipulate or investigate databases, create symbology, select RGB or CMYK, or create labels by customizing their properties. These base map layers will prove to be useful for all resource specialists for the variety of land management activities in which they are engaged.

ARCHAEOLOGY DISCIPLINE

Conceptual Phase

The archaeologist is responsible for preserving, protecting, and managing historic and cultural properties on BLM lands. The purpose of the archaeology discipline is to analyze the scientific and socio-cultural values of cultural resources, to provide a basis for allocation of cultural resources, to make cultural resources an important part of the planning system, and to identify information needed when existing documentation is inadequate to support a reasonable cultural resource-based land use allocation.⁵²

Archaeology data is only one of a few owned by the BLM that is considered sensitive data and not readably available to the public. The need to protect and preserve these cultural and historic areas is the primary reason this data is classified sensitive, and one method of protection is to ensure its privacy. The archaeologist is responsible for identifying, maintaining, and analyzing all historic and cultural entities located on BLM lands.

The responsibilities of the archaeologist include identifying and documenting all archaeological sites, isolated findings, and features. Inventories are prepared by conducting extensive ground surveys. Such inventories do not always result in the

⁵² BLM, *Garnet Resource Area Management Plan*, 94.

identification of archeological resources, but even then, they are extremely important for recording of all surveyed areas for future land management planning or analysis.

Archaeological sites and isolated findings are areas where historic or cultural resources have been discovered, and found significant. The Missoula Field Office defines an archaeological site as finding five or more features inside a twenty-five square meter area, or finding ten or more features inside a fifty square meter area. Isolated finds are items usually found outside an archaeological site. Isolated findings are classified as finding fewer than five features in less than a twenty-five square meter area. Basically, isolated finds represent low land use locations, while sites indicate higher land use areas.

Monitoring is another important component utilized by the Missoula Field Office archaeologist in protecting and preserving these cultural and historic entities. Both archaeological sites and isolated findings require monitoring to determine if any changes have occurred in these areas over time.

The National Register of Historic Places is the nation's official list of historical and cultural resources noteworthy of federal preservation. Authorized under the National Historic Preservation Act of 1966, the National Register is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect the United State's archeological resources.⁵³

The federal government is obligated to follow standard protocol for the National Register of Historic Places when classifying archaeological resources. Under the federal program, sites are classified as eligible or not eligible. An eligible site is considered culturally or historically significant, and meets one of four following criteria:

⁵³ National Register of Historic Places. *Welcome*. Washington D.C: Government Printing Office On-line. Available from Internet, <http://www.nationalregisterofhistoricplaces.com>, Accessed 3 January 2008.

- The site is associated with events that have made a significant contribution to the broad patterns of our history.
- The site is associated with the lives of persons significant in our past.
- The site embodies the distinctive characteristics of a type, period, or method of construction, or that represents the work of a master, or that possess high artistic values, or that represents a significant and distinguishable entity whose components may lack individual distinction.
- The site yields or may be likely to yield, information important in prehistory or history.⁵⁴

These sites are assigned a Smithsonian number and protected through standardized federal regulations.

Significant (eligible) sites can affect the ability and intricacy of proposed land management practices, and it is imperative that these sites are identified and inventoried. Montana's Archaeological Records Office is responsible in assigning the Smithsonian number to eligible sites. If a proposed project has the potential to adversely affect an eligible site, it must be mitigated accordingly.

Although archaeological sites and isolated finds are classified as two separate archaeological areas, they are populated with the same kinds of data. Data collected in archaeology sites and isolated findings include: inventory number, Smithsonian number, eligibility, age, type, and size. The inventory number represents the inventory polygon. The age indicates the historic period, prehistoric period, or multi-component. The type describes the land use, and the size documents the acreage using categories.

The archaeologist is required by law to protect and preserve eligible archaeological sites, and site monitoring allows the archaeologist to document sites using photographs to report any change in structure, and in the condition of the area. Natural erosion and misuse are two examples causing change, which can occur in archaeological

⁵⁴ National Register of Historic Places. *Welcome*.

areas. Restoration and/or stabilization projects are undertaken when these cultural and historic areas require maintenance and support.

Archaeological features are the foundation of archaeological sites and findings, and found in both types of areas. Features include: cabins, cabin foundations, tipi rings, mining prospect pits, bottles, ditches, mine tailings, flake, dam, bone, mills, etc, basically anything containing any cultural or historic significance. Features come in a wide array of shapes and sizes, and they must all be documented for further evaluation and analysis. Because of the various types of features, three datasets including points, lines and polygons are necessary to account for their extreme diversity.

Archaeology inventories, archaeology areas, archaeological monitoring, archaeological point features, archaeological line features, and archaeological polygon features are the six datasets designed for this project. Geodatabase technology used for the archaeology discipline will prove successful in organizing all archaeological components, identifying places where archaeological inventories have been conducted, discovering where cultural and historical entities are located, and planning for future restoration and preservation projects. One relationship class is created to document the monitoring of these archaeological entities, when necessary.

Logical Phase

The logical phase instituted in this section involves the combination of the research conducted in the previously discussed conceptual phase, the current availability of GIS data, data collection methods and techniques, local and federal requirements, and the archeologist's individual GIS needs. Shapefiles are presently available containing

past archaeology inventories, and individual archeological features. Their primary geographic components are a great foundation for additional archaeology information.

Extensive correspondence was done between the GIS specialist and archeologist to identify which design elements would prove to be useful and acceptable. The archeologist wanted the geodatabase design to remain simple, although capturing all of the important geospatial data. The GIS specialist also spoke with other seasonal employees to better grasp the overall scope of the archaeology discipline. The next section will describe the intricacies of this design beginning with the importance of the data, and finishing with the data design, described down to its finest detail.

The next section introduces many data design elements used throughout the design of this project. Design elements that are used for various tables will only be explained once, but their meaning and significance will be discussed as they are introduced to the geodatabase. All other specialized data elements will be discussed in their order of appearance.

Archaeology Feature Dataset

The archaeology feature dataset contains all cultural and historic data currently needed by the archaeologist to accomplish her job responsibilities. The purpose of this feature dataset is to organize all data required by the archaeology discipline into a geodatabase schema that can organize the data effectively, construct relationships between similar data, and assign topology rules to ensure data integrity when needed.

This research and design method produced five feature classes, one object class, and one relationship class. These include: archaeology inventory (ArchInv) feature class, archaeology area (ArchArea) feature class, archaeological monitoring (ArchMon) object

class, archaeological point feature (ArchPoint) feature class, archaeological line feature (ArchLine) feature class, and the archaeological polygon feature (ArchPoly) feature class.

The ArchMon feature class is the only relationship class designed in archaeology feature dataset. The ArchMon relationship class is associated with the ArchArea feature class and the ArchMon object class in a one-to-many relationship. Within this study, relationship classes are named after their destination table. For example, the ArchArea feature class is the origin table, while ArchMon is the destination table. This naming convention was used to name all relationship classes, giving them a consistent naming scheme.

ArchInv Feature Class

The archaeological inventory (ArchInv) feature class is a polygon layer giving the locations of all areas previously inventoried by the Missoula Field Office. It is important to document all prior inventories to ensure the presence or absence of cultural and/or historical entities. Archaeological Inventories provide a foundation of all land previously surveyed by the Missoula Field Office. (Table 11).

Table 11, ArchInv Feature Class.

ArchInv Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
InvNum	Short Integer	5	. . .	Inventory Identification Number
InvDate	Year	4	. . .	Inventory Date
ArchClass	Text	2	ArchClass	Archaeology Classification
Eligible	Text	3	Yes/No	Distiguishes elibility or not
ArchType	Text	10	ArchType	Inventory Findings
FieldTech	Text	20	. . .	Field Technician Surveying
Note	Text	50	. . .	Additional Information

The shape field is a feature class’s default field, which describes the geometric shape of the feature class, which may be point, line, or polygon. This and other default

tables contain the geographic coordinates of a feature class and do not need to be represented in this project. The shape field is the only geographic field displayed in this design that illustrates whether features are points, lines, or polygons.

The inventory number (InvNum) is an important field used to document all conducted inventories, whether or not archaeological entities have been discovered. The inventory date (InvDate) documents the date the inventory is conducted. The year of inventory allows the archaeologist to run queries, map inventories, and perform analyses based on the year.

The archaeological class (ArchClass) field documents the archaeological class of the area, and the ArchClass domain lists the archaeological classes which include: 1) literature search, 2) research & specific areas, and 3) research & entire areas. The Eligible field is important in identifying if eligible archaeological areas were discovered in that particular inventory. A Yes/No domain is used to address whether eligible areas were discovered.

The archaeology type (ArchType) field identifies the type of archaeology area discovered, which refers to either archaeological sites or isolated findings. The ArchType domain contains three options: archaeological sites, isolated findings, or none. If archaeological sites or isolated findings are discovered, more data is documented in the following fields for further analysis.

A field technician (FieldTech) field is present in the majority of datasets within this project. The FieldTech is the name of the individual who collected the data and is extremely important in identifying the person responsible for the initial data. The

FieldTech field allows the GIS user to trace the data back to its origin and provides the opportunity to investigate the data by asking questions if necessary.

All datasets throughout these data designs contain a Note field. This field presents the opportunity to document any additional information during data collection, monitoring, etc. The note field is very versatile, and may be used for any prudent information that may assist the GIS user in better understanding the data elements, or environmental conditions not captured in the database.

ArchArea Feature Class

The archaeology (Arch) polygon feature class is important in documenting all of the essential information regarding any discovered archaeological areas. If an archaeological entity is determined culturally and/or historically significant, this data is captured in this feature class. The two classifications of archaeological areas are archaeological site or isolated findings.

As mentioned previously, the Missoula Field Office defines an archaeological site as finding five or more features inside a twenty-five square meter area, or finding ten or more features inside a fifty square meter area. Isolated finds are items usually found outside an archaeological site. Isolated findings are classified as finding fewer than five features in less than a twenty-five square meter area. The ArchArea feature class is responsible for determining whether the area is an archeological site, or an isolated find. Data captured for the two geographic areas are similar, with the exception of size, so they were combined for database efficiency. Future design will capture the individual artifacts and features data (Table 12).

Table 12, ArchArea Feature Class.

ArchArea Feature Class					
Field Name	Data Type	Length	SubType	Domain	Description
Shape	Geometry				Polygon
ArchNum	Short Integer	5	...	...	Unique ArchArea Identification Number
ArchType	Text	8		AreaType	Whether ArchSite or ArchFind
Eligibility	Text	3	...	Yes/No	Classified as Eligible or Not
SmithNum	Text	8	...	...	Official Smithsonian Number
ArchAge	Text	8	ArchAge	Prehis/His/Both	Approximate Age
LandUse	Text	15	LandUse	PreLU/HistLU/MultiLU	Land Use
ArchSize	Text	8	...	ArchSize	Size of Area
FieldTech	Text	20	...	...	Field Technician Collecting Data
Date	Year	4		...	Data Collection Date
Picture	Blob	...	...	...	Picture of Arch Entity
Note	Text	50	...	...	Additional Information

The archaeology number (ArchNum) field is the unique archaeology identification number used to distinguish archaeology sites and finds alike. The archaeology type (ArchType) establishes if the archeological entity is an archeological site or isolated find. The ArchType coded value domain contains the option to select either archaeology site or isolated find. The Eligibility field identifies whether the archeological site or find has been classified as eligible or not. The Smithsonian number (SmithNum) is an important field developed by the Smithsonian Institute and is used universally throughout the nation. An example of a SmithNum is 24PW0426. SmithNum is based on the two-digit state ID number (24), two-letter county code (PW), and four-digit archeological identification number (0426).

Archeological age (ArchAge) identifies the age of the archeological entity. The Subtype ArchAge, allows the selection of three separate time periods using three coded value domains. These domains are Prehistoric (Prehis), Historic (His), and Combination (Comb). The Prehist coded-domain contains the 1) Paleo, 2) Middle and 3) Late time

periods, the Hist coded-domain contains 1) 1800-1850, 2) 1860, 3) 1870, 4) 1880, 5) 1890, and 6) 1900+, and the Both selection contains one option, 1) Both.

The land use (LandUse) field describes the land use of the area. The subtype, LandUse, permits the selection of three separate coded value domain behaviors: prehistoric (PreLU), historic (HistLU), and multi-component (MultiLU). The PreLU selections are: 1) lithic scatter, 2) quarry, 3) camp and 4) other; The HistLU selections are: 1) mining, 2) grazing, 3) homestead and 4) other. And the MultiLU allows for manual written text to describe land use combinations. This presents an ideal opportunity to document additional information in the note field, further describing the archaeological age or land use if necessary.

The archaeological size (ArchSize) field is important in describing the size of an archaeological site. The domain is called ArchSize and contains the selections: 1) small, <.1 acre, 2) medium, .1-.5 acre, 3) large, .5-1 acre, and 4) x-large, >1 acre. Note: Isolated findings will all contain a small size, because they are less than twenty-five square meters.

Pictures play an important role in identifying, describing, and monitoring natural resources, and utilized in many databases within this design. Pictures are used to document change in the environment over time, illustrate condition changes, or assist specialists in locating specific sites. The Picture field stores pictures that can be retrieved in ArcMap at will. In many instances, more than one picture is necessary to capture a resource entirely, such as the case with large archaeological sites. A hyperlink is established within the pictures field, which allows the GIS user to store multiple photographs. These photographs may be named according to the area, specific location,

identification number, date, or a combination of these. This naming scheme will assist the GIS user to determine the time and location the photograph was taken.

The ArchArea feature class will contain the capability of mapping any of its associated data, such as displaying archaeological area types, eligible areas, the age of the areas, land use, or even size. Many area features in the ArchArea feature class require monitoring, therefore a monitoring object class was created to satisfy this need. This object class is described in the next section.

ArchMon Object Class

The archaeology-monitoring (ArchMon) object class is designed to monitor archaeological sites and findings for their protection and preservation from natural or man-made forces. This table focuses primarily on the Notes and Picture fields for monitoring. Notes may be taken on a number of occasions to document any change in the area or structures of concern. Pictures will be used to visually illustrate these changes over time (Table 13).

Table 13, ArchMon Object Class.

ArchMon Object Class				
Field Name	Data Type	Length	Domain	Description
MonDate	Year	4	. . .	Monitoring Date
ArchNum	Short Integer	5	. . .	Unique Arch Identification Number
SmithNum	Text	8	. . .	Official Smithsonian Number
FieldTech	Text	20	. . .	Field Technician Surveying
Picture	Blob	. . .	. . .	Picture of Arch Entity
Note	Text	50	. . .	Additional Information

The monitoring date (MonDate) field is an extremely important field in any monitoring table, and documents the year the site monitoring was conducted. The year was chosen instead of individual dates due to their enhanced mapping and query ability, as opposed to individual dates. The Year data type are the year the data was collected,

and using this type instead of individual dates, makes the data more consistent and available for queries, analysis, and mapping. This field allows the GIS user to periodically review changes over a period of time.

As mentioned previously, photography is used as a critical monitoring tool that captures the current state of habitat, environmental conditions, structural conditions, and the methods and processes utilized. Monitoring database tables especially benefit from photographs, due to their unique quality to capture that particular moment. Photographs ultimately assist observers in visually assessing the success or failure of a site or project.

There is a one-to-many relationship class designed between the archaeology area (ArchArea) class and the archaeology-monitoring (ArchMon) table. They are connected through the ArchNum field (Table 14).

Table 14, ArchMon Relationship Class.

ArchMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	ArchNum
Key Field in Destination Class	ArchNum

When one-to-many relationship classes are created within feature classes and monitoring tables, the identical geographic element may be documented on multiple occasions allowing the researcher to analyze conditions, trends, and developments. A one-to-many relationship allows for easy access between these datasets for observation, editing, and ultimately, analysis. All monitoring object classes presented in this design will contain a one-to-many relationship for these exact purposes. They will also contain a ‘Mon’ suffix in the object class and relationship class names to signify it’s a monitoring table.

ArchPoint Feature Class

The previous archaeological datasets have only contained archaeological areas, although archaeological features are the basis for identifying these areas of concern. Archaeological features are the foundation of archaeology and determine whether areas are culturally or historically significant. As mentioned previously, three feature classes containing points, lines and polygons were designed to accommodate the variety of archaeological features.

The archaeology point feature (ArchPoint) feature class is a point layer capturing the individual archeological artifacts and features located on BLM lands using x and y coordinates. As the ArchArea feature class concentrates on archaeology sites and findings, the ArchPoint and other feature feature classes will document their many archeological artifacts. ArchPoint captures the data of objects that are small, and affectively associated with a particular geographic point on the ground (Table 15).

Table 15. ArchPoint Feature Class.

ArchPoint Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
FeatNum	Short Integer	8	. . .	Feature Identification Number
ArchNum	Short Integer	5	. . .	Unique ArchArea Identification Number
PtFeat	Text	30	PtFeat	Feature Identity
FieldTech	Text	20	. . .	Field Technician Collecting Data
Date	Year	4	. . .	Data Collection Date
Picture	Blob	. . .	. . .	Picture of the Point Feature
Note	Text	50	. . .	Additional Information

The feature number (FeatNum) field is endemic to all archaeological features, whether they are located in this point feature class, or in the archaeology line and polygon feature classes that follow. The FeatNum field helps identify which archaeological site or isolated find the feature was discovered. Because the ArchArea feature class and the

ArchPoint feature class share this common field, a simple join in ArcMap can be performed to connect these datasets in a many-to-one relationship. Queries and subsequent analysis may then be performed on the relationship's conclusions.

The archaeology number (ArchNum) field shares the identification number of the archaeological area, presented previously. This field ties the feature class to the archaeological site or isolated finding, and will be a useful tool when mapping.

The point feature (PtFeat) field contains the descriptive data of the archaeological item. Most archaeological objects are mapped as point features, and there are a vast number of features found in western Montana. The Missoula Field Office contains a list of archaeological point features that include over fifty objects. These fifty plus objects will be placed in to a coded value domain called point feature (PtFeat), housing these various archaeological features. Examples of archaeological point features include: bone, boiler, fence post, flake, grave, ore bin, and tent platform.

The FieldTech, Date, Picture, and Note field will provide additional important information to this feature class. The Picture and Note fields are particularly important in documenting archaeological features. The Picture field will capture the state of the object when it was discovered, and the Note field provides additional information, frequently needed in archaeology.

ArchLine Feature Class

The archaeology line feature (ArchLine) feature class provides the same feature information as the ArchPoint feature class, except that the geographic features are defined as lines. ArchLine captures all of the linear archaeological features found in the field, which cannot be classified as points or polygons. ArchLine features include things

such as fences, dams, ditches, trenches, trails roads, and stone alignments to name a few (Table 16).

Table 16, ArchLine Feature Class.

ArchLine Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
FeatNum	Short Integer	8	. . .	Feature Identification Number
ArchNum	Short Integer	5	. . .	Unique ArchArea Identification Number
LineFeat	Text	30	LineFeat	Feature Identity
FieldTech	Text	20	. . .	Field Technician Collecting Data
Date	Year	4	. . .	Data Collection Date
Picture	Blob	. . .	. . .	Picture of the line feature
Note	Text	50	. . .	Additional Information

Notice how all of the fields are similar to the ArchPoint feature class, apart from the line feature (LineFeat) field. The LineFeat field contains the identities of the archaeological objects. The line feature (LineFeat) coded value domain will list these line features in a drop down list for easy data entry, and map query capabilities.

The ArchNum is again used to link the archaeological area to the feature that had been discovered. Due to the common ArchNum field, a relationship may be created and various analyses performed.

ArchPoly Feature Class

The archaeology polygon feature (ArchPoly) feature class provides the same feature information as the previous two archaeological feature classes, except that the geographic features are defined as polygons, and contain different objects (Table 17).

Table 17, ArchPoly Feature Class.

ArchPoly Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
FeatNum	Short Integer	8	. . .	Feature Identification Number
ArchNum	Short Integer	5	. . .	Unique ArchArea Identification Number
PolyFeat	Text	30	PolyFeat	Feature Identity
FieldTech	Text	20	. . .	Field Technician Collecting Data
Date	Year	4	. . .	Data Collection Date
Picture	Blob	. . .	. . .	Picture of the Polygon Feature
Note	Text	50	. . .	Additional Information

The polygon feature (PolyFeat) field captures the type of archaeological features, which require area dimensions instead of points or lines. The Missoula Field Office captures close to twenty polygon features. The polygon feature (PolyFeat) coded value domain will house these features, which include: activity area, building, mill, and trash dump to name a few.

The ArchPoly feature class contains the same capability as the ArchPoint and ArchLine feature classes. They can all be linked to the ArchArea feature class by performing a simple join in ArcMap 9.2. The ArchNum field is the key field that identifies which archaeological area the feature was discovered. Future comparisons and analysis can be performed from this relationship join.

The archaeology feature dataset contains all of the geographic information required by the Missoula Field Office archaeologists to preserve, protect, and manage the historic and cultural entities on BLM lands. Although archaeology data is carefully protected, there is a strong need to organize and categorize this data in an efficient manner. The geodatabase provides the archaeologists the tools necessary to collect, organize, maintain and create maps based on the associated data.

Inventories can be taken, and documented for future land management planning. The archaeological areas can be documented efficiently and requirements set forth by federal and local agencies. Monitoring is conducted for archaeological areas that need additional attention and support; relationships are built between the archaeological areas and monitoring datasets for advanced data management. All of the various archaeological features can be documented in an organized and highly efficient manner. The three archaeological feature datasets contain relationships classes, which connect them to their discovered archaeological area. The archaeology feature dataset contains basic components designed in a complex manner, which ultimately will assist the GIS users with their data needs in a user-friendly GIS environment.

FISHERIES DISCIPLINE

Conceptual Phase

The fisheries biologist surveys, measures, and evaluates fish habitat and populations on Missoula Field Office lands. In particular, proposed land management activities are evaluated that may affect fish and their habitat. The fisheries biologist designs and implements fish habitat restoration projects based on field data calculations and scientific investigation.

Fish presence and absence data is valuable in identifying and documenting the location of fish species. Inventorying the location of fish helps the field office make informative management decisions. For instance: Westslope Cutthroat Trout and Bull Trout are designated by the BLM as sensitive species; their geographic location has special implications for the design of management projects that concern fisheries. It is

therefore important to make fish presence data available to all Missoula Field Office staff for the various activities conducted on BLM lands.

Fish passage barriers are natural or artificial (man-made) elements that may restrict fish movement or migration. Barriers include: waterfalls, sub-surface channels, seasonal channels, culverts, diversion dams, and mine tailings. Barriers may or may not restrict fish access to important spawning and rearing habitats, although knowing the locations of barriers in relation to fish populations and their habitat helps the fisheries biologist prioritize and plan projects. Fish barriers are closely observed to minimize affects on fish habitat, while construction and maintenance projects are performed when necessary to protect fish habitats.

Habitat improvement and maintenance projects are implemented where needed to stabilize or improve habitat conditions.⁵⁵ Stream restoration projects are conducted to improve the fish habitat in a particular location. Restoration projects are based on the results of habitat and population surveys indicating that conditions have deteriorated from historic conditions. Restoration methods vary considerably, and include: restoration of large woody debris, bank stabilization, livestock barriers (fencing), fish passage improvements, and others. Stream health not only affects aquatic habitat, but it influences terrestrial wildlife, livestock, riparian habitat, and other natural processes.

Restoration monitoring is necessary to examine the affects of the restoration projects and determine their success or failure. Increases in fish abundance and improvements in riparian habitat are two indicators of restoration project success.

Fish presence, fish passage barriers, restoration projects, and restoration monitoring are critical to the effectiveness of BLM fish programs and are used on a daily

⁵⁵ BLM, *Garnet Resource Area Resource Management Plan*, 34.

basis by the Missoula Field Office. Fish presence is important in protecting and preserving the habitat. Fish passage barriers affect fish migration and are addressed accordingly. Restoration projects are conducted when fish habitat is deemed unacceptable, and their monitoring is important to document their success or failure, providing documentation for future approaches and considerations.

Logical Phase

This logical phase is the result of discussions between the author and the fisheries specialist concerning data and field operations. These discussions focused extensively on encouraging the fisheries discipline to improve its GIS data. The author accompanied the fisheries specialist on a number of field operations to better understand the needs of this discipline.

The design requires determining where fish are located, their monitoring over time, restoration projects, monitoring historic restoration projects, and fish barrier information. The intention of this design is to create a feature dataset that provides the fisheries biologist with the geospatial tools necessary to document and map fisheries data, support land management decisions, and conduct analysis.

Fisheries Feature Dataset

The fisheries biologist is responsible for ensuring the protection and preservation of fish habitat on or near BLM lands. This feature dataset design provides representations of fish presence data, fish barrier information, stream restoration and monitoring data in a geodatabase format.

Three feature classes, two tables, and two relationship class were designed to meet the requirements of this work including: Fish presence (FishPres) feature class, fish

presence monitoring (FishPresMon), fish barriers (FishBarr) feature class, stream restoration (StrRest) feature class, and restoration monitoring (RestMon) object class.

Two relationship classes named fish presence monitoring (FishPresMon) and restoration monitoring (RestMon) were created; both containing a one-to-many cardinality.

FishPres Feature Class

The fish presence (FishPres) feature class is a line layer that contains the geographic line coordinates of the fisheries biologist’s stream analysis segments. The FishPres feature class was designed using the National hydrologic Dataset (NHD) stream layer provided by the United States Geological Survey (USGS). The NHD stream segments are larger than the lesser fisheries analysis segments, thus the NHD segments were divided into smaller segments that would correspond to the analysis areas used by the fisheries biologist. This layer retained the NHD segment identification numbers for later upgrades to the NHD dataset (Table 18).

Table 18, FishPres Feature Class.

FishPres Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
ReachCode	Short Integer	14	. . .	NHD Stream Segment Identification Number
MStrSeg	Short Integer	16	. . .	Unique MiFO Stream Segment Identification Number

The ReachCode is the stream segment field that contains the NHD identification number that amounts to a 14-digit code that identifies stream segments. This code is used by the USGS to identify stream segments, although for the purposes of this design, it will be used for future updates to this layer when they are required.

As mentioned previously, the fisheries biologist at the Missoula Field Office uses smaller stream segments for fisheries analysis than those provided by the NHD, thus

requiring stream segments to be redesigned. The Missoula stream segment (MstrSeg) field contains the 14-digit NHD code, in addition to a 2-digit code to represent these smaller stream analysis sections.

FishPresMon Object Class

The fish presence monitoring (FishPresMon) object class gives the presence or absence of fish found in streams on BLM lands, using the previously defined stream analysis segments. Data in this table is used to identify fish habitats that may need to be closely monitored or improved.

The FishPresMon object class is designed to capture presence and specie data over time, giving it the capability to document and analyze fisheries data and trends. The historic data will prove extremely useful to the fisheries biologist when conducting investigations. The FishPresMon object class will contain a relationship to the FishPres feature class, mainly using the geographic line feature designed for the Missoula Fisheries analysis segments (Table 19).

Table 19, FishPresMon Object Class.

FishPresMon Object Class				
Field Name	Data Type	Length	Domain	Description
MStrSeg	Short Integer	16	. . .	Unique MiFO Stream Segment Identification Number
FishPres	Text	3	Yes/No	Fish Presence or Absence
Method	Text	12	Method	Inventory Method
Abund	Text	10	Abund	Abundance of Fish in Stream Segment
NGPWSTr	Text	8	Yes/No	Genetically Pure Westslope Cutthroat Trout Presence
GPWSTr	Text	3	Yes/No	Not Genetically Pure Westslope Cutthroat Trout Presence
GPBullTr	Text	3	Yes/No	Genetically Pure Bull Trout Presence
NGPBullTr	Text	3	Yes/No	Not Genetically Pure Bull Trout Presence
RBTr	Text	3	Yes/No	Rainbow Trout Presence
BrownTr	Text	3	Yes/No	Brown Trout Presence
BrookTr	Text	3	Yes/No	Brook Trout Presence
FieldTech	Text	20	. . .	Field Technician Collecting Data
MonDate	Year	4	. . .	Monitoring Date
Note	Text	50	. . .	Additional Information

The fish presence (FishPres) field indicates the presence or absence of fish using a Yes/No coded-domain. The Method field is the technique applied to inventory fish presence. The Method coded value domain includes: (1) visual, (2) electronic shock, (3) snorkel, (4) trapping, (5) other. The abundance (Abund) field indicates the abundance of fish located in that particular stream segment. The abundance (Abund) coded value domain contains the options (1) abundant, (2) common, (3) incidental, (4) rare, and (5) unknown.

The presence or absence of individual fish species is given in the next seven fields: genetically pure westslope cutthroat trout (GPWSCTr), not genetically pure westslope cutthroat trout (NGPWSCTr), genetically pure bull trout (GPBullTr), not genetically pure bull trout (NGPBullTr), rainbow trout (RBTr), brown trout (BrownTr), and brook trout (BrookTr). All of these fields contain a Yes/No domain to account for their presence or absence. As mentioned previously in the conceptual phase of fisheries, westslope cutthroat trout and bull trout are classified as sensitive species, and with the re-introduction of these fish species, it is important to document the genetically pure and not genetically pure species. The genetically pure presence is closely monitored, to ensure their protection.

The FishPresMon relationship class is used to connect the FishPres feature class and the FishPresMon object class. It contains a one-to-many relationship cardinality, and the MStrSeg field is used as the key field or unique identifier to link records in the table to the feature class. This relationship will allow multiple monitoring sessions of one stream analysis segment (Table 20).

Table 20, FishPresMon Relationship Class.

FishPresMon Relationship Class	
Type	One-to-Many
Cardinality	Simple
Key Field in Origin Class	MStrSeg
Key Field in Destination Class	MStrSeg

FishBarr Feature Class

The fish barrier (FishBarr) feature class is a point layer identifying potential fish barriers located on streams that cross BLM lands. The barriers are examined and observed for any affect on fish habitat, and if affects are found, actions are taken to correct the problem (Table 21).

Table 21, FishBarr Feature Class.

FishBarr Feature Class					
Field Name	Data Type	Length	Subtype	Domain	Description
Shape	Geometry	. . .	. . .	. . .	Point
BarrID	Short Integer	4	. . .	. . .	Barrier Identification Number
BarrType	Text	12	BarrType	Nat/Man	Type of Fish Barrier
FieldTech	Text	20	. . .	. . .	Field Technician Collecting Data
Date	Year	4	. . .	. . .	Data Collection Date
Picture	Blob	. . .	. . .	. . .	Picture of Barrier
Note	Text	50	. . .	. . .	Additional Information

The barrier type (BarrType) field identifies the type of barrier. The BarrType subset allows for the natural barriers (Nat), and man-made barriers (Man) coded value domain options. The Nat coded-domain contains (1) waterfalls, (2) subsurface flow, (3) seasonal channels, and (4) other. The Man coded value domain contains (1) culverts, (2) diversion dams, (3) mine tailings, and (4) other.

StrRest Feature Class

The stream restoration (StrRest) is a polygon feature class that describes the data collected for stream restoration projects. Stream restoration projects are executed to improve the natural stream system (Table 22).

Table 22, StrRest Feature Class.

StrRest Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
ProjName	Text	. . .	. . .	Name of Restoration Project
ProjNum	Short Integer	5	. . .	Unique Project Identifier
Date	Year	4	. . .	Date of Restoration Project
ProjLead	Text	20	. . .	Name of Project Leader
RestType	Text	5	RestType	Type of Stream Restoration Conducted
Picture	Blob	. . .	. . .	Picture of the Area
Note	Text	50	. . .	Additional Information

The project name (ProjName) field is given to individual restoration projects, usually named after their location. The project number (ProjNum) field is a five-digit project identification number. The project lead (ProjLead) field identifies the specialist responsible for leading the project.

The restoration type (RestType) field documents the type of restoration project conducted. The restoration type (RestType) coded-domain lists the restoration methods used for each project, including: (1) large woody debris (LWD), (2) bank stabilization (BS), (3) livestock exclosures (LSE), (4) fish pass improvements (FPI), and (5) Other.

The pictures will be linked using a hyperlink throughout this design, which connects the features to a folder located outside the geodatabase schema. A hyperlink will open up a folder, and proceed to open up one, or multiple pictures if necessary. It is possible to store multiple pictures in one folder and name the pictures according to project and date. If an area is too large, and multiple pictures are necessary to capture the entire area, the different photographs can be documented in the naming scheme. For instance, Garnet08ph1 could be used for a picture-naming scheme. Garnet is the area, 08 the year, and ph1 is the first photograph.

RestMon Table

The restoration-monitoring (RestMon) table is used to examine the affects of stream restoration projects on streams and surrounding habitat. The RestMon table is intended to connect to the StrRest feature class in a one-to-many relationship. It contains the record of dates when restoration projects have been monitored to determine if they have been successful or not. It also contains information regarding the field technician responsible for collecting data, and a picture field used to capture an image of the area (Table 23).

Table 23, RestMon Object Class.

RestMon Object Class				
Field Name	Data Type	Length	Domain	Description
ProjNum	Short Integer	5	. . .	Unique Project Identifier
MonDate	Year	4	. . .	Monitoring Date
Successful	Text	12	Yes/No	Successful or Unsuccessful Restoration
FieldTech	Text	20	. . .	Field Technician Monitoring
Picture	Blob	. . .	. . .	Picture of the Area
Note	Text	50	. . .	Additional Information

The fish presence (FishPres) field is used to document any modifications in the restoration project area over time. The successful field identifies the success or failure of the restoration project, and contains a Yes/No domain to allow for this option. Pictures are attached to this layer, because of their importance in identifying transformations in landscape and habitat.

A relationship class was designed to permanently link the StrRest feature class and RestMon object class. A one-to-many relationship is the cardinality between the two datasets. This relationship class provides the convenience of looking up the monitoring data when examining the stream restoration feature in ArcMap. This relationship class

will also allow the observation of restoration project monitoring through the use of photographs (Table 24).

Table 24, RestMon Relationship Class.

RestMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	ProjNum
Key Field in Destination Class	ProjNum

The fisheries feature dataset contains the capability to satisfy many of the geospatial needs of the fisheries biologist at the Missoula Field Office. Fish presence and fish species information was designed to capture monitoring information, and will provide the field office with historic fish data, and the means to provide support to land management decisions. Restoration projects and their monitoring were captured in this design. The methods and techniques are now located in a geodatabase, making it easier to determine their success or failure. Fish barrier information are captured to observe their location, condition, and affect on fish habitat and populations.

HYDROLOGY DISCIPLINE

Conceptual Phase

The hydrologist is responsible for assessing and monitoring stream channels and riparian habitat conditions. The hydrologist also determines water quality conditions, and identifies and remediates pollutant sources. The hydrologist is primarily responsible for the health and management of riparian and wetland sites, while maintaining or enhancing the value of riparian areas for wildlife, recreation, fishery, and aquatic life.⁵⁶ Riparian habitat, river morphology and riparian monitoring are three datasets designed for this project. The riparian habitat feature class contains the geometric components of the

⁵⁶ BLM, *Garnet Resource Area Resource Management Plan*, 41.

riparian habitat, while documenting the habitat components in the riparian monitoring table for multiple studies over time. The river morphology feature class will contain the structural components of the stream segment, and the riparian monitoring feature class will contain the necessary monitoring data necessary to successfully monitor riparian habitat.

Riparian habitat is the vegetation community immediately adjacent to rivers, streams, and wetlands. Riparian habitat is identified by the presence of vegetation requiring free or unbound water or moist conditions.⁵⁷ Riparian habitat contains areas dominated by riparian vegetation, adjacent to water bodies, with high values for wildlife habitat, visual and recreational enjoyment, watershed and water quality protection, and livestock forage.⁵⁸

River morphology is the formation and structure of river bodies. Many river classification methods have been developed through the years to classify river morphology. The Rosgen Classification of Natural Rivers and the Montgomery and Buffington Classification are popular classification methods utilized by many governmental agencies. The hydrologist at the Missoula Field Office exercises the Rosgen Classification to identify stream sinuosity, channel material, and slope. The Montgomery and Buffington Classification is used to assist in feature morphology. Specific objectives of the Rosgen stream classification include:

- Predict a river's behavior from its appearance.
- Develop specific hydraulic and sediment relationships for a given stream type and its state.
- Provide a mechanism to extrapolate site-specific data to stream reaches having similar characteristics.

⁵⁷ BLM, *Garnet Resource Area Resource Management Plan*, 128.

⁵⁸ BLM, *Garnet Resource Area Resource Management Plan*, 41.

- Provide a consistent frame of reference for communicating stream morphology and condition among a variety of disciplines.⁵⁹

The reason for classifying streams on the basis of channel morphology is to aid in the understanding of stream condition and potential behavior under the influence of different types of change.⁶⁰

Riparian monitoring is important in identifying change in riparian habitat. Specialized data in the riparian monitoring table contains: status, plant species, habitat type, and functional rating. Status determines whether the river segment has been assessed. Plant species is determined by identifying key indicator and weed species. The habitat key is used to identify riparian habitat types. Functional rating is determined per agency guidelines for proper functioning condition, functional at risk, nonfunctional, and unknown. This dataset allows the hydrologist to closely record all riparian changes over time in a database structure for easier observation, monitoring, and database management. If riparian and stream components are found unhealthy, measures are taken to correct these problems through restoration and improvement practices.

Logical Phase

This logical phase is a combination of the conceptual research described previously, and involved extensive discussions between the author and the hydrologist about data needs, data collection techniques, classification systems, and hydrologic concepts and processes. The hydrologist at the Missoula Field Office is familiar with the

⁵⁹ Environmental Protection Agency. *Fundamentals of the Rosgen Stream Classification System*. Washington D.C. On-line. Available from Internet, http://www.epa.gov/watertrain/stream_class/index.htm, accessed 4 January 2008.

⁶⁰ EPA, *Fundamentals of the Rosgen Stream Classification System*, http://www.epa.gov/watertrain/stream_class/index.htm.

capabilities of a GIS system, and was eager to improve the data management system of his discipline.

The intention of the new database design is to create a feature dataset that provides the hydrologist with the geospatial tools necessary to document and map hydrology data, use the data to support land management decisions, and conduct hydrological analysis based on the newly created hydrology design.

Hydrology Feature Dataset

The Hydrology Feature Dataset stores the information necessary to support the assessment and monitoring of riparian habitat and stream channels on Missoula Field Office lands. The geodatabase design for this resource discipline incorporates riparian habitat conditions, stream channel assessment, and riparian monitoring techniques.

One feature class, two tables, and two relationship classes are designed in this feature dataset. The datasets include a riparian habitat (RipHab) feature class, a stream morphology (StrMorph) object class, and a riparian monitoring (RipMon) object class. There are two relationship classes named RipMon (1-M), and StrMorph (1-1). These relationship classes share the RipHab feature class as the origin table.

RipHab Feature Class

The riparian habitat (RipHab) feature class is a line layer containing information about the riparian habitat and conditions along streams. The RipHab feature class represent stream segments used for mapping riparian habitats (Table 25).

Table 25, RipHab Feature Class.

RipHab Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
StrName	Text	20	. . .	Name of the Stream
ReachCode	Short Integer	14	. . .	National Hydrographic Dataset Identification Number
RipID	Text	16	. . .	Unique MiFO Riparian Stream Segment ID

The ReachCode field contains the NHD identification number found in the NHD stream layer. The hydrologist assesses riparian stream habitat data and stream morphology using a smaller stream segment than provided by the NHD. So, a sixteen-digit riparian identification number (RipID) was designed to further divide the stream segments. The fourteen-digit NHD number, in addition to two-digit prefix identification number make up these smaller segments, and are housed in the Riparian Identification (RipID) field.

RipMon Object Class

The riparian monitoring (RipMon) table is a riparian monitoring table designed to assist the Missoula Field Office in monitoring riparian and stream characteristics over time. It is intended to be associated with the RipHab feature class in a one-to-many relationship using the RipID key code. This relationship will allow the associated tables to be observed simultaneously, and closely monitored for apparent changes in riparian habitat over time (Table 26).

Table 26, RipMon Object Class.

RipMon Object Class				
Field Name	Data Type	Length	Domain	Description
RipID	Text	17	. . .	Unique Missoula Field Office Stream Segment ID
Assessed	Text	12	Yes/No	Whether Segment is Assessed or Not
KeySpec	Text	7	Specie	Key Species in the Stream Segment
IndSpec	Text	7	Specie	Indicator Species in the Stream Segment
WeedSpec	Text	7	Wspecie	Primary Weed Species in the Stream Segment
RipHab	Text	14	RipHab	Riparian Habitat of the Stream Segment
FR	Text	6	StrFR	Functional Rating of the Stream Segment
FieldTech	Text	20	. . .	Field Technician Collecting Data
MonDate	Year	4	. . .	Monitoring Date
Note	Text	50	. . .	Additional Information

The riparian identification (RipID) number field contains the riparian stream segment used by the hydrologist to conduct analysis of riparian habitat. The hydrologist conducts analysis for approximately 100 to 150 feet along the stream. The Assessed field identifies whether the segment has been assessed or not, using a Yes/No coded value domain to distinguish the difference.

Plant species are identified by their scientific genus and species names. The United States Forest Service combines the first three letters of the genus and first three letters of the species name. For example, the scientific name for wheat grass is *Agropyron pauciflorum*, and the code is AGRPAU. The Key Species (KeySpec), Indicator Species (IndSpec), and Weed Species (WeedSpec) fields follows this standardized coding of plant species.

The Specie coded value domain located in the KeySpec and IndSpec fields lists the scientific names of riparian plant species located in western Montana. The Weed Species (Wspecie) coded value domain contains a list of the coded weed species. These coded value domains will allow for drop-down menus of these scientific names, making editing and observation of these two datasets easier.

Key species are historically dominant vegetative species used to identify riparian habitat. Key species are primary goals in managing riparian habitat, and require attention to maintain or improve their presence. Indicator species are indicators of the existing habitat type, and weed species are an invasive plant species, which have spread from other parts of the world.

Habitat type is an aggregation of all land areas potentially capable of producing similar plant communities at climax.⁶¹ Riparian habitat types are classified using a combination of two coded species. The first six-letter code identifies the primary species, and the second six-letter code identifies the secondary species. The Riparian Habitat (RipHab) coded value domain accommodates this representation, and provides a drop list containing all possible habitat combinations for western Montana.

The Functional Rating (FR) field is the current functional rating of the stream segment, and the StrFR coded value domain is based on the functional rating classification system utilized by the BLM which includes: (1) Proper Functioning Condition (PFC), (2) Functional at Risk/Upward (FAR/U), (3) Functional at Risk/Downward (FAR/D), (4) Functional at Risk/Not Apparent (FAR/NA), (5) Non Functional (NF), and (6) Unknown (UNK).

The RipHab feature class and RipMon object class employ a one-to-many relationship class using the RipIDID field as the unique identifier. This relationship allows the GIS user to observe these tables and closely monitor riparian habitat alterations over time. Refer to Table 25 for the relationship class’s details. The RipMon relationship class allows a single stream segment to be monitored on multiple occasions (Table 27).

Table 27, RipMon Relationship Class.

RipMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	RipID
Key Field in Destination Class	RipID

⁶¹ BLM, *Garnet Resource Area Resource Management Plan*, 125.

StrMorph Object Class

The stream morphology (StrMorph) object class describes the structural components of stream channels. Structural components include the stream channel, streambed, stream flow, stream sinuosity, and stream slope. These components are necessary for the Hydrologist at the Missoula Field Office to positively assess the health of streams on BLM lands. The StrMorph table is connected to the RipHab feature class using in a one-to-many relationship class (Table 28).

Table 28, StrMorph Object Class.

StrMorph Object Class				
Field Name	Data Type	Length	Domain	Description
RipID	Text	17	. . .	Unique Missoula Field Office Stream Segment ID
StrType	Text	3	StrType	Rosgen Sinuosity Classification Type
ChMat	Text	10	ChMat	Stream Channel Material
StrBedSl	Text	3	StrBedSl	Slope of the Stream Bed
FieldTech	Text	20	. . .	Field Technician Collecting Data
Date	Year	4	. . .	Data Collection Date
Note	Text	50	. . .	Additional Information

The Stream Type (StrType) field identifies the current sinuosity of the stream. Sinuosity directly relates to the meandering geometry of the stream segment; it is calculated by the ratio of stream length to valley length.⁶² The StrType coded domain includes the following categories: (1) A, (2) B, (3) C, (4) D, (5) E, (6) F, (7) G, and (8) DA. These categories range from low (A) to high (DA) sinuosity. The hydrologist determines the sinuosity and places the results in the appropriate category using the Rosgen classification method. Figure 7 describes the hierarchy in the Rosgen method of classification more clearly.

⁶² EPA, *Fundamentals of the Rosgen Stream Classification System*, http://epa.gov/watertrain/stream_class/22set.htm.

When streams are discovered unhealthy, the appropriate restoration projects are proposed and conducted to improve their status.

The Key to the Rosgen Classification of Natural Rivers

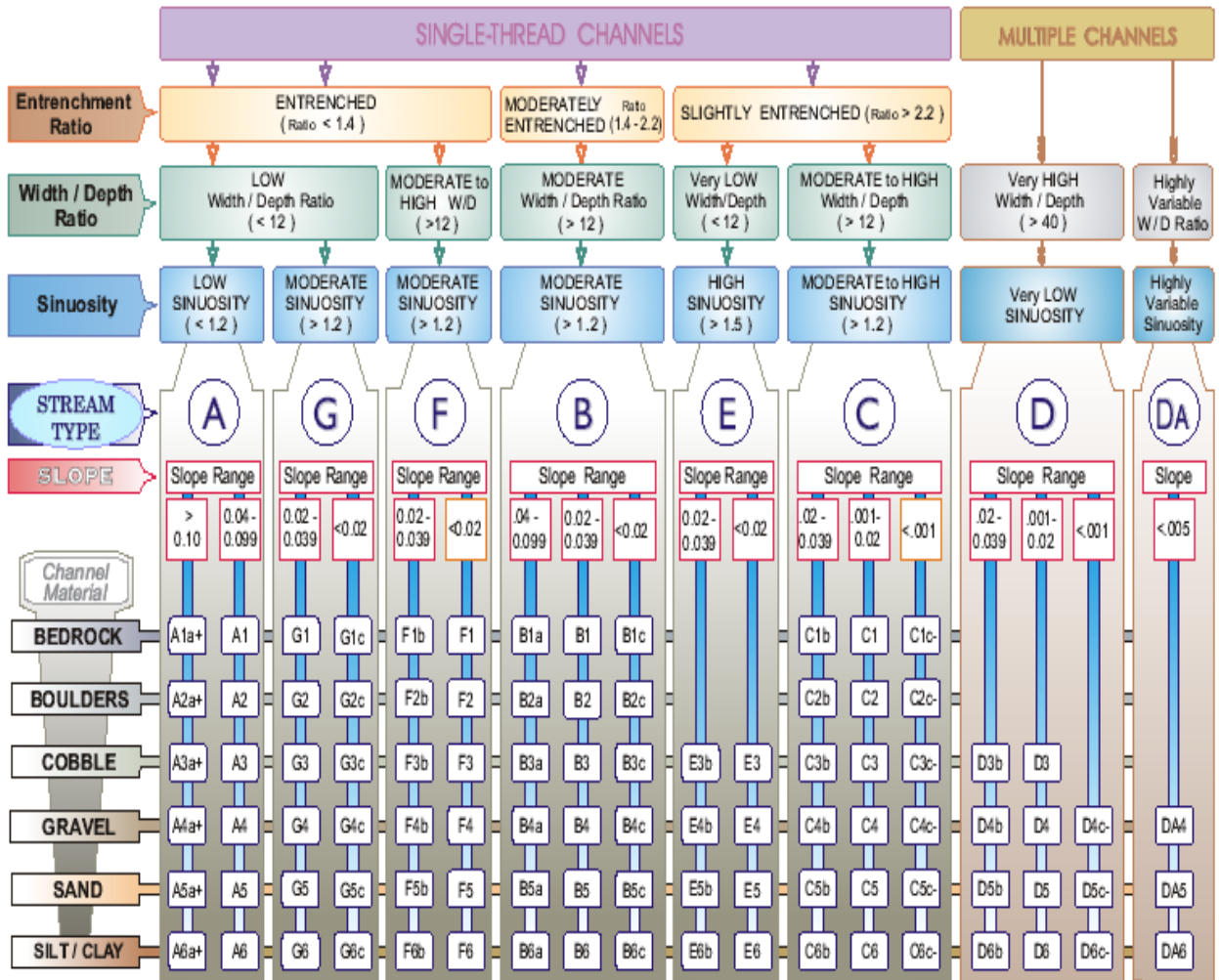


Figure 7, Rosgen Classification of Streams.⁶³

The Channel Material (ChMat) field is the channel material field. The ChMat coded domain contains (1) bedrock, (2) boulders, (3) cobble, (4) gravel, (5) sand, and (6) silt/clay.

⁶³ Rosgen, Dave. Wildland Hydrology Consultants. *The Key to the Rosgen Classification of Natural Rivers*. Pagosa Springs, CO. On-line. Available from Internet, http://www.wildlandhydrology.com/assets/ARM_5-3.pdf. Accessed 24 December 2007.

The Stream Bed Slope (StrBedSl) field indicates the slope angle of the streambed. The StrBedSl coded domain contains: (1) A+ (>.10), (2) A (.04-.099), (3) B (.02-.039), (4) C (.02), (5) C-(<.02), and (6) Nul.

A one-to-many relationship class called StrMorph is designed to link the RipHab feature class to the StrMorph object class using the RipID field as the unique identifier. This relationship will allow the monitoring of StrMorph elements over time (Table 29).

Table 29, StrMorph Relationship Class.

StrMorph Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	RipID
Key Field in Destination Class	RipID

RANGELAND DISCIPLINE

Conceptual Phase

The Missoula Field Office rangeland management specialist is responsible for the management of livestock grazing and rangeland health. The objective of the rangeland discipline is to maintain, or where practical, enhance site productivity on all public lands available for livestock grazing. The conditions include the maintenance of current healthy vegetative cover, improve unsatisfactory vegetative conditions, prevention of noxious weeds from invading new areas, and limiting utilization levels to provide for plant maintenance.⁶⁴

“The Taylor Grazing Act of 1934, signed by President Theodore Roosevelt, was intended to “stop injury to the public grazing lands by preventing overgrazing and soil deterioration; to provide for their orderly use, improvement, and development; and to stabilize the livestock industry dependent upon the public range. This Act was pre-empted by the Federal Land Policy and Management Act of 1976.”⁶⁵

⁶⁴ BLM, *Garnet Resource Area Resource Management Plan*, 29.

⁶⁵ U.S. Bureau of Land Management: Department of the Interior. *The Taylor Grazing Act*: Washington D. C. On-line. Available from Internet,

The Montana/Dakotas Standards for Rangeland Health and Guidelines for Livestock Grazing Management is a document designed to assist in following these standards and guidelines. Livestock grazing is closely supervised and managed to ensure the lessee follows appropriate measures.

Livestock grazing is divided into allotments leased to companies or individuals. Data associated with grazing allotments include: allotment name, allotment number, authorization number, animal unit months, seasonal use, allotment type, standard status, guideline status, and public acres.

A spring is a point where groundwater flows out of the ground, and important in providing water to grazing herds on BLM lands. Springs are managed through the rangeland discipline, and categorized according to the grazing allotments in which they reside. The BLM monitors springs, and their location is vital to protect and preserve these natural water sources. Two primary sets of data are necessary to document springs, in addition to their names and associated pictures. These include types of springs and information regarding those who lease the springs. Types of springs include those that are developed and those that are undeveloped. Developed springs usually contain man-made structures to assist in the functionality of the spring, whereas undeveloped springs are left in their natural state.

Lessee information is also an important component in rangeland management. The rangeland specialist grants leases on grazing allotments to individuals and organizations with the intention that these participants will follow the regulations set forth by the BLM. Lessee information is considered personal and confidential and

http://www.blm.gov/wy/st/en/field_offices/Casper/range/taylor.1.html, Accessed 15 February 2007.

includes: lessee name, address, telephone number, permits date, etc. The rangeland specialist will monitor the conditions of a lease, to assure that the appropriate actions are taken by the lessee to abide by the terms of the contract. Their correspondence is vital in keeping this agreement on track.

The rangeland specialist is responsible for determining current rangeland health by evaluating conditions such as riparian and upland health, water quality, air quality, and wildlife habitat quality. The rangeland specialist calculates current health by using the combination of primary and secondary species composition, primary and secondary species percentages, vegetation percentages, utilization percentages, and seral stage to determine the health of rangelands. In the event rangelands are considered unhealthy, monitoring is used to assess conditions over time.

The Missoula Field Office utilizes the Daubenmire vegetative survey method. The Daubenmire method consists of systematically placing a 20cm x 50cm quadratic frame in different positions along a tape on permanently located transects. Transects are paths which are traveled from a known point, in which monitoring is conducted by recording and occurrences of vegetative habitat. The vegetation attributes monitored include canopy cover, frequency, and composition by canopy cover. It is also extremely important to establish photo plots, and take both close-up and general view photographs. This allows the portrayal of resource values and conditions, and furnishes visual evidence of vegetation and soil changes over time.⁶⁶

The seral stage is the ecological condition derived by comparing the existing condition to the National Resources Conservation Service (NRCS) Soil Survey. The

⁶⁶ National Oceanic and Atmospheric Administrative (NOAA): Department of Commerce. *Daubenmire Method*: Washington D.C. On-line. Available from Internet. <http://www.darrp.noaa.gov/northwest/cbay/pdf/cb-mon1m.pdf>, 12 August 2008.

NRCS Soil Survey identifies vegetation by its potential natural community (PNC). In a seral stage, the vegetation has not theoretically attained a steady state (climax stage) with its environment, and current populations of some species are being replaced by other species.⁶⁷ The seral stage is categorized by early, mid, late, and PNC. Early seral stage is 25% of the PNC, mid seral stage is 25-49% of PNC, late seral is 50-74% of PNC, and PNC is 75-100% of PNC. The overall rangeland health is determined by the range specialist, and based on a combination of these survey findings.

The Missoula Field Office undertakes many rangeland improvement projects to enhance the health and stability of rangelands. If rangelands are deemed unhealthy, rangeland improvement techniques are utilized to improve and restore a healthy habitat. Rangeland improvement techniques include: fence development or demolition, spring development and maintenance, pipeline development and maintenance, tank development and maintenance. In many cases, these techniques are evaluated in conjunction with other specialists to ensure all aspects of design, implementation, and maintenance are addressed appropriately.

Livestock grazing allotments, lessee data, rangeland health, rangeland transects, rangeland monitoring, rangeland improvements, and springs are seven datasets designed for this project. Allotments describe physical characteristics and livestock capabilities of the individual rangelands. The lessee information portrays the personal and confidential information for each lessee. The rangeland health classifies present health, while the rangeland monitoring documents health over a period of time.

⁶⁷ Hansen, Paul J., Robert D. Pfister, Keith Boggs, Bradley J. Cook, John Joy, and Dan K. Hinckley. *Classification and Management of Montana's Riparian and Wetland Sites*. Missoula, Montana: Miscellaneous Publications No.54, 1995, pg. 644.

Logical Phase

This logical phase is an outgrowth of the conceptual research described previously. It is the result of discussions between the author and the rangeland specialist that concerned rangeland discipline's needs for data, data collection techniques, classification systems, vegetative analysis, rangeland health quality, and the concepts and processes involved in rangeland management. The rangeland specialist was eager to understand the capabilities of GIS, and share any and all information necessary to improve the methods used in geospatial data analysis.

The intention of the logical phase of the design is to create a feature dataset that provides the rangeland specialist with the geospatial tools necessary to document and map rangeland data, use the data to support rangeland management, and conduct the analysis necessary to accomplish the objectives of the rangeland discipline.

Rangeland Feature Dataset

The rangeland feature dataset stores geographic data needed to maintain or enhance livestock grazing areas. Livestock grazing allotments, rangeland health, rangeland transects, rangeland monitoring, personal lessee information, range improvement, and natural springs are the data elements designed for this work. The rangeland feature dataset provides organized, interrelated data elements designed to meet the range discipline's geographic goals.

Four feature classes, three object tables, and three relationship classes were designed for this work including: allotment (Allot) feature class, rangeland health (RngHlth) object class, range transect (RngTran) feature class, range monitoring (RngMon) object class, range improvement (RngImp) feature class, Spring feature class,

and range lessee (RngLess) object class. The relationship classes include the RngHlth, RngMon, and RngLess relationship classes.

Allot Feature Class

The allotment (Allot) feature class is a polygon layer containing livestock grazing allotment information necessary to manage allotments. It contains the boundaries of allotments, which are the foundation of rangeland management. Allotments lay the groundwork for the rangeland specialist to conduct rangeland health assessments, rangeland monitoring, and rangeland improvement projects (Table 30).

Table 30, Allot Feature Class.

Allot Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
AllotName	Text	30	. . .	Name of Allotment
AllotNum	Short Integer	5	. . .	Unique Allotment Identification Number
AuthNum	Short Integer	7	. . .	Unique Permit Identification Number
PubAUMS	Short Integer	4	. . .	Animal Unit Months
TimeUse	Text	20	. . .	Time Use of Allotment
AllotCat	Text	12	AllotCat	Category of the Allotment
Note	Text	50	. . .	Additional Information

The allotment name (AllotName) field gives the common name of the allotment, based mostly on its geographic location, such as Devil Mountain allotment. The allotment number (AllotNum) field is the identification number of the allotment, while the authorization number (AuthNum) field documents the permit identification number. The AuthNum field distinguishes the separate leases, which is important because multiple allotments may be given to a single lessee.

The public animal unit months (PubAUMS) field documents the amount of forage necessary to sustain one animal for one month. PubAUMs is determined through rangeland health, food supply, and livestock characteristics.

The time use (TimeUse) field documents the dates the allotment is in use. The allotment category (AllotCat) field recognizes the allotment category, and the AllotCat coded value domain contains (1) improvement, (2) maintenance, and (3) custodial categories. Improvement allotments will require improvement, maintenance allotments do not require improvements, and custodial allotments are areas where change is not feasible.⁶⁸

RngHlth Object Class

The rangeland health (RngHlth) object class documents the health of grazing allotments. Rangeland health is determined by a number of environmental factors including upland health, riparian health, water quality, air quality and wildlife habitat quality. The RngHlth object class is intended to connect to the Allot feature class in a one-to-many relationship class. This relationship will be discussed later in the rangeland design (Table 31).

Table 31, RngHlth Object Class.

RngHlth Object Class				
Field Name	Data Type	Length	Domain	Description
AllotName	Text	30	. . .	Name of Allotment
AllotNum	Short Integer	5	. . .	Unique Allotment Identification Number
UpHlth	Text	30	HlthStat	Status of Upland Health
RipHlth	Text	30	HlthStat	Status of Riparian Health
WtrQua	Text	30	HlthStat	Status of Water Quality
AirQua	Text	30	HlthStat	Status of Air Quality
WldHabQua	Text	30	HlthStat	Status of Wildlife Habitat Quality
FieldTech	Text	20	. . .	Field Technician Collecting Data
MonDate	Year	4	. . .	Monitoring Date
Note	Text	50	. . .	Additional Information

The upland health (UpHlth) field documents the current health status of the allotment's uplands. The riparian health (RipHlth) field describes the status of riparian

⁶⁸ BLM, *Garnet Resource Area Resource Management Plan*, 96.

health. The water quality (WtrQua) field documents the current health of water quality. The air quality (AirQua) field stores information regarding the health of the air quality. The wildlife habitat quality (WldHabQua) field documents the health status of wildlife habitat. These five fields contain a health status (HlthStat) coded value domain which categorizes the status of health by: (1) meeting (M), (2) not meeting (NM), (3) not meeting/but progressing (NM/BP), and (4) not applicable (NA). If rangeland health is found inadequate, action is taken and improvement techniques and practices are implemented to reverse the trend.

A one-to-many relationship class is used to link the Allot feature class to the RngHlth table using the AllotNum field as the key field. Monitoring is conducted to determine if range health is adequate (Table 32).

Table 32, RngHlth Relationship Class.

RngHlth Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	AllotNum
Key Field in Destination Class	AllotNum

RngTran Feature Class

The range transect (RngPlot) feature class contains the basic geospatial point information necessary to conduct rangeland monitoring. Transects are used as long-term point locations where the Daubenmire vegetative monitoring method begins. In the field, transects are identified with large metal spikes driven in to the ground (Table 33).

Table 33, RngTran Feature Class.

RngTran Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
AllotName	Text	30	. . .	Name of Allotment
AllotNum	Short Integer	5	. . .	Allotment Number Identification Number
TranNum	Short Integer	8	. . .	Unique Transect Number
Degree	Short Integer	3	Degree	Degree from Point which Monitoring is Conducted
Picture	Blob	. . .	. . .	Pictures of the Transect Point

The transect number (TranNum) field captures the individual transect numbers.

The number incorporates the allotment number and a two-digit suffix number. For instance, if the plot number were 10045-01, 10045 would indicate the allotment number, and 01 would reference the transect number.

Monitoring is performed from these point locations in a particular compass direction measured in degrees. The Degree field identifies the direction from which the transect travels from the point location. The Degree range value domain limits the selections to values between 0 and 359. The picture field is used to identify that particular transect in the field. A picture folder for each transect is used to identify the surrounding area, geographic features, and the metal spike itself. These pictures will assist the resource specialist greatly in locating the many transects.

RngMon Object Class

The range monitoring (RngMon) object class is a table used to document, monitor, and evaluate rangeland health from the transect locations discussed in the previous section. It is the intention to link the RngTran and RngMon datasets using a one-to-many-relationship class. This relationship will allow this table to document the

monitoring of transects multiple times. Rangeland monitoring records vegetative components, percentage yields, and species composition (Table 34).

Table 34, RngMon Object Class.

RngMon Object Class				
Field Name	Data Type	Length	Domain	Description
TranNum	Short Integer	8	. . .	Unique Transect Number
PriSpec	Text	7	Specie	Primary Species Found During Monitoring
SecSpec	Text	7	Specie	Secondary Species Found During Monitoring
PriPerc	Short Integer	3	Perc	Percentage of Primary Species Found
SecPerc	Short Integer	3	Perc	Percentage of Secondary Species Found
VegPerc	Short Integer	3	Perc	Percentage of Total Vegetation Cover
UtilPerc	Short Integer	3	Perc	Percentage of Utilization
SeralStg	Text	5	Seral	Seral Stage of the Monitoring Plot
FieldTech	Text	20	. . .	Field Tech Collecting Data
Picture	Blob	. . .	. . .	Pictures of the Monitoring Plot
MonDate	Year	4	. . .	Monitoring Date
Note	Text	50	. . .	Additional Information

The primary species (PriSpec) and secondary species (SecSpec) fields document the primary and secondary species discovered along the transect. The Specie coded value domain captures the scientific six-letter coded specie name, which was also utilized in the RipHab feature class in the hydrology feature dataset.

The primary percentage (PriPerc) field is the percentage of primary species discovered, and the secondary percentage (SecPerc) field documents the secondary species percentage. The vegetation percentage (VegPerc) field documents the percentage of vegetation found along the transect, and the utilization percentage (UtilPerc) field documents the percent of forage amount consumed by livestock. The percentage fields contain a percent (Perc) range value domain, which contains the numbers 0-100, indicating percentages. This domain will assist the GIS user considerably by defining a range for valid data entries, in this case, not to exceed 100 percent.

The seral stage (SeralSt) field documents the seral stage of the transect. The Seral coded value domain used the categories described in the conceptual design of rangelands. The seral stage is series of classes, which determine the vegetative state, and located in the Seral coded value domain. This domain includes: (1) early (<25%), (2) mid (25-49%), (3) late (50-75%), and (4) potential natural community (PNC) (>75%). PNC refers to the acceptable vegetative state, and is the aim of these analyses. If the seral stage of plant communities are found to be less than 75%, improvement potential is evaluated, and further developments may occur.

The range monitoring (RngMon) relationship class connects the RngPlot feature class and RngMon table in a one-to-many relationship class, using the PlotNum field as the key field. This table is designed to document multiple monitoring sessions, and assist the specialists in identifying progress through time (Table 35).

Table 35. RngMon Relationship Class.

RngMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	PlotNum
Key Field in Destination Class	PlotNum

RngLess Table

The range lessee (RngLess) table contains the confidential information of the lessee responsible for occupying the grazing allotments. The lessee's information is categorized as sensitive data by the Missoula Field Office, and not available for public use. A lessee may lease multiple allotments based on requirements acceptable by the BLM. In turn, permits may be designed for multiple grazing allotments to accommodate these instances. It is intended to link the Allot feature class with this object class in a

one-to-one relationship, allowing the GIS user direct access to the allotment data and lessee information (Table 36).

Table 36, RngLess Object Class.

RngLess Object Class				
Field Name	Data Type	Length	Domain	Description
AuthNum	Short Integer	7	. . .	Unique Permit Identification Number
Name	Text	30	. . .	Name of Lessee
Street	Text	30	. . .	Street Address of Lessee
State	Text	2	. . .	State Address of Lessee
Zip	Short Integer	5	. . .	Zip Code of Lessee
Phone	Short Integer	10	. . .	Phone Number of Lessee
PermitDate	Year	4	. . .	Permit Start Date
ExpDate	Year	4	. . .	Permit Expiration Date
Picture	Blob	. . .	. . .	Picture of Lessee
Note	Text	50	. . .	Additional Information

The authorization number (AuthNum) field is the permit number given to each individual permit. The AuthNum is important to identify individual permits, because in some cases, a single lessee may occupy multiple allotments. The Name field contains the legal name of the lessee. The Street, State and Zip fields contain the address information of the lessee, and the Phone field captures the phone number of the lessee, including area code.

The permit date (PermitDate) field gives the beginning date of the permit, while the expiration date (ExpDate) captures the expiration date of the permit. A Picture field is added to take a photograph of the lessee.

The RngLess table forms a one-to-one relationship with the Allot feature class using the AuthNum as the key field. This one-to-one relationship will provide the design the capability to link allotments to permits. Only one allotment can contain a permit, yet one person can have many permits. This developed the use of the authorization number, which identifies the lessee based on their permits, not allotments (Table 37).

Table 37, RngLess Relationship Class.

RngLess Relationship Class	
Type	Simple
Cardinality	One-to-One
Key Field in Origin Class	AuthNum
Key Field in Destination Class	AuthNum

RngImp Feature Class

The range improvement (RngImp) feature class is a polygon layer containing range improvement project information. Rangeland improvement is necessary when rangelands need maintenance or improvements. The geographic location of range improvement projects does not follow any of the legal boundaries or monitoring transects mentioned previously. There may be a need for rangeland improvement projects that lie on multiple allotments, or a variety of transects

As mentioned previously in the Hydrology Feature Dataset, restoration projects may all be placed in to a three separate feature classes to represent points, lines and polygons. Then an associated object class can be created to represent the monitoring data, and link these feature classes. This is only a suggestion, as it stands now, the individual disciplines desire their own restoration or improvement projects. Table 38 describes the range improvement project.

Table 38, RngImp Feature Class.

RngImp Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
AllotNum	Short Integer	5	. . .	Unique Allotment Identification Number
ProjNum	Short Integer	8	. . .	Range Improvement Project Number
ProjType	Text	10	RngImp	Type of Range Improvement Project
Date	Year	4	. . .	Range Improvement Project Date
ProjLead	Text	20	. . .	Name of Project Leader
Note	Text	50	. . .	Additional Information

The project number (ProjNum) contains a 4-digit identification number. The project type (ProjType) field indicates the type of improvement project performed, and the range improvement (RngImp) coded value domain values include: (1) fencing construction or removal (Fence), (2) spring development (SprDev), (3) pipeline construction or maintenance (PipeLn), (4) tank construction or maintenance (Tank), and (5) Other. Other may be described in the Note field, with any other project information. Additional domain selections may be added to this domain as needed.

Spring Feature Class

The spring feature class is a point layer containing the location of hydrologic springs, and their associated information (Table 39).

Table 39, Spring Feature Class.

Spring Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
AllotNum	Short Integer	5	. . .	Unique Allotment Identification Number
SprName	Text	20	. . .	Name of Spring
SprType	Text	12	SprType	Developed or Undeveloped Spring
Picture	Blob	. . .	. . .	Picture of Spring

The spring name (SprName) field is determined by the geographic location of the spring. For instance, if a spring were located near Copper Creek, the spring name is Copper Creek Spring. This helps BLM employees and public identify spring locations using familiar names and locations.

The spring type (SprType) Field identifies the type of spring, and the SprType coded-domain categorizes the springs as (1) developed or (2) undeveloped. A developed spring usually contains man-made structures such as pipelines and tanks to assist in livestock grazing. Undeveloped springs are usually natural untouched hydrologic springs.

RECREATION DISCIPLINE

Conceptual Phase

The outdoor recreation planner is responsible for recreation, travel management, and visual resources on Missoula Field Office lands. Recreation management consists of overseeing all recreation activities used by the public and commercial businesses. Travel management is the regulation of travel routes on BLM lands for various activities throughout the year. Recreation and travel management policies rely mainly on coordinated efforts to regulate land use activities through the authorized use of trails, roads, and area closures.

There are numerous outdoor recreation activities in western Montana. Missoula Field Office lands offer a variety of recreation activities and human amenities. Outdoor recreation include: hiking, fishing, hunting, mountain biking, rock climbing, boating, camping, swimming, horseback riding, cross-country (CC) skiing, all terrain vehicle (ATV) use, and snowmobiling. The BLM offers amenities on recreation sites including: restrooms, drinking water, parking, handicap access, boat launching, and fishing access.

The BLM contains an elaborate system of roads and trails throughout their lands. These routes may be used for horseback riding, hiking, snowmobile use, bicycling, ATV use, and CC skiing. Routes are regulated through road and area restrictions designated in the travel management plan.

The travel management plan regulates seasonal use of all travel routes through BLM lands. Road and area restrictions are used to regulate these land uses. Gates allow the BLM to regulate road use in an effective manner. Road and area restrictions are primarily based on land use activities, seasonal uses, and special management areas.

Area restrictions are necessary to regulate public activities, wildlife protection, hunting regulations, visual resources, and environmental protections. Public activities include things such as hiking, fishing, snowmobiling, cross-country skiing, horseback riding, camping, boating, etc. Wildlife protection is practiced in areas of critical wildlife habitat, including winter range areas and areas of known threatened or endangered species.

Missoula Field Office contains two trails that qualify for the national trail system: the Lewis and Clark National Historic Trail and the Garnet Range National Winter Recreation Trail. These trails require special attention and specific regulations. The three categories of a national trail are historic, recreational, and scenic. The Lewis and Clark National Historic Trail contains historical significance, and therefore requires protection. The Garnet Range National Winter Recreation Trail designation recognizes the areas outstanding winter recreation opportunities. The geographic location and amenities of these trails are important in assuring their protection and utilization.

Commercial businesses specializing in outfitter and guide management activities within BLM lands are required to obtain a five-year Special Recreation Permit (SRP), and allocate 3% of their total revenues to the BLM. These outfitters provide a wide spectrum of recreation activities for their clients, which are conducted on BLM lands. These activities are overseen by the BLM to ensure the protection and preservation of trails and campsites.

Some BLM lands are called Special Management Areas (SMA) because they require special care due to their unique characteristics and functionality. They are managed under various local and federal regulations based on their unique purposes

including: historic landmarks, recreation activities, scenic beauty, and wildlife habitat. Regulations are placed on special management areas for their protection and preservation. Three examples include: Wilderness Study Areas (WSA), Area of Critical Environmental Concern (ACEC) and Visual Resource Management areas (VRM).

Wilderness Study Areas (WSA) are set aside by the United States Congress since they possess the basic wilderness characteristics of being at least 5,000 acres in size, being primarily natural, and because they have outstanding opportunities for solitude or primitive and unconfined types of recreation.⁶⁹ WSA are managed to protect these wilderness values until such time that congress decides whether or not to designate them as official Wilderness Areas.

Areas of Critical Environmental Concern (ACEC) are an administrative designation by the BLM that requires areas to have special management. These are areas that have special management practices in place to protect and prevent irreparable damage to important historic artifacts, cultural landmarks, scenic vistas, fish and wildlife resources, or other natural items. They may also be designated to protect life and promote safety from natural hazards.⁷⁰

Visual Resource Management areas (VRM) are established by the BLM in order to identify the visual values of an area and establish objectives for managing these values in concert with other resource management actions. Visual resources are viewed as tools to assist the outdoor recreation specialist in management decisions, and placed into categories serving two purposes: (1) an inventory tool for portraying the relative value of the visual resource, and (2) a management tool for portraying the visual management

⁶⁹ BLM, *Garnet Resource Area Resource Management Plan*, 130.

⁷⁰ BLM, *Garnet Resource Area Resource Management Plan*, 123.

objectives. There are four VRM classes (I, II, III, and IV), ranging from preserving the existing character of the land to the application of major land modifications.⁷¹

Class I is provided primarily for natural ecological changes; however, this does not preclude very limited management activity. This class contains WSA and other similar situations where management activities are to be restricted. Class II requires that management activities be designed and located to blend into the natural landscape and not be apparent to the casual visitor. Class III provides that management activities may be evident to the casual visitor; however, the activity should remain subordinate to the visual strength and natural character of the landscape. Finally, Class IV provides that management activities may be visually apparent to the casual observer and may also become dominant in the landscape.⁷²

Regulations are placed on recreational activities within WSAs, ACECs, and VRMs to ensure their protection and preservation. These areas of special concern are regulated using areas restrictions, road restrictions, and the use of gates to enforce these policies.

Area restrictions, road restrictions, trails, gates, recreation sites, VRMs, SMAs, and SRPs are nine datasets designed for this project. It is the responsibility of the outdoor recreation planner to oversee BLM lands and resources to ensure that they are preserved and protected for future generations of people seeking outdoor recreation experiences.

A GIS containing area restrictions, road restrictions, special management areas, special recreation permits, trails, recreation sites, gates, and visual resource management

⁷¹ BLM, *Garnet Resource Area Resource Management Plan*, 23.

⁷² BLM, *Garnet Resource Area Resource Management Plan*, 91,92.

areas will assist greatly in organizing and coordinating the responsibilities placed on the recreation discipline.

Logical Phase

Once again, this logical phase is a combination of the conceptual research described previously. It is the result of discussions between the author and outdoor recreation planner concerning the recreation discipline's data needs, data collection techniques, classification systems, recreation activities, governmental classifications and regulations, and the concepts and processes involved in recreation management. The rangeland specialist was eager to understand the capabilities of GIS, and share any and all information necessary to improve the methods used in geospatial data management and analysis.

The intention of the logical phase design in this instance is to create a feature dataset that provides the recreation discipline with the geospatial tools necessary to document and map recreation data, use the data to support recreation management and planning, and conduct the analysis necessary to accomplish the objectives of the recreation discipline.

Recreation Feature Dataset

The recreation feature dataset stores all recreation data needed to organize, manage, and maintain the variety of recreational activities on Missoula Field Office lands. The recreation discipline maintains, develops, and improves recreation resources for public activity. Management of roads, areas, special management areas, visual resources, recreation sites, trails and gates are essential to the daily recreational demands present on public lands. The purpose is to develop comprehensive databases to assist the

recreation specialist in managing these many activities in an effective geodatabase structure.

Seven feature classes and one object class have been designed to accomplish this work. These include: area restriction (ArRest) feature class, road restriction (RdRest) feature class, special management area (SMA) feature class, trail feature class, recreation site (RecSite) feature class, gate feature class, visual resource management (VRM) feature class, and the special recreation permit (SRP) object class.

ArRest Feature Class

The area restriction (ArRest) feature class is a polygon layer containing area restrictions currently enforced on Missoula Field Office lands. The ArRest feature class captures the area restrictions developed from a variety of land management regulations. The area may be restricted for hunting, wilderness study areas, areas of environmental concern, sensitive wildlife habitat, etc (Table 40).

Table 40, ArRest Feature Class.

ArRest Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
AreaType	Text	2	AreaType	Type of Area Restriction
ORV	Text	15	DateCl	Off Road Vehicle Restriction Dates
MotorATV	Text	15	DateCl	Motorcycle and ATV Restriction Dates
SnowMob	Text	15	DateCl	Snowmobile Restriction Dates
Note	Text	50	. . .	Additional Information

The area type (AreaType) field categorizes the area restriction in to a numeric grouping. For instance, area type 1 contains a yearlong restriction. AreaType was developed as a way to categorize the many various date combinations in to a simple numeric code. A coded value range domain called AreaType was created to house the options 1 through 7, each containing their own restriction dates.

For mapping purposes, it was important to capture the numeric area type restriction, and the actual dates, which are located in the following fields: off road vehicle (ORV), motorcycle and all terrain vehicle (MotorATV), and snowmobile (SnowMob). These fields house the actual restriction dates by means of the date closed (DateCl) coded value domain. These options in the DateCl coded value domain include: (1) Yearlong, (2) 9/1-12/1, (3) 9/1-4/30, (4) 9/1-5/14, and (5) 10/15-12/1, etc.

RdRest Feature Class

The road restriction (RdRest) feature class is a line layer containing all road restrictions located on Missoula Field Office lands. Road restrictions are roads that have exceptions to the area restrictions in which they lie. Mostly, BLM roads follow area restriction regulations, but in some cases there are exceptions that involve a different set of restrictions. The road restriction layer applies to this particular situation (Table 41).

Table 41, RdRest Feature Class.

RdRest Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
RdType	Text	2	RdType	Type of Road Restriction
ORV	Text	15	DateCl	Off Road Vehicle Restriction Dates
MotorATV	Text	15	DateCl	Motorcycle and ATV Restriction Dates
SnowMob	Text	15	DateCl	Snowmobile Restriction Dates
Note	Text	50	. . .	Additional Information

The road type (RdType) field categorizes the area restriction in to an alphabetic grouping. The RdType field contains the letters, which relate to specific closure dates. The road type (RdType) coded value domain lists these letters: (1) A, (2) B, (3) C, (4) D, (5) E, (6) F, (7) G, (8) H, (9) I, (10) J, and (11) K. The remaining fields of off road vehicle (ORV), motorcycle and all terrain vehicle (MotorATV), and snowmobile

(SnowMob) include the restriction dates for these roads. The date closed (DateCl) coded value domain is used again from the ArRest feature class, and contains the same options: (1) Yearlong, (2) 9/1-12/1, (3) 9/1-4/30, (4) 9/1-5/14, and (5) 10/15-12/1, etc.

The reason for capturing the categories and restriction dates of area and road restrictions is strictly due to the mapping capabilities that both sets of data provide. One might want to label the area restrictions, and symbolize the road restrictions with colors, or vice versa. Area and road restriction maps are furnished to the public to provide these regulations established by the BLM.

Gate Feature Class

The gate feature class is a point layer containing all gate information on Missoula Field Office lands. Gates are utilized to help regulate area, road, and ownership characteristics. They are also based on land management regulations set forth for a variety of reasons. Gate closures are based on needs of the WSAs, ACEC's, VRM, wildlife and environmental habitat, etc. Gates are closely related to road and area restrictions, and in most cases, used to enforce the area and road restrictions (Table 42).

Table 42, Gate Feature Class.

Gate Feature Class				
Field Name	Data Type	Length	Domain	Description
Object_ID	Object ID	. . .	. . .	Default Object ID
Shape	Geometry	. . .	. . .	Point
GTName	Text	30	. . .	Name of the Gate
GTNum	Text	5	. . .	Unique Gate Identification Number
GType	Text	15	GType	Type of Gate or Barrier
FeedRd	Text	20	. . .	Access Road to the Gate
WSCode	Text	3	WSCode	Watershed Code
KeyCode	Text	5	KeyCode	Individual Key Code
DateCl	Text	15	DateCl	Dates Gate is Closed
ForestService	Text	3	Yes/No	Shared with Forest Service
FWP	Text	3	Yes/No	Shared with Fish Wildlife and Parks
PlumCreek	Text	3	Yes/No	Shared with Plum Creek Timber
Stimson	Text	3	Yes/No	Shared with Stimson Lumber
Private	Text	3	Yes/No	Shared with Private Owner
Other	Text	3	Yes/No	Shared with Other Party
Picture	Blob	. . .	. . .	Picture of the Gate
Note	Text	50	. . .	Additional Information

The gate name (GTName) is the name of the gate, based on its geographic location, usually mimicking the route names. The gate number (GateNum) field is associated with the route number of the road. For instance, gate 4302 is positioned on route 4302. If there are numerous gates on a single road, an alpha-code is added to the end starting with the letter A. For example: 4302A, 4302B and 4302C. The feeder road (FeedRd) field is used to document adjacent larger roads to help BLM employees find gates when applicable.

The gate layer captures other road closure techniques besides gates such as kelly humps and guardrails for easier documentation and manageability. Kelly humps are mounds of rock, gravel, and dirt, restricting the access of large vehicles. The gate type (GType) field identifies the structural type of gate, and the GType coded value domain includes these options: (1) powder river, (2) steel bar, (3) wire, (4) kelly hump, and (5) guardrail. Powder river gates are another type of gate that are 16x2 feet, and contain four

vertical bars. Guardrails are similar to guardrails on major road systems, and deny all motor vehicle access.

The distribution of gate keys is an important tool in managing lands, regulations, and access on BLM lands. Various keys are designed to provide access depending on circumstances. Examples of different situations include: access to certain individuals, access for specific periods in time, or access to certain areas. The Missoula Field Office contains a master key, which opens all gates. Sub-master keys are then provided to individuals requiring access to areas, and individual keys to specific gates. An alphanumeric code is used to identify this hierarchy of gate keys. The letter A signifies a master key, opening all gates on Missoula Field Office lands. The letters AA signify a sub-master key, which represents an additional letter for the watershed location, and open all gates within that particular watershed. For instance, the key AAC, the AA identifies it's a sub-master (watershed) key, and the letter C represents East Garnet.

The watershed code (WSCode) captures the keys that open gates located on the various watersheds. The watershed code (WSCode) coded value domain contains the selections for each watershed. These include: (1) AAA (Blackfoot), (2) AAB (West Garnet), (3) AAC (East Garnet), (4) AAD (Marcum Mountain), (5) AAE (Hoodoos), and AAF (Philipsburg).

Individual gates also contain specific key codes, which are classified by watershed and assigned numbers. For instance, the gate key AAC-1 opens only the gate in East Garnet that is allocated the number 1. The next gate would contain AAC-2 in East Garnet. This method provides the BLM with a method of assigning gate keys for specific purposes. The key code (KeyCode) field documents the individual key codes for

the gates, and the key code (KeyCode) coded value domain lists the many selections including: AAA-1, AAA-2, AAB-1, AAB-2, AAC-1, etc.

The date closed (DateCl) field documents the dates the gate is closed by using the date closed (DateCl) coded value domain described in the previously discussed ArRest and RdRest feature classes. It is important to standardize as many components of a geodatabase, such as domains, to establish consistency between data elements.

Gates play a vital regulatory role in the policies established by the BLM, and in turn are not subject to one set of rules or regulations. In many cases, gates are shared with other agencies, organizations and private parties. The gates are designed to handle this type of situation by their unique construction, which allows many locks to be placed on a single gate. The next six fields document these gate relationships by using a Yes/No coded domain value. The main organizations sharing BLM gates are: U.S. Forest Service; Montana Department of Fish, Wildlife, and Parks, Plum Creek Timber, Stimson Lumber, and private organization or individuals. These fields will identify who has locks on these gates.

SMA Feature Class

The special management area (SMA) feature class is a polygon layer containing areas critical of environmental concerns (ACEC) and wilderness study areas (WSA). Their sensitive nature requires special management regulations. The area, road, and gate restrictions are enforced as a result of these special management regulations (Table 43).

Table 43, SMA Feature Class.

SMA Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
SMAName	Text	30	. . .	SMA Name
SMANum	Short Integer	2	. . .	SMA Identification Number
SMAType	Text	15	SMAType	Type of Special Management Area
Note	Text	50	. . .	Additional Information

The special management area name (SMAName) field documents the name of the special management area. The special management area number (SMANum) field is the identification number used to document the special management area. The special management area type (SMAType) field captures the type of SMA present, and the SMAType coded value domain contains (1) Areas Critical of Environmental Concern (ACEC) and (2) Wilderness Study Area (WSA).

VRM Feature Class

The visual resource management (VRM) feature class is the visual resource management polygon layer. This layer is essential to a VRM’s location and classifications (Table 44). The idea behind VRMs is to protect and preserve the intrinsic beauty of our natural landscapes, and in doing so, protect their visual worth through various corridors.

Table 44, VRM Feature Class.

VRM Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Polygon
VRMName	Text	20	. . .	Name of Visual Resource Management
VRMCI	Text	4	VRMCI	Visual Resource Management Class
VRMCat	Text	4	VRMCat	Location of VRM from the Source
Date	Year	4	. . .	Data Collection Date
Note	Text	50	. . .	Additional Information

The visual resource management name (VRMName) field captures the name of the management area. The visual resource management class (VRMCI) contains the class of this area using the visual resource management class (VRMCI) coded value domain, which includes (1) I, (2) II, (3) III, and (4) IV. The roman numerals identify the restrictions and regulations placed on that visual resource management area. The details of the VRM classes were described in the conceptual section of the recreation discipline.

The visual resource management category (VRMCat) field is necessary to identify the VRM's location from the potential source. The visual resource management category (VRMCat) coded value domain documents the three categories. For instance, the VRM may be located in the foreground, middle ground, or background of the visual source. The visual source is represented by a road, trail, or scenic view.

RecSite Feature Class

The recreation site (RecSite) feature class is a point layer containing all established recreational sites located on Missoula Field Office lands. Many recreational activities are available on public lands, and RecSite layer incorporates all conventional activities and available amenities (Table 45).

Table 45, RecSite Feature Class.

RecSite Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
SiteName	Text	20	. . .	Name of Recreation Site
SiteNum	Short Integer	5	. . .	Recreation Site Number
PriAct	Text	20	PriAct	Primary Activity of Recreation Site
Park	Text	3	Yes/No	Parking Access
Bath	Text	3	Yes/No	Bathroom Access
Camp	Text	3	Yes/No	Camping Access
Fish	Text	3	Yes/No	Fishing Access
Boat	Text	3	Yes/No	Boat Launch Access
HCA	Text	3	Yes/No	Handicap Access
Water	Text	3	Yes/No	Drinking Water Access
Fire	Text	3	Yes/No	Fire Ring Access
Fee	Text	3	Yes/No	Recreational Site Fee
Picture	Blob	. . .	. . .	Picture of Recreation Site
Note	Text	50	. . .	Additional Information

The site name (SiteName) field identifies the name of the recreation site, usually named by its geographic location. The site number (SiteNum) field is the identification number of each recreation site.

The primary activity (PriAct) field identifies the recreation site’s primary recreational activity using the (PriAct) coded domain. The PriAct coded domain classifies the principal activity of the recreation site including: (1) boat launch (BL), (2) camping (Camp), (3) scenic (Scene), (4) fishing access (FA), (5) historic site (HS), (6) day use area (DUA), (7) memorial (Mem), (8) swim (Swim), (9) wildlife viewing (WV), and (10) trailhead (TH). Choosing which activity is the primary one is based on a hierarchal classification scheme designed by the outdoor recreation planner. For instance, boat launching is limited to a handful of sites, placing it higher than other activities in that recreational site.

The Park, Bath, Camp, Fish, Boat, HCA (handicap access), Water, Fire, and Fee fields list all of the available amenities in a recreation site. They all contain a Yes/No domain to ensure easy documentation, mapping capabilities, and labeling functionality.

Trail Feature Class

The Trail feature class is a line layer containing all trails on Missoula Field Office lands. Trails are used for various activities, and the trail layer identifies these activities for easier management (Table 46).

Table 46, Trail Feature Class.

Trail Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
TrName	Text	30	. . .	Name of Trail
TrNum	Short Integer	4	. . .	Unique Trail Identification Number
PriAct	Text	20	PriTrAct	Primary Trail Activity
Foot	Text	3	Yes/No	Hiking Activity
Bike	Text	3	Yes/No	Bicycle Activity
ATV	Text	3	Yes/No	All Terrain Vehicle Activity
Snow	Text	3	Yes/No	Snowmobile Activity
CCSki	Text	3	Yes/No	Cross Country Skiing Activity
LewClark	Text	3	Yes/No	Historical Lewis & Clark Trail
WintRec	Text	3	Yes/No	National Winter Recreation Trail
Note	Text	50	. . .	Additional Information

The trail name (TrName) field documents the trail name, and the trail number (TrNum) field captures the trail identification number. The primary activity (PriAct) field is the primary trail activity; using the PriTrAct coded domain which includes: (1) foot, (2) bike, (3) all terrain vehicle (ATV), (4) snowmobile (Snow), (5) cross country ski (Ccski), (6) lewis and clark (LewClark), and (7) winter recreation (WintRec). This domain is similar to the various recreational activities described in the previous layer.

The hiking (Foot), bike (Bike), all terrain vehicle (ATV), snowmobile (Snow), cross country ski (CCski), Lewis and Clark (LewClark), winter recreation (WintRec) are the various types of trail activities located on BLM lands. They all contain a Yes/No domain, which allows the documentation of multiple trail activities on a single trail. This also helps the Missoula Field Office manage these trails to accommodate all activities.

SRP Object Class

The special recreation permit (SRP) table is designed for local business and outfitter trail use. SRPs are based on trails designated for used by these outside businesses and outfitting organizations, which provide a wide variation of activities for their clients. Outfitters are required to purchase a five-year special recreation permit. The SRP object class may be connected to the trail feature class using a simple join function in ArcGIS 9.2. The SRPs are based off of trails, and their relationship is important to observe the trails associated with each SRP. (Table 47).

Table 47, SRP Object Class Class.

SRP Object Class				
Field Name	Data Type	Length	Domain	Description
TrNum	Short Integer	4	. . .	Unique Trail Identification Number
PermNum	Text	13	. . .	Permit Number
Permitee	Text	30	. . .	Name of Permitee
ExpDate	Year	4	. . .	Permit Expiration Date
SRPUse	Text	10	SRPUse	Intended Use of Permitee
Note	Text	50	. . .	Additional Information

The permit number (PermNum) field contains the Missoula Field Office identification number, which includes the Missoula Field Office id, the recreation permit’s year, and the permit number. For example: MT100-RP08-01. MT100 is the Missoula Field Office, RP08 is recreation permit year 2008, and 01 is the first permit granted in the year 2008.

The name of the organization or company for is captured in the Permittee field. The expiration date (ExpDate) captures the termination date of the permit. The permit start date is unnecessary due to the five-year requirement. The special recreation permit use (SRPUse) field contains the intended use of the permit. The SRPUse coded value domain includes: (1) Hike, (2) Bike, (3) Snowmobile, (4) ATV, (5) CC ski, (6) Horseback and (7) Other.

The recreation feature dataset contains all necessary geographic data to assist the outdoor recreation planner the geospatial tools necessary to plan land management activities, regulate the many recreational activities, and organize all recreation in an effective and meaningful manner.

WILDLIFE DISCIPLINE

Conceptual Phase

The wildlife biologist is responsible for terrestrial wildlife management. Wildlife of concern includes: threatened and endangered T&E), sensitive species, migratory bird, and big game species. Threatened and endangered species are listed and regulated under the Endangered Species Act (ESA). Various mammals and birds are managed as sensitive species by the BLM. Many migratory birds summer in northern latitudes and winter in Mexico or Central and South America. Big game species include elk, deer, moose, and bighorn sheep.

As noted above, the threatened and endangered species are protected under the Endangered Species Act. Their distributions, nests, den, and forage sites, are inventoried and monitored by the BLM. Surveys are conducted on lands that have not yet been reviewed, and monitoring is utilized to document any population trends. For instance,

when Marcum Mountain begins the initial steps in the watershed management plan, the entire area is surveyed for sensitive and T&E species. Following the initial survey, land management practices and regulations are adopted where necessary to protect and preserve their populations and the natural habitat. Monitoring will then be performed to observe population trends and habitat conditions.

Public information is available on species distribution, but nest, den, and forage site locations are considered confidential. Surveys are conducted on lands where proposed land management projects are considered to determine species presence or absence, and to avoid or mitigate potential adverse affects.

The BLM State Director recognizes sensitive species as species of special concern. These species are not listed or regulated under the ESA. Presence or absence surveys are conducted during watershed assessments and other project activities. Inventories are conducted on lands that have not been surveyed. If inventories detect the presence of sensitive species, monitoring surveys are conducted after project completion. Nest locations for sensitive birds are documented when discovered. If nests are active, a buffer zone is established around nests to protect the site.

Migratory birds are protected under the Migratory Bird Treaty Act. Interim management guidelines have been developed for project level activities. Bird Species of Conservation Concern (Fish and Wildlife Service) and Bird Conservation Priorities in Montana (Montana Partners in Flight) are guiding documents.⁷³ Migratory birds of concern are inventoried, monitored, and timing and area restrictions are developed to mitigate project level activities. Timing and area restrictions are implemented during

⁷³ Fish and Wildlife Service: Department of the Interior. *A Guide to the Laws and Treaties of the United States for Protecting Migratory Birds*. Washington D.C. On-line. Available from Internet, <http://www.fws.gov/migratorybirds/intrnltr/treatlaw.html>, Accessed 3 August 2008.

migration periods and in known migration areas, based on historic migratory patterns.

Bird monitoring collects the data necessary for the wildlife biologist to conduct scientific evaluation. Migratory birds not of concern are surveyed, but management guidelines do not apply.

Big game management is coordinated with the Montana Department of Fish, Wildlife, and Parks (FWP). The BLM manages habitat and FWP manages populations of big game. The distribution of big game, and components such as summer range, winter range, and birthing areas, are mapped. Habitat restoration projects benefiting big game, and projects with potential adverse affects to big game are analyzed by the BLM and FWP. Proposed projects with beneficial affects for big game are carried forward; projects that may cause adverse affects on big game population or habitat are abandoned.

There is a strong desire in the wildlife resource discipline at the Missoula Field Office to develop geospatial data in to a geodatabase format to support their needs and requirements. The datasets designed to reach these goals include: breeding bird survey routes, breeding bird monitoring, nests, nest monitoring, big game species, and threatened and T&E species.

Logical Phase

As noted previously, the logical phase is an outgrowth of the conceptual research described previously. Discussions were conducted with the wildlife biologist concerning the wildlife discipline's data needs, data collection techniques, classification systems, wildlife habits, governmental classifications and regulations, and the concepts and processes involved in wildlife management. The wildlife biologist was eager to

understand the capabilities of GIS, and share any and all information necessary to improve the methods used in the geospatial data analysis of his discipline.

The intention of the logical phase design in this case is to create a feature dataset that provides the wildlife discipline with the geospatial tools necessary to document and map recreation data, use the data to support wildlife management and planning, and conduct the analysis necessary to accomplish the objectives of the wildlife discipline.

Wildlife Feature Dataset

The wildlife feature dataset organizes all geodatabase data needed for terrestrial wildlife management. Management of threatened and endangered species, sensitive species, migratory bird, and big game species are GIS data designed to assist the Missoula Field Office in accomplishing their wildlife responsibilities.

A raptor route (RapSurRt) feature class, a raptor monitoring (RaptorMon) object class, a nest (Nest) feature class, a nest monitoring (NestMon) object class, a sensitive bird species (SensBirds) feature class, a sensitive mammal (SensMam) feature class, were designed for this work. Two relationship classes were also created within this dataset called raptor monitoring (RaptorMon), and nest monitoring (NestMon).

RapSurRt Feature Class

The raptor survey route (RapSurRt) feature class is a line layer identifying all raptor routes used by the Missoula Field Office for monitoring. There are six total bird routes used to monitor, observe success, and identify bird species. The RapSurRts are mainly primary and secondary roads traveled by wildlife biologist during various times of the year to count breeding birds.

This particular feature class contains the geographic locations and monitoring segments within the bird routes. The wildlife biologist travels these raptor routes, and with the help of other specialists, identifies bird species through close observation. The monitoring segments allow the captured data to be specific to the road segment (Table 48).

Table 48, RapSurRt Feature Class.

RapSurRt Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Line
RtNum	Short Integer	2	. . .	Bird Route Number
SegNum	Text	5	. . .	Unique Route Segment IdentificationNumber
RapName	Text	15	RtName	Bird Route Name
Mile	Short Integer	5	. . .	Segment Miles
Note	Text	50	. . .	Additional Information

The bird route number (RtNum) feature class delineates the six bird routes using the numbers from 01 to 06. The segment number (SegNum) fields contains an assigned bird route number and the road segment number combined. An example is 01-01, where 01 identifies the bird route, and 01 delineates the first road segment within the bird route.

The bird route name (BRName) field gives the route name, and relates to the agency responsible for the resulting data. The Missoula Field Office records its own raptor survey route, FWPs has ownership of the state raptor route, and the FWS contains a bald eagle route and three additional routes numbered one, two and three. The RtName coded-domain includes these separate routes: (1) MiFORap, (2) StateRap, (3) Bald Eagle, (4)Survey1, (5) Survey2, (6) and Survey3. The Missoula Field Office conducts surveys on all of the above routes described, and shares their findings with the route owner.

RapMon Object Class

The raptor monitoring (RapMon) object class is a dataset designed to capture monitoring data from survey the previously described raptor routes over time. The RapMon feature class will be linked to the RapSurRt feature class described in the previous section. These two datasets will be linked using a one-to-many relationship class, which is ideal for monitoring. Raptor monitoring is necessary to identify trends and fluctuations in bird populations (Table 49).

Table 49, RapMon Object Class.

RapMon Object Class				
Field Name	Data Type	Length	Domain	Description
SegNum	Text	5	. . .	Unique Route Segment IdentificationNumber
BEPres	Short Integer	3	. . .	Number of Bald Eagles Sited
JBEPres	Short Integer	3	. . .	Number of Juvenile BEs Sited
Ghawk	Short Integer	3	. . .	Number of Goshawks Sited
RTHawk	Short Integer	3	. . .	Number of Red Tail Hawks Sited
SwHawk	Short Integer	3	. . .	Number of Swainsons Hawks Sited
GGowl	Short Integer	3	. . .	Number of Great Gray Owls Sited
FlaOwl	Short Integer	3	. . .	Number of Flammulated Owls Sited
FieldTech	Text	20	. . .	Field Technician Monitoring
MonDate	Year	4	. . .	Monitoring Date
Note	Text	50	. . .	Additional Information

The bald eagle presence (BEPres), juvenile bald eagle presence (JBEPres), goshawk (Ghawk), red tail hawk (RTHawk), swainson’s hawk (SwHawk), great gray owl (GGowl), and flammulated owl (FlaOwl) are species fields designed to capture the number of birds counted within each route segment. Notice the monitoring date (MonDate) field, which is highly important for any monitoring dataset.

A one-to-many relationship class is designed to link the RapSurRt feature class and RapMon object class using SegNum as the unique identifier. This relationship class will prove useful when documenting monitoring over time (Table 50).

Table 50, RapMon Relationship Class.

RapMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	SegNum
Key Field in Destination Class	SegNum

Nest Feature Class

The nest (Nest) is a point feature class that captures the geographic locations of all known nests located on or near Missoula Field Office lands (Table 51).

Table 51, Nest Feature Class.

Nest Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
Date	Year	4	. . .	Year Nest was Discovered
NestNum	Short Integer	6	. . .	Unique Nest Identification Number
NType	Text	20	NType	Type of Nest
Sensitive	Text	3	Yes/No	Whether Bird is Sensitive or Not
FieldTech	Text	20	. . .	Field Technician Collecting Data
Picture	Blob	. . .	. . .	Picture of Nest
Note	Text	50	. . .	Additional Information

The nest number (NestNum) field is a combination of the nest discovery year and a chronological identification number. For example, the nest number may be 08-001. The number 08 represents the year, and 001 represents the first nest discovered in the year 2008.

The nest type (Ntype) field indicates the bird species occupying the nest, and the Ntype coded value domain contains: (1) bald eagle, (2) golden eagle, (3) goshawk, (4)

great gray owl, (5) flammulated owl, (6) red tail hawk, and (7) swainsons hawk. The Sensitive field delineates whether the birds are classified as sensitive species or not.

NestMon Object Class

The nest monitoring (NestMon) object class is designed to examine nests over a period of time. The NestMon object class will be linked to the Nest feature class using a one-to-many relationship necessary to manage monitoring scenarios. The BLM will systematically observe these nests and evaluate the population trends of the species. Nest monitoring includes whether the nests are active, whether offspring was produced, the success of the offspring, and condition of the nests (Table 52).

Table 52, NestMon Object Class.

NestMon Object Class				
Field Name	Data Type	Length	Domain	Description
NestNum	Short Integer	6	. . .	Unique Nest Identification Number
MonDate	Year	4	. . .	Monitoring Date
NStatus	Text	10	NStatus	Whether Nests are Active or Inactive
NSucc	Text	15	NSucc	Whether Nests are Successful or Unsuccessful
OffSpr	Short Integer	2	. . .	Number of Off-Spring Sited
FieldTech	Text	20	. . .	Field Technician Monitoring
Picture	Blob	. . .	. . .	Picture of the Nest
Note	Text	50	. . .	Additional Informaiton

The nest status (Nstatus) field classifies whether the nests are active or inactive, and the nest status (Nstatus) coded domain lists (1) active, (2) inactive. In some cases, an occupied nest may not succeed. The nest success (NSucc) field addresses these instances, and the NSucc coded domain lists (1) successful, (2) unsuccessful and (3) not applicable. The offspring (OffSpr) field allows the field technician to document the number of offspring observed, while the nest success (NSucc) field explains whether the offspring in the nest were successful.

The NestMon table is linked to the Nest table by a one-to-many relationship class using the NestNum field as the unique identifier. The NestMon relationship class allows the documentation of nest data on multiple occasions, and satisfies the geospatial data necessary for geospatial analysis (Table 53).

Table 53, NestMon Relationship Class.

NestMon Relationship Class	
Type	Simple
Cardinality	One-to-Many
Key Field in Origin Class	NestNum
Key Field in Destination Class	NestNum

SensMam Feature Class

The sensitive mammal (SensMam) feature class is a point layer used to identify the location of sensitive and T&E mammal species on Missoula Field Office lands. The BLM documents any sightings of mammal species classified as sensitive or T&E species. The mammal sightings are placed into this feature class, and further analysis may be performed when land management projects are proposed in that location. Future analysis may include buffers, and further investigations of the area (Table 54).

Table 54, SensMam Feature Class.

SensMam Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
SpecClass	Text	10	SpecClass	Whether Species is Classified Sensitive or T&E
SpecSighted	Text	10	MamSight	Type of Species Sighted
Date	Year	4	. . .	Date Species was Sighted
FieldTech	Text	20	. . .	Field Technician Collecting Data
Note	Text	50	. . .	Additional Information

The species classification (SpecClass) field determines if the species are classified as sensitive or T&E. The species classification (SpecClass) coded value domain contains

the options: (1) special, or (2) T&E. The species sighted (SpecSighted) field identifies the species found at that location, while the mammal sighting (MamSight) value domain houses all mammal species, both sensitive and T&E. These current mammals species include: (1) townsend’s big eared bat (TBEB), (2) fringed myotis bat (FMB), (3) long-legged myotis bat (LLMB), (4) long-eared myotis bat (LEMB), (5) fisher (F), (6) North American wolverine (NAW), (7) grizzly bear (GB), (8) Canadian lynx (CL), and (9) wolf (W). The date, field technician and note fields will provide additional information important to this layer.

SensBirds Feature Class

The sensitive birds (SensBirds) feature class is a point layer used to identify the location of sensitive and T&E bird species on Missoula Field Office lands. The BLM collectively documents any sightings of bird species classified as sensitive or T&E species. The SensBirds feature class is similar to SensMam feature class, and used to produce the same results, only using birds as the primary focus instead of mammals. Similar analysis may be conducted on point locations as mentioned above (Table 55).

Table 55, SensBirds Feature Class.

SensBirds Feature Class				
Field Name	Data Type	Length	Domain	Description
Shape	Geometry	. . .	. . .	Point
SpecClass	Text	10	SpecClass	Whether Species is Classified Sensitive or T&E
SpecSighted	Text	10	BirdSight	Type of Species Sighted
Date	Year	4	. . .	Date Species was Sighted
FieldTech	Text	20	. . .	Field Technician Collecting Data
Note	Text	50	. . .	Additional Information

The species classification (SpecClass) field is the same as used in the SensMam feature class, and the species classification (SpecClass) coded value domain captures the

option of (1) sensitive, or (2) T&E species. The species sighted (SpecSighted) field identifies the multiple bird species, and the bird sighting (BirdSight) coded value domain houses all of the options. These options include: (1) black tern (BT), (2) common loon (CL), (3) flammulated owl (FO), (4) golden eagle (GE), (5) great gray owl (GGO), (6) loggerhead shrike (LS), (6) long-billed curlew (LBC), (7) northern goshawk (NG), (8) peregrine falcon (PF), (9) Brewer's sparrow (BS), (10) Swainson's hawk (SH), (11) trumpeter swan (TS), (12) black-backed woodpecker (BBW), and (13) three-toed woodpecker (TTW).

It had been the author's intention to continue work to design data to identify big game habitat areas, including their winter and summer ranges. Big game species include white tail deer, mule deer, elk, moose, and big horn sheep. The Montana Fish, Wildlife, and Parks (FW&Ps) agency contains these datasets in shapefile format, and update them regularly. However, it has been concluded that it is unnecessary to design these datasets as feature classes in the Missoula geodatabase. It would require an unnecessary amount of work to convert and update these datasets regularly; instead, they can still be utilized for analysis in their present condition.

The wildlife feature dataset contains all of the geospatial data necessary to satisfy the requirements of the responsibilities of the wildlife discipline.

Chapter Review

This chapter began by displaying the parameters of the spatial reference system used for mapping; it introduced the resource disciplines studied and identified their responsibilities; it examined the information products necessary to accomplish this work.

The Albers equal area conic projection was reviewed based on its requirements by the Montana/Dakotas BLM. The datum and map scale were also discussed.

The conceptual phase of design reviewed the responsibilities and tasks of six resource disciplines, and the GIS datasets were established accordingly.

The logical phase described the seven feature datasets needed for this geodatabase created in this project. Within each feature dataset, feature classes, associated tables, and relationship classes were defined in great detail. Tables were created for each database, and descriptions were employed to explain the associated data.

Geodatabase elements were the primary focus of this section. The ArGIS 9.2® geodatabase format was utilized to organize GIS data for easy storage, editing, manageability, and ultimately maximizing the performance of geospatial data.

Within the six resource disciplines examined, thirty-three feature classes, eleven object classes, ten relationship classes, fifty-one domains and three subtypes were created to establish this geodatabase design. In the next chapter the author will create a model diagram to assist in the visual representation of this geodatabase design.

CHAPTER FIVE **SUMMARY and CONCLUSIONS**

Introduction

This chapter reviews the work accomplished in this thesis, by examining the initial problems faced by the Missoula Field Office, and introducing the need for a geodatabase model to assist in their geospatial needs. The theoretic approach is discussed to demonstrate the need for effective and open communication, and a sense of ownership by all parties involved in the design. The GIS approach is discussed to identify how results of the model were formed, and how the goals were reached.

In addition, this chapter presents the entire geodatabase design model so that all of feature datasets for the different BLM disciplines can be seen in relationship to one another. The model is diagramed using standardized geodatabase symbolization to assist the reader in observing basic components and relationships within the geodatabase. Next, the portions of model that concern each feature dataset are extracted from the diagram and presented one at a time so that their basic GIS components and relationships can be discussed. Finally, conclusions are drawn, and suggestions are given for implementing the model. Avenues for further research and design are also investigated.

Review

Unfortunately, the Missoula Field Office BLM has faced many issues in the past concerning GIS. Without the use of data or methodology standards, the data has been captured, created, and organized in a number of ways, most of which do not fully utilize the capabilities of GIS. This lack of GIS organization and design has made it

increasingly difficult to find data, create maps, or run analysis or studies using GIS as the primary geospatial tool.

The Missoula Field Office currently stores all of its GIS data in coverage and shapefile formats. These formats lack the organization, maintenance and processing capabilities of the newer geodatabase format. The Missoula Field Office BLM utilizes a number of shapefiles to support its land management decisions, yet only a few of them contain the in-depth characteristics of a useable GIS layer.

Due to the vast amount of geographic data needs of the Missoula Field Office, and because of the analytical capabilities presented in the newest GIS software, the author proposed the geodatabase model to the BLM in the summer of 2006. The author proceeded to conduct a needs assessment, and investigate the geodatabase model, eventually adopting this assignment in to this thesis.

The Missoula Field Office contained only a few specialized field office wide datasets to record their land management data. In many cases, they are found in several locations, in different formats, and do not include the appropriate database elements. The design elements presented here are original designs created solely for this thesis. The sources included the geographic data available at the BLM, Montana Fish, Wildlife, and Parks (FW&P), information provided by the resource specialists, resource management plans, and a number of other BLM documents.

Fortunately, the Missoula Field Office acquired additional assistance from an outside organization in 2007 to develop a geodatabase design, and the contract was for approximately one year. Due to job responsibilities and GIS tasks of the author, and the

differences in the goals and methodology used, the author opted to separate the two design projects.

The fundamental differences in the two design approaches included working strictly with the Missoula Field Office as opposed to incorporating input from other field offices. It was necessary for the author to maintain close proximity of the geodatabase designers and the references found in the Missoula Field Office, thus he opted to proceed with a design that involved only that organization.

The author played more of a supportive role in educating the Missoula employees in the intricacies of the geodatabase model, presented design options to the faculty during the final assessment stage, and made suggestions concerning the fundamentals of GIS. Regardless of the design differences, the primary and ultimate goal is to design an efficient GIS for the Missoula Field Office resource specialists to assist in their geospatial needs.

Approach

The theoretical approach used in this assignment included a specific focus on the Missoula Field Office as a case study, and a considerable amount of attention on the individual resource disciplines. To accomplish this, a positive rapport was needed between the GIS specialist and each resource specialist. This was essential to the success of the design project. Many resource specialists are not familiar with GIS, and in some cases ill at ease with the software and its concepts. For both parties, it was essential that the appropriate questions were asked that would explain the scientific techniques involved and the corresponding GIS functionality.

The authors approach was to keep the design as simple as possible, only including the data necessary to meet each discipline's geospatial needs. In some cases, large databases are preferred and seen as highly advanced and sophisticated systems. This is a misconception, and in many cases, these datasets tend to be too extensive and cumbersome, containing a surplus of unnecessary and unwanted data. GIS datasets may also contain a large amount of dissimilar data that otherwise can be organized in to separate tables or feature classes. All of the above concerns ultimately tend to create more problems and deter people from the best use of GIS.

The main theoretical approaches within this project were to develop a simple geodatabase schema design to accommodate the data needs of each discipline, while using all necessary geodatabase functionality. The design will involve cooperation from the resource specialists, which in turn will provide a sense of ownership to all GIS users.

A main component in this design was to identify the job responsibilities of all of the individuals involved, and capture the data needs of the resource disciplines. The author worked on numerous BLM GIS projects prior to the investigation of this project, which familiarized him with the specialists' data needs. Most of the projects warranted the creation of GIS data elements and associated tabular data.

The GIS approach utilized the advanced functionality of the geodatabase model, customized the design for each of the disciplines, and captured all data needs of the Missoula Field Office, while keeping the schema simple and intuitive. Object classes were utilized to their full potential in housing the data, and separating it out into similar categories. Relationship classes were devised to connect appropriate data elements, making it easier to manipulate and manage the data. Relationships allowed effective

monitoring storage using the one-to-many cardinality for data management. Design considerations included mapping functionality, update requirements, historic data preservation, federal and local regulations and requirements, and being user friendly.

The BLM Geodatabase Model

The geodatabase model diagram was created using Microsoft Visio 2007, and Geodatabase Diagrammer PS. Microsoft Visio is a diagram building software utilized by a number of professions to build and illustrate diagrams for various purposes. The Geodatabase Diagrammer PS extension allows the use of familiar geodatabase symbols for illustration. Microsoft Office Visio makes it easy for IT and business professionals to visualize, explore, and communicate complex information. Visio diagrams communicate information at a glance. Instead of static pictures, data is illustrated in data-connected diagrams, which dramatically increase data design perception.⁷⁴

The following sections illustrate the geodatabase model, beginning with the complete geodatabase, which is then separated into individual resource disciplines for further discussion. The feature datasets are labeled at the top of large green boxes and further identified with feature dataset symbols. Feature classes, object classes, and relationship classes are displayed under each feature dataset. Feature classes contain the standard point, line, or polygon symbols within their title boxes, and object classes display a table symbol within theirs. Thick green lines are used to illustrate the relationship classes, and to connect the appropriate datasets. These lines are labeled as origin/destination or feature class/table. The relationship lines contain a green box defining the relationship class name, cardinality, and unique identifier or key code.

⁷⁴ Microsoft Corporation. *Microsoft OfficeVisio 2007 Product Overview*. Microsoft Corporation. On-line. Available from Internet, <http://office.microsoft.com/enus/visio/HA101656401033.aspx>, Assessed 9 June 2008.

The previous chapter concentrated on discussing and explaining the data components down to their finest detail. A total of fifty-four tables were created to illustrate the complexity of the system in the previous chapter. It is rather difficult to identify the organization and components of a complex geodatabase system, so the following models were created. The following diagrams do not intend to dissect the data elements in to their finest data components. Instead, they illustrate the organization, data types, relationships, and are discussed more broadly, explaining the data's purpose and function. Figure 8 illustrates Missoula Field Office geodatabase model in its entirety.

Natural Resource Geodatabase Diagram

Missoula Field Office BLM Case Study

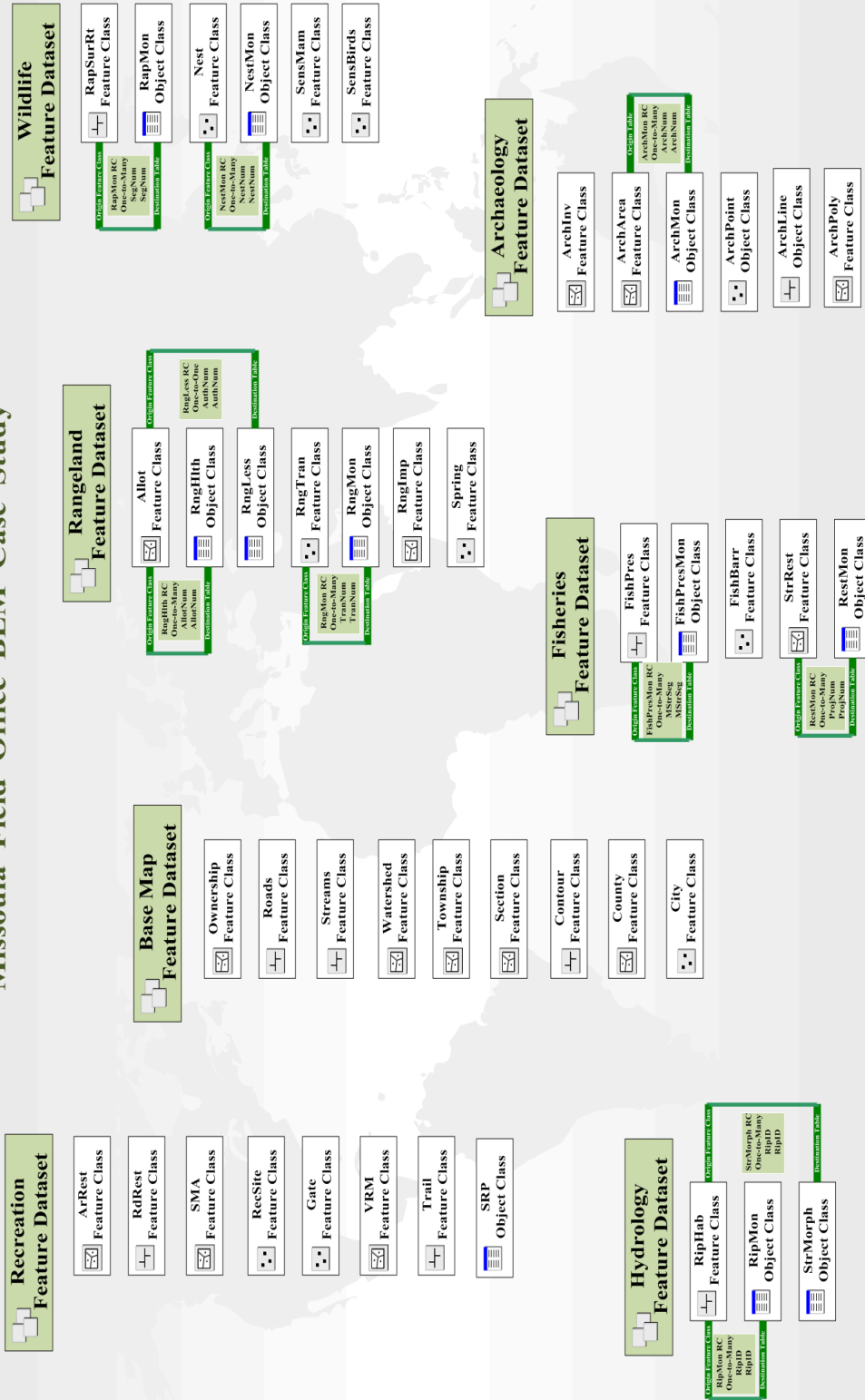


Figure 8, The BLM Geodatabase Model.

Base Map Feature Dataset Model

The base map feature dataset is background data used for orientation, display, elevation, direction, and provides the basis for analysis. Base map information designed for this project includes ownership, infrastructure, environmental features, survey information, elevation data, man-made features, and political boundaries (Figure 9).

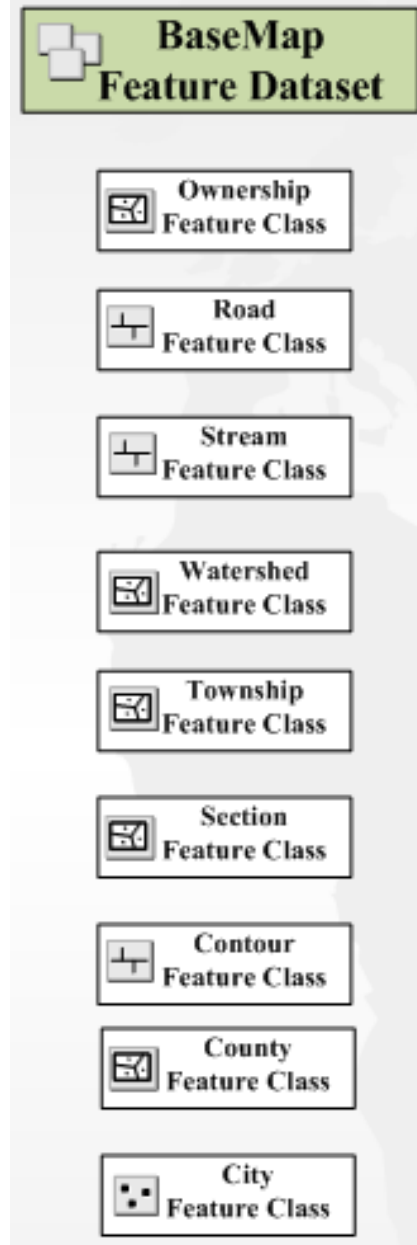


Figure 9, Base Map Model.

The base map feature dataset contains the ownership feature class, road feature class, streams feature class, watershed boundary feature class, township feature class, sections feature class, contour feature class, county feature class, and city feature class.

The ownership feature class is used to identify ownership of the land, and provides the Missoula Field Office with access and potential partnerships for land management projects. The road feature class provides direction, orientation, and access to BLM lands. The stream layer provides orientation, and the basis for the creation of fisheries and hydrologic layers used for land management analysis.

The watershed layer displays the watershed boundary areas, which are important in watershed management analysis. The township and sections layers provide orientation and location information developed by the township and range surveys. The contour layer provides elevation data used for navigation, orientation, and additional hypsography analysis. The county and city layers provide orientation and location information.

These datasets help solidify the geodatabase by supplying the map reader or GIS user with background information necessary to build useful maps and conduct necessary analysis.

Archaeology Feature Dataset Model

The archaeology feature dataset captures the data requirements of the archaeology discipline. The archaeology inventories, areas, area monitoring, and various features and artifacts are represented in the archaeology model. It first reviews the archaeology inventory, then the archaeology areas discovered (archsites or archfinds), next illustrates the monitoring, and finally the three archaeology features found (Figure 10).

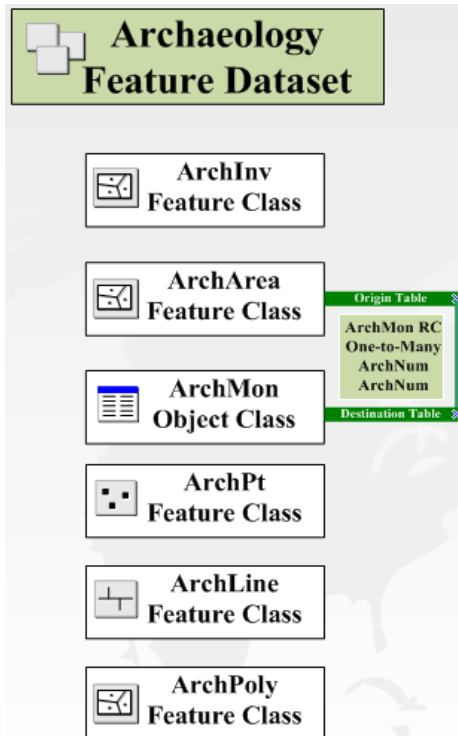


Figure 10, Archaeology Model.

The archaeology inventory (ArchInv) feature class, archaeology areas (ArchArea) feature class, archaeology area monitoring (ArchMon) object class, archaeology points (ArchPt) feature class, archaeology lines (ArchLine) feature class, and archaeology polygons (ArchPoly) feature class are the six datasets contained in the archaeology feature dataset. The archaeology monitoring (ArchMon) relationship class is the only relationship class contained in this feature dataset.

Notice the symbols next to the feature or object classes. These symbols represent the geographic representation of the data such as point, line, polygon, or table. The relationship class is located on the right side of the model, represented in green. Basic relationship data is located within the green relationship box.

ArchInv documents all investigations on BLM lands in the search of archaeological entities. The inventory location is extremely important and used for

referencing in the case that proposed land management activities are considered in that area. Although the ArchInv feature class's main function is to define where archaeology investigations have taken place, they also capture whether archaeological artifacts or sites were discovered.

If archaeological areas have been discovered, the ArchArea feature class documents the essential archaeological information. The ArchArea feature class stores all prudent information concerning archaeological sites and isolated findings discovered, such as age, type, land use, governmental requirements, and size. The ArchArea feature class documents all necessary requirements and records data associated with archaeological sites and isolated findings.

The ArchMon object class contains the monitoring data necessary to protect and preserve important archaeological findings and sites. Pictures and notes are used to document monitoring. A relationship class is used to link the ArchArea and ArchMon datasets together. The relationship class is a one-to-many relationship, and uses the ArchNum field as the key field. This type of relationship will allow the ArchMon object class the capability to store the monitoring information in a useable geospatial environment for easy management, documentation, and analysis.

The ArchPoint, ArchLine, and ArchArea feature classes document the individual archaeological features or artifacts discovered. Three datasets are necessary to compensate for the various types of archaeological features found in Western Montana. Some archaeological entities require a geographic point, line, or polygon representation. For instance, an archaeological building requires a polygon representation, while an arrow head may only require a point representation.

The archaeological feature dataset contains all of the necessary geospatial data in a powerful geodatabase structure to capture inventory, discovered archaeological areas, monitoring, and individual features, which are necessary to document, protect, and preserve these historic and cultural entities.

Fisheries Feature Dataset Model

The fisheries feature dataset includes all of the geospatial data desired by the fisheries biologist. Fish presence, fish species distribution, fish monitoring, fish barriers, stream restoration, and stream restoration monitoring data is contained in the fisheries feature dataset (Figure 11).

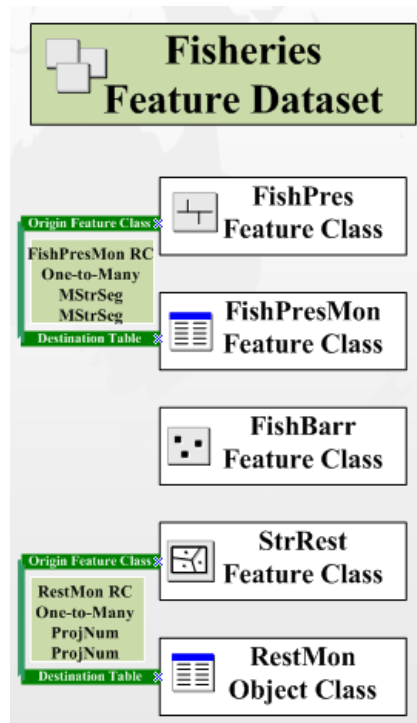


Figure 11, Fisheries Model.

The fish presence (FishPres) feature class, fish presence monitoring (FishPresMon) object class, fish barrier (FishBarr) feature class, stream restoration (StrRest) feature class, and restoration monitoring (RestMon) table are the five datasets present in the fisheries feature dataset. The fish presence monitoring (FishPresMon)

relationship class and restoration monitoring (RestMon) relationship class are the two relationship classes present.

The FishPres feature class contains the linear geographic features needed to document fisheries data. The FishPresMon object class houses all of the prudent fisheries data including fish presence and species distribution throughout BLM lands. The FishPresMon relationship class was designed to connect these datasets in to a one-to-many relationship. The MstrSeg field was used as the unique identifier linking these datasets with a common denominator. This relationship allows fish monitoring to occur without overwriting historic fish presence data.

The FishBarr feature class helps locate fish barriers on BLM lands for their maintenance, improvement, or removal. The StrRest feature class contains the basic information of the restoration project during implementation such as the type of restoration technique conducted, pictures of the project, date, etc. The RestMon object class documents the stream restoration projects over time. Pictures are an important component in monitoring the results of stream restoration projects.

The RestMon relationship class links the StrRest feature class and the RestMon object class. This relationship was designed to support continuous monitoring efforts for stream restoration projects. The RestMon relationship class contains a one-to-many relationship cardinality to allow multiple monitoring sessions for one particular restoration project. The fisheries feature dataset contains all of the desired geospatial fisheries data by the fisheries biologist at the Missoula Field Office.

Hydrology Feature Dataset Model

The hydrology feature dataset contains all of the desired geospatial data for the hydrologist at the Missoula Field Office. Datasets needed include riparian habitat monitoring and stream morphology information. Refer to Figure 12.

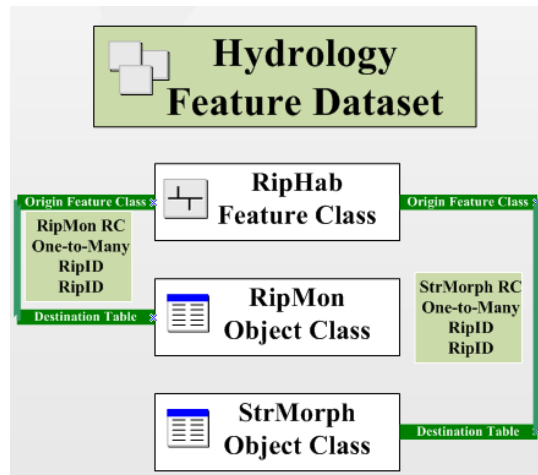


Figure 12, Hydrology Model.

The hydrology feature dataset contains the riparian habitat (RipHab) feature class, riparian monitoring (RipMon) object class, and stream morphology (StrMorph) object class. The RipHab feature class contains the geographic coordinates of stream segments, although divided in to smaller stream segments necessary for riparian analysis. The RipMon object class will capture all of the important riparian habitat information. Due to the change in habitat and the need to monitor these changes, a one-to-many relationship class was designed to adequately store monitoring data. The RipMon relationship class was created to link the RipHab feature class to the RipMon object class. The RipID, which is the smaller riparian analysis segment, is the key field linking the two datasets.

The StrMorph object class documents significant stream morphology data. Due to the changes in stream morphology and the need to capture these changes using monitoring techniques, a relationship class was also created to link it to the RipHab

object class. This relationship is also has a one-to-many cardinality relationship, which is ideal in documenting the changes in river morphology over the years. The RipID is also the key field used to link these datasets.

These datasets will be extremely useful to the Hydrologist at the Missoula Field Office to capture and maintain riparian habitat and stream morphology data. In turn, the schema of the hydrology feature dataset will store, manage, and provide additional analytical ability to the hydrologist.

Rangeland Feature Dataset Model

The rangeland feature dataset contains all of the geospatial data necessary for the rangeland specialist to adequately perform his duties and responsibilities. Data needed includes allotment boundaries and associated data, the health of the rangelands, personal lessee information, transect locations, transect monitoring data, range improvement projects data, and natural spring locations. Additionally, three relationship classes were designed to assist in connecting the object classes to the appropriate feature classes. The relationship classes and their components will be described following the illustration of the rangeland model (Figure 13).

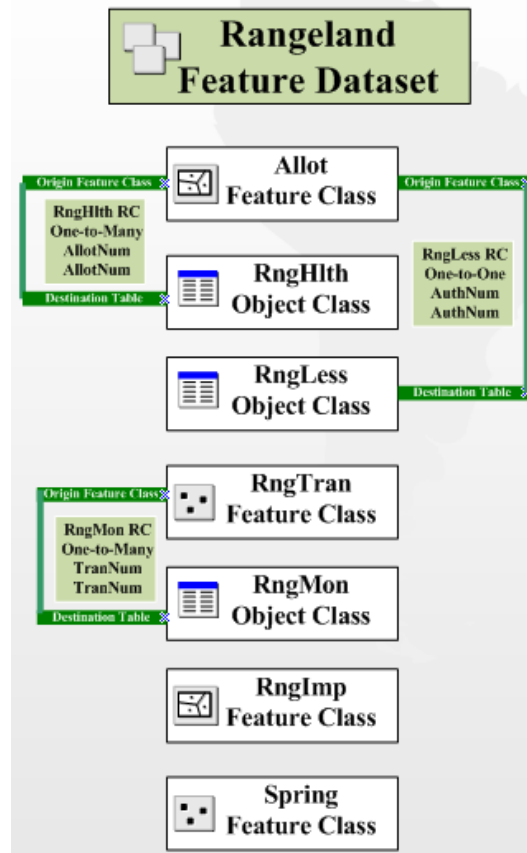


Figure 13, Rangeland Model.

The rangeland feature dataset contains the allotment (Allot) feature class, rangeland health (RngHlth) object class, rangeland lessee (RngLess) object class, rangeland transect (RngTran) feature class, rangeland monitoring (RngMon) object class, rangeland improvement (RngImp) feature class, and spring feature class.

The Allot feature class contains the grazing allotment boundaries, and associated allotment management data. The RngHlth object class documents the health of rangelands, based on each allotment. The rangeland's health is subject to change over time, so a one-to-many relationship class was created to document these changes. The RngHlth object class was connected directly to the Allot feature class by using the AllotNum as the unique identifier.

The RngLess table documents all personal lessee information, which are the individuals or companies that rent the grazing allotments. This information is important for the rangeland specialist in managing the allotments, contacting the lessee, and documenting historic lease information. A one-to-one relationship class was created to link the Allot feature class to the Lessee object class. The authorization number (AuthNum) was used as the unique identifier, not the AllotNum. The reason for using the AuthNum is because one person or company may occupy multiple allotments, and the AuthNum is unique to the individual lessee.

The RngTran feature class contains the geographic coordinates of the monitoring transects and additional data about the transect itself. The RngMon object class is where all of the vegetative information is stored from monitoring transects. A one-to-many relationship class was designed to capture the monitoring data multiple times. The transect number (TranNum) was used as the unique identifier linking the RngTran feature class and RngMon object class. This relationship will provide the means to document information about a single transect on multiple occasions. It will also provide easier manageability and editing capabilities between these datasets.

The RngImp feature class will document the improvement projects conducted on BLM lands, and the Spring feature class documents the natural spring locations. The rangeland feature dataset captures all of the prudent information necessary for the rangeland specialist to accomplish their duties and responsibilities.

Recreation Feature Dataset Model

The recreation feature dataset contains all recreation information necessary for the outdoor recreation planner to plan and manage outdoor recreation. This includes area and

road restriction information, special management area data, recreation data, visual resource management information, trails data, and special recreation permit information (Figure 14).

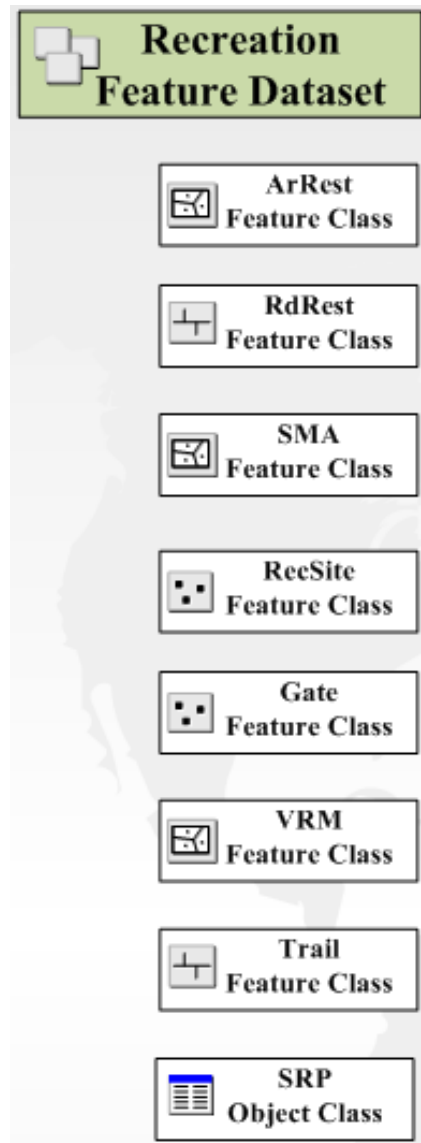


Figure 14, Recreation Model.

The datasets included in the recreation feature dataset are: area restriction (ArRest) feature class, road restrictions (RdRest), special management areas (SMA) feature class, recreation site (RecSite) feature class, Gate feature class, visual resource

management (VRM) feature class, trail feature class, and a special recreation permit (SRP) table.

The ArRest and RdRest feature classes contain the road and area restriction data necessary to manage the Missoula Field Office lands. These two restriction datasets share the common goal to regulate activities on and accesses to BLM lands. The ArRest feature class is the main restriction dataset, and is initially referenced when observing restrictions. The RdRest feature class is used as an exception to the ArRest's regulations. For instance, if an area has a restriction from 12/1 to 4/1, and a road within that area is given a road restriction, that particular road does not follow that area restriction. The ArRest and RdRest feature classes are based on special management areas, visual resource areas, wildlife habitat, environmental characteristics, etc.

The SMA feature class contains the wilderness study area (WSA) and areas of critical concern's (ACEC) geographic and classification data. The RecSite feature class contains the recreation sites located on or near BLM lands. The RecSite also provides the multiple recreational activities and amenities available at these locations. The VRM captures the visual resource management areas, and their classification system.

The Trail feature class includes the geographic location and trail type information. The SRP identifies the special recreation permits acquired by outside parties on BLM trails.

Wildlife Feature Dataset Model

The wildlife feature dataset contains all of the geospatial data necessary for the wildlife biologist at the Missoula Field Office to accomplish his job duties and responsibilities. Data necessary to achieve these goals include wildlife habitat data, such

as bird species, big game species, sensitive and T&E species, and habitat monitoring information (Figure 15).

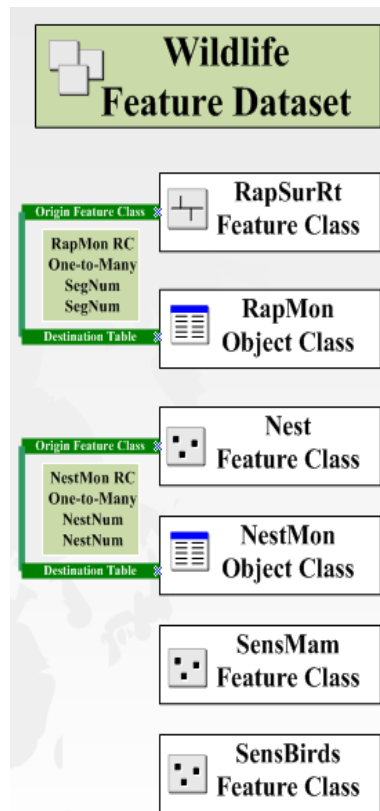


Figure 15, Wildlife Model.

The wildlife feature dataset contains the raptor survey route (RapSurRt) feature class, raptor monitoring (RapMon) object class, nest feature class, nest monitoring object class, sensitive mammals (SensMam) feature class, and sensitive bird (SensBirds) feature class.

The raptor survey routes and nest data will provide useful documentation of bird conditions on BLM lands. The techniques are already established and would require only minimal modification. The monitoring data will be extremely useful for population trends, and habitat analysis.

Wildlife habitat data will also be used from the Montana FWP website to satisfy wildlife habitat needs. The layers are available in shapefile format, and include white tail deer, mule deer, elk, moose, and big horn sheep, including their winter and summer habitats. Instead of converting these habitat layers, and going through the process of upgrading, they can be used as they are. These layers can be brought in ArcMap and used for analysis when necessary. The wildlife feature dataset fulfills all of the data requirements of the wildlife discipline, with exception of the FWP's habitat data.

Implementation

Implementation is the last component in geodatabase design, and involves a vast amount of planning and preparation. Although this project does not implement this particular geodatabase model, the author would like to briefly discuss the process, and recommend some approaches which may be useful.

The creation of the geodatabase would mainly involve the GIS specialist. Once the logical phase of design is final, the geodatabase creation can be produced with minimal ease. There were 54 tables created for this thesis, all intended to capture every minute component of the feature datasets, feature classes, object classes, subsets, domains, and relationship classes. They have all been outlined down to each individual geodatabase component and may be used as a step-by-step guide during the developmental stage of each resource discipline's feature dataset.

Once the geodatabase is created, data will have to be moved from already established datasets. Much of this can be done within the base map feature dataset, because these layers have already been created and will not require advanced design processes. The GIS specialist will be required to manipulate data from specialized

datasets currently in use by the Missoula Field Office using the loading process. An example of specialized data that needs to be loaded includes rangeland's grazing allotment boundary. This dataset is already available in shapefile format, and converting it to the new design will require few modifications. The effort invested in this stage primarily depends on the data's format, associated data, and level of complexity. This stage has the potential to require multiple processing steps, and may take an adequate amount of time.

Most of the data not previously documented or georeferenced will have to be collected and added into the GIS. But before this can be done, some the primary datasets will have to be created. Examples of the primary datasets include: fishery's fish presence analysis segments, hydrology's stream analysis segments, wildlife's bird monitoring routes, etc. Many of these layers can be developed from previously existing data, such as roads and streams, and will need to be modified to meet the needs of the resource specialists. Roads and streams can be copied, modified, and converted to the specialized feature classes and given the appropriate data elements merely by editing and manipulating them.

As mentioned above, data collection will be the largest phase to complete the Missoula Field Office geodatabase. The BLM practically doubles in faculty in April when seasonal employees return for work. Seasonal employees are a huge asset to the productivity of the BLM, and can be utilized to collect much of the necessary data. The data collection will need to be done in stages that must be prioritized ahead of time.

High, medium, and low priorities can be assigned to the data in the implementation process. High priority would contain the primary datasets, many of

which house the important geospatial data, and are linked to object classes. In many cases, the object classes contain large amounts of analytical information, so the feature classes must be developed first to ensure the appropriate relationships can exist. Medium priority data would include data that contains the historical data kept in hard-copy files. Although the BLM may not contain much geospatial data within a useable GIS format, the organization possesses large amounts of data found in hard copy filing records. If salvaged, this data can prove extremely useful for future analysis. Low priority contains the data not yet acquired. Although this status does not take away from the data's significance, gathering geospatial data for the first time requires a great amount of time and effort. This would be left until last. Much of the data consists of object classes where the data has not yet been captured in tabular or geographic form. For instance, the recreation discipline's recreation sites and trails have not yet been created, so they could be created last in the implementation process. Once completed, however, these datasets can be integrated into to overall design of the project.

One important innovation to data input is the synchronized and uniform data capture capabilities available in geographical positioning systems (GPS) units. The geodatabase model itself adds tremendous functionality to entering, managing, organizing, and analyzing data, including its compatibility to GPS. ESRI's ArcPad is the GPS unit of choice at the Missoula Field Office. Geodatabase schemas may be directly imported into this hand-held device, saving time and energy from manually adding all design elements. In turn, the GPS units have the capability to automatically download data into the geodatabase once the field technician has returned. This ease of data

transfer will provide extremely useful results in time, training, functionality, and efficiency.

Due to the complexity of a complete geodatabase system for the Missoula Field Office, data stewards will have to be assigned to manage, edit, and update the system. Given the current workload presented to the GIS specialists, additional resources are needed to assist in maintaining the elements of the geodatabase. Once created, each resource discipline will have to be responsible for its own specialized datasets. The GIS specialist may serve as the gatekeeper; responsible for protecting and upgrading the data annually after field season is complete in the fall months. The GIS specialist will contain sole permission to all data located in the geodatabase, to ensure no one can alter the principle copy of the datasets.

The geodatabase is extremely versatile, and not all elements of the design and implementation have to be fine tuned at this time. Modifying data elements to meet the needs of the specialist will be an ongoing process throughout the life of the geodatabase. Many geodatabase components have the capacity for change and modification, such as domains, relationships, fields, topology, etc. This allows the GIS user the freedom to improve the system, to develop better efficiency, accommodate change in methods and techniques, and increase the overall productivity of the geodatabase design.

Conclusions

The geodatabase model created in this thesis conforms to the methods of data management and the research practices of the Missoula Field Office. GIS has introduced a plethora of geospatial management capabilities that is unmatched in any analog based

system, and has the ability to easily improve their productivity, efficiency and analytical ability.

The author has concentrated on the specialized data needs necessary to facilitate an effective and efficient GIS system for the Missoula Field Office BLM. According to the responsibilities, duties, and tasks of these six resource specialists, this geodatabase design will prove successful in assisting the Missoula Field Office BLM in capturing and analyzing their geospatial data needs. The author would like to suggest additional ideas based on universal and future design considerations.

Initially, it was the intention to include all eleven disciplines, and a great deal of attention was placed on the remaining five disciplines. Tables were made, monitoring designs were considered, and discussions took place between specialists. The research and development stages presented here, and the methods and techniques applied may be used to continue the design and establish the remaining resource discipline's data within the Missoula Field Office, and ultimately other agencies and organizations requiring resource geodatabase modeling.

Developing a BLM wide geodatabase model would require more design elements. Based on the large geographic area of BLM lands and different management practices throughout, additional designed elements will need to be considered. The elements presented in this design may better support surrounding field offices, yet lack the data needs of further BLM regions.

My suggestion in regards to designing a regional or country-wide geodatabase is to start at one particular field office such as Missoula, and adequately design all necessary data. Next, move from one field office to another, modifying the data design,

while standardizing similar needs. Most field offices close to one another will most likely share many data similarities, with only minor revisions. Revisions may include adding and subtracting fields, subsequent tables, or entire feature datasets. It is anticipated that adjacent field office data will only change slightly, while further field offices may require major transformations.

In creating a universal geodatabase, the main focus is to develop feature classes and object classes that meet high data standards, by sharing common fields and descriptions. The riparian data in the hydrology discipline is a great example. The riparian feature class was first created to house the geographic data of riparian analysis, based from the stream feature class. The riparian monitoring and stream morphology object classes were designed to capture the riparian and morphology data. If the same concepts were used in other field offices, key fields could be created within all field offices to standardize the feature classes, subsequently standardizing the object classes.

Another component in universal design is the differences in the geographic and tabular data throughout the field offices. The feature and object classes do not have to be exact to accomplish data consistency. Only principle key fields such as the stream naming scheme will need to be identical throughout the design. The data can be joined at the regional level, connecting datasets in to one large master dataset. By dividing the data amongst field offices, and only containing their necessary key data elements, unnecessary and unwanted data will not crowd the field office datasets. This cuts down on large unnecessary databases with scattered data on the field office level.

Additionally, the author suggests combining restoration and improvement projects in to three feature classes including a point, a line, and polygon to accommodate the

various geographic entities in restoration projects. The hydrologist, rangeland specialist, wildlife biologist, and fisheries biologist and others work together on restoration projects, because in some form or another, these natural or man-made occurrences are linked environmentally. They could all contain associated monitoring object classes. With the use of subsets, the project leading discipline can be identified, while most of the remaining data would remain similar. If these projects were assimilated in to the three feature classes, it would reduce the need for multiple project datasets scattered throughout the geodatabase.

Management desires a system to store how funds are distributed throughout the Missoula Field Office. Restoration projects, as well as other funded projects, are the main sources in the distribution of funds. A management object class can be created to house all of the management data necessary, and all participating feature classes could contain a management code field, which links the associated datasets with the management object class. This would assist management greatly to identify, run analysis, and oversee where funds are distributed geographically throughout the Missoula Field Office.

A geodatabase model will assist the Missoula Field Office greatly in capturing, organizing, and analyzing its geographic data in the most efficient manner. The geodatabase provides structural integrity, manageability, data integrity, advanced GIS analysis capabilities, and improved user-friendly abilities. The geodatabase model described above illustrates the way geospatial data may be considered for the Missoula Field Office BLM. Methods, techniques, objectives, and responsibilities for the BLM will ultimately change over time, but it is the hope that many of the design considerations

developed within this thesis will potentially provide a basis or foundation for the current geodatabase requirements.

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