TEMPLATES FOR CREATING STANDARDIZED CARTOGRAPHIC PRODUCTS FOR MONTANA COUNTY PRE-DISASTER MITIGATION PLANS

Bruce Albert Koerner

The University of Montana

Follow this and additional works at: http://scholarworks.umt.edu/etd

Recommended Citation

TEMPLATES FOR CREATING STANDARDIZED CARTOGRAPHIC PRODUCTS FOR MONTANA COUNTY PRE-DISASTER MITIGATION PLANS

By

Bruce A. Koerner

B.A. Northern Arizona University, Flagstaff, Arizona, 1992

Thesis

presented in partial fulfillment of the requirements for the degree of

Master of Arts
in Geography, GIS/Cartography Option

The University of Montana
Missoula, MT

Spring 2007

Approved by:

Dr. David A. Strobel, Dean
Graduate School

Dr. Paul B. Wilson, Chair
Geography

Dr. Sarah J. Halvorson
Geography

Dr. James W. Burfeind
Sociology
The Montana Critical Infrastructure GIS Committee, on behalf of the Montana Department of Administration, has been involved for several years in concentrated efforts to make various types of map products available to those involved in emergency management throughout the state. As a component of this process, the Committee authorized funding for a project devoted to the development of standardized map products for pre-disaster mitigation (PDM) plans during the spring of 2006, and the research was completed later that year. The requirement for the development of these plans was established by the Disaster Mitigation Act of 2000. In Montana, implementation of this legislation has taken place at the county and Indian reservation levels of government.

The scope of the research conducted was divided into several components. First, various goals were established in order to provide a general sequence of events for the work. These began with identifying any cartographic requirements established by law and included decisions regarding the actual map construction and techniques for describing the processes utilized. Similarly, assumptions regarding software and other issues were made. Numerous experts in the areas of natural and man-made hazards, emergency management, and other fields were contacted in order to identify those cartographic products that would be most useful. The overall mapmaking process was established, map templates were constructed, and detailed instructions were compiled for use by others. The results of this research compiled in a report and submitted to the GIS Committee in November of 2006. This thesis represents the further development of the results of that research.
ACKNOWLEDGMENTS

Thank you to the members of the thesis committee: Paul Wilson, Sarah Halvorson, James Burfeind of The Department of Sociology, the members of the Montana Critical Infrastructure and Structures Data Model (CISDM) Committee of who funded this research, all of those who work in emergency management in Montana, and the faculty and staff of The Geography Department of The University of Montana.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>List</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF MAPS</td>
<td>x</td>
</tr>
<tr>
<td>Section</td>
<td></td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1-1</td>
</tr>
<tr>
<td>a. Background</td>
<td></td>
</tr>
<tr>
<td>b. Diversity in Montana</td>
<td></td>
</tr>
<tr>
<td>c. Evolution of Emergency Management</td>
<td></td>
</tr>
<tr>
<td>d. Summary of Factors</td>
<td></td>
</tr>
<tr>
<td>e. Problem Statement</td>
<td></td>
</tr>
<tr>
<td>f. Section Summary</td>
<td></td>
</tr>
<tr>
<td>2. METHODOLOGY</td>
<td>2-1</td>
</tr>
<tr>
<td>a. Standards Set By Law</td>
<td></td>
</tr>
<tr>
<td>b. Identify Cartographic Products for Montana Pre-disaster Mitigation Plans</td>
<td></td>
</tr>
<tr>
<td>c. Cartographic Principles for Building Pre-disaster Mitigation Maps</td>
<td></td>
</tr>
<tr>
<td>d. Creating Map Templates</td>
<td></td>
</tr>
<tr>
<td>e. Instructions for Creating Cartographic Products</td>
<td></td>
</tr>
<tr>
<td>f. Section Summary</td>
<td></td>
</tr>
<tr>
<td>3. CARTOGRAPHIC PRODUCTS FOR PRE-DISASTER MITIGATION PLANS</td>
<td>3-1</td>
</tr>
<tr>
<td>a. Mapping Standards Set by Law</td>
<td></td>
</tr>
<tr>
<td>b. Existing Cartographic Products</td>
<td></td>
</tr>
<tr>
<td>c. Interviews with DES Personnel</td>
<td></td>
</tr>
<tr>
<td>d. Disaster and Emergency Exercises</td>
<td></td>
</tr>
<tr>
<td>e. Project Literature Review</td>
<td></td>
</tr>
<tr>
<td>f. Results</td>
<td></td>
</tr>
<tr>
<td>g. Section Summary</td>
<td></td>
</tr>
<tr>
<td>4. CARTOGRAPHY FOR PRE-DISASTER MITIGATION PLAN MAPS</td>
<td>4-1</td>
</tr>
<tr>
<td>a. Format</td>
<td></td>
</tr>
</tbody>
</table>
b. Map Components

c. The Mapped Area

d. Base Layers

e. Base Layers for Thematic Maps

f. Marginal Information

g. Priorities

h. Section Summary

5. TEMPLATES FOR COUNTY PRE-DISASTER MITIGATION PLANS . 5-1

a. Process For Making Maps

b. Location Maps

c. Inventory Asset Maps

d. Natural Hazard Maps

e. Man-Made Hazard Maps

f. Cumulative Risk Maps

g. Section Summary

6. SUMMARY AND CONCLUSIONS . . . . . . . . . 6-1

a. Conclusions

b. Distribution Plan

BIBLIOGRAPHY . . . . . . . . . . . . . . . . . . . 7-1

APPENDIX . . . . . . . . . . . . . . . . . . . . . . . 8-1

A. STATEMENT OF WORK
# TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-1 Composite of Maps in PDM Plans</td>
<td>3-5</td>
</tr>
<tr>
<td>5-1 Hill County Basements</td>
<td>5-28</td>
</tr>
<tr>
<td>5-2 Roofing Material</td>
<td>5-29</td>
</tr>
<tr>
<td>5-3 Hill County Bridge Specifications</td>
<td>5-35</td>
</tr>
<tr>
<td>5-4 Fujita Scale of tornado Categories</td>
<td>5-52</td>
</tr>
<tr>
<td>5-5 Comparison of Richter Magnitude and Mercalli Intensity Scale</td>
<td>5-78</td>
</tr>
<tr>
<td>5-6 Types of Landslides</td>
<td>5-85</td>
</tr>
<tr>
<td>5-7 Contributing Factors to Landslides</td>
<td>5-86</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------------------------</td>
</tr>
<tr>
<td>3-1</td>
<td>PDM Plan Status</td>
</tr>
<tr>
<td>4-1</td>
<td>Page Format</td>
</tr>
<tr>
<td>4-2</td>
<td>Balancing Map Elements as on a Fulcrum</td>
</tr>
<tr>
<td>4-3</td>
<td>Location Map Symbols and Annotation</td>
</tr>
<tr>
<td>4-4</td>
<td>Geometric Point Symbols</td>
</tr>
<tr>
<td>4-5</td>
<td>Mimetic Point Symbols</td>
</tr>
<tr>
<td>4-6</td>
<td>Poor Mimetic Symbols</td>
</tr>
<tr>
<td>4-7</td>
<td>Visual Variable Shape</td>
</tr>
<tr>
<td>4-8</td>
<td>Visual Variable Size</td>
</tr>
<tr>
<td>4-9</td>
<td>Variable Width Diagram</td>
</tr>
<tr>
<td>4-10</td>
<td>Screen Tints</td>
</tr>
<tr>
<td>4-11</td>
<td>Pattern Characteristics</td>
</tr>
<tr>
<td>4-12</td>
<td>Patterns Can Yield More Categories</td>
</tr>
<tr>
<td>4-13</td>
<td>Patterns Can Be Bland and Hard to Read</td>
</tr>
<tr>
<td>4-14</td>
<td>Color Schemes From <em>Color Brewer</em></td>
</tr>
<tr>
<td>4-15</td>
<td>Names Oriented With the Map</td>
</tr>
<tr>
<td>4-16</td>
<td>Priorities for Lettering Point Symbols</td>
</tr>
<tr>
<td>4-17</td>
<td>Examples of Poorly and Correctly Lettered Maps</td>
</tr>
<tr>
<td>4-18</td>
<td>Shaded Relief as a Base Layer</td>
</tr>
<tr>
<td>4-19</td>
<td>Hydrography as a Base Map Layer</td>
</tr>
<tr>
<td>4-20</td>
<td>A Map That Includes All Roads</td>
</tr>
<tr>
<td>4-21</td>
<td>Classified Road Layers</td>
</tr>
<tr>
<td>4-22</td>
<td>Building Polygons for Urban Areas</td>
</tr>
<tr>
<td>4-23</td>
<td>PLSS as a Base Layer</td>
</tr>
<tr>
<td>4-24</td>
<td>Critical Structures of Sanders County</td>
</tr>
<tr>
<td>4-25</td>
<td>Point Symbols Pile Up In Towns</td>
</tr>
<tr>
<td>4-26</td>
<td>Emergency Shelters of Sanders County</td>
</tr>
<tr>
<td>4-27</td>
<td>Stacked Functions</td>
</tr>
<tr>
<td>4-28</td>
<td>Stacked Symbols for Multi-Functional Critical Structures</td>
</tr>
</tbody>
</table>
4-29 Capacity Rating of Bridges Map Using Point Symbols
4-30 At-Risk Populations, Hill County, Montana
4-31 Transportation As the Base For Census Blocks
4-32 Chloropleth Mapping Must Be Done With Derived Values
4-33 Examples of Map Borders
4-34 Longitude and Latitude Placement Relative to the Neatline
4-35 Parts of a Title Subordinated
4-36 Do Not Vary Letter Spacing of Titles.
4-37 Titles Can Be Either Centered, Left Justified, or Right Justified
4-38 Possible Title Locations
4-39 Place Symbol Definitions to the Right of the Symbols
4-40 Right and Wrong Horizontal Legend Boxes
4-41 A Graphic Scale
4-42 Different Styles of Graphic Scales
4-43 Compass Roses
4-45 Entire Type Fonts are Devoted to North Arrows
5-1 Geodatabase Structure
5-2 Spatial Reference System
5-3 Setting the Spatial Reference System
5-4 Base Data Feature Datasets
5-5 Precipitation Value Grouping
5-6 NAIP Tile Grid
5-7 Cadastral Vs. Road Layers
5-8 Joining the RESIMPDWELL Table
5-9 Basement Layer Properties Dialog Box
5-10 Basement Summarize Dialog Box
5-11 Basements
5-12 Roofing Material
5-13 Symbol Property Editor
5-14 Dams in Montana
5-15 Calculating Sr_Per1000 Values
<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-16</td>
<td>Add XY Data Dialog Box</td>
</tr>
<tr>
<td>5-17</td>
<td>Join Data Dialog Box</td>
</tr>
<tr>
<td>5-18</td>
<td>Number of Tornadoes Per Montana County</td>
</tr>
<tr>
<td>5-19</td>
<td>Isarithmic Density Map</td>
</tr>
<tr>
<td>5-20</td>
<td>Winter Storm Formation</td>
</tr>
<tr>
<td>5-21</td>
<td>Montana Wind and Thunderstorms</td>
</tr>
<tr>
<td>5-22</td>
<td>Select Magnitude 3.0+</td>
</tr>
<tr>
<td>5-23</td>
<td>Fuels Reduction Priority Areas Map</td>
</tr>
<tr>
<td>5-24</td>
<td>Symbols for Property Types</td>
</tr>
<tr>
<td>5-25</td>
<td>Man-Made Disaster Geodatabase</td>
</tr>
</tbody>
</table>
MAPS

<table>
<thead>
<tr>
<th>Map</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-1 Hill County Location Map</td>
<td>5-11</td>
</tr>
<tr>
<td>5-2 Geographic Coordinates of Hill County</td>
<td>5-12</td>
</tr>
<tr>
<td>5-3 Natural Characteristics of Hill County</td>
<td>5-15</td>
</tr>
<tr>
<td>5-4 NAIP Imagery of Fresno Reservoir</td>
<td>5-17</td>
</tr>
<tr>
<td>5-5 Land Ownership in Hill County</td>
<td>5-23</td>
</tr>
<tr>
<td>5-6 Land Ownership in Hill County and Havre</td>
<td>5-25</td>
</tr>
<tr>
<td>5-7 Law Enforcement and Fire Stations in Hill County</td>
<td>5-32</td>
</tr>
<tr>
<td>5-8 Road and Highway Bridges in Hill County</td>
<td>5-34</td>
</tr>
<tr>
<td>5-9 Storage Capacity of Dams in Lincoln County</td>
<td>5-40</td>
</tr>
<tr>
<td>5-10 Purposes of Dams in Lincoln County</td>
<td>5-41</td>
</tr>
<tr>
<td>5-11 At Risk Population, 65 Years and Older</td>
<td>5-47</td>
</tr>
<tr>
<td>5-12 Total Population Dot Map</td>
<td>5-48</td>
</tr>
<tr>
<td>5-13 Young At Risk</td>
<td>5-49</td>
</tr>
<tr>
<td>5-14 Valley County Tornadoes</td>
<td>5-60</td>
</tr>
<tr>
<td>5-15 Winter Storm Damage and Fatalities</td>
<td>5-64</td>
</tr>
<tr>
<td>5-16 Winter Storm Damage and Fatalities 1970-2000</td>
<td>5-67</td>
</tr>
<tr>
<td>5-17 Wind and Thunderstorms in Cascade County</td>
<td>5-72</td>
</tr>
<tr>
<td>5-18 Hail Storms on the Fort Peck Indian Reservation</td>
<td>5-75</td>
</tr>
<tr>
<td>5-19 Earthquakes in Montana</td>
<td>5-83</td>
</tr>
<tr>
<td>5-20 Earthquakes in Madison County</td>
<td>5-84</td>
</tr>
<tr>
<td>5-21 Landslide Susceptibility and Incidence in Montana</td>
<td>5-89</td>
</tr>
<tr>
<td>5-22 Landslide Susceptibility and Incidence in Park County, Montana</td>
<td>5-92</td>
</tr>
<tr>
<td>5-23 Structure Locations</td>
<td>5-99</td>
</tr>
<tr>
<td>5-24 Total Outbuildings</td>
<td>5-101</td>
</tr>
<tr>
<td>5-25 Location Map of Missoula County</td>
<td>5-109</td>
</tr>
<tr>
<td>5-26 Missoula County Population Dot Map</td>
<td>5-110</td>
</tr>
<tr>
<td>5-27 Missoula County Rural Fire Districts</td>
<td>5-111</td>
</tr>
<tr>
<td>5-28 Missoula City Police Patrol Zones</td>
<td>5-113</td>
</tr>
<tr>
<td>5-29 Partial Listing of Hazardous Sites in Missoula County</td>
<td>5-115</td>
</tr>
</tbody>
</table>
TEMPLATES FOR CREATING STANDARDIZED CARTOGRAPHIC PRODUCTS FOR MONTANA COUNTY PRE-DISASTER MITIGATION PLANS

INTRODUCTION

Background

This thesis represents the further development of a project conducted by The Department of Geography of the University of Montana for the Montana Department of Administration and the Montana Critical Infrastructure GIS Committee during 2006. The second portion of the overall project titled, Methods and Procedures for Developing Map Symbology and Cartographic Products for Emergency Management in Montana, focused on the development of map templates for use in county and Indian reservation Pre-disaster Mitigation (PDM) Plans (Appendix A). By law, counties in the United States are required to prepare PDM plans and to implement these plans as resources become available. The purpose of PDM plans is to have county Disaster and Emergency Services (DES) personnel examine county infrastructures and facilities in order to evaluate risk, identify and prioritize potential mitigation projects, and plan for response and recovery from either natural or man-made (technological/industrial) disasters.

Consequently, the objectives of this research were to study the PDM plan guides, and the actual contents of numerous county PDM plans, in order to create a list of maps that might be included in the plans. This list would then be used to create map templates (example maps) that could be used by either the counties or their contractors for designing useful cartographic products for the plans. In addition to the map templates, applicable cartographic principles, data sources for building the maps, step-by-step instructions for creating them with ArcGIS 9.1, and the conceptual and theoretical bases for interpreting them were to be researched and provided in the report.

By way of introduction, the larger issues related to why this work was necessary in the year 2006 need to be examined in order to properly frame the problem statement of this thesis, which concerns the development of standardized map products for PDM plans. The research conducted for the project provided the initial clues for this background information and pointed to three different sets of circumstances that had
evolved somewhat simultaneously. The convergence of these circumstances made this research necessary. The first factor was the characteristics and incredible diversity of the people and landscape of Montana and their associated vulnerabilities to the various types of hazards. The second was the development of thematic mapping, and how it has come to be used to portray and analyze man-made (technological/industrial) and natural disasters. And finally, the third was the evolution of emergency management within the United States and its implications for Montana. Each of these areas will be covered in some detail in order to provide the necessary framework. However, in order to provide the reader with some basic information regarding the terms and conventions used in this thesis, that issue will be dealt with first.

**Definitions and Conventions**

The usage and definitions of terms such as risk, hazard, and disaster, have evolved over the years and are greatly dependent upon the perspective or occupation of the user. Similarly, the various types of risks, hazards, and disasters are categorized in a number of different ways. As an example, Keith Smith in his book *Environmental Hazards*, initially groups all types of hazards together under the heading of environmental hazards. He provides a working definition of the term as “extreme geophysical events, biological processes and major technological accidents, characterized by concentrated releases of energy or materials, which pose a largely unexpected threat to human life and can cause significant damage to goods and the environment.” Smith goes on to establish a typology, or taxonomy, for hazards and disasters that is based primarily upon the type of event. These include atmospheric (climate), hydrologic, geologic, biologic, and technologic, and are base primarily on the nature of the event providing the initial cause of the disaster.1

Conversely, various government agencies use the terms in other ways. For example, The Department of Homeland Security in the *National Response Plan*, uses the term incident instead of disaster, and defines it as “an occurrence or event, natural or human-caused [emphasis added], that requires an emergency response to protect life or property…” In the same document, the definition for the term (major) disaster is based

---

upon the level of response required. In this case, a determination is required by the President of the United States that the magnitude of the disaster is such that Federal assistance is required to supplement the response and recovery efforts of the state and local governments.\textsuperscript{2} Other government agencies, such as the Montana Emergency Services Division, discuss and assess vulnerability to hazards that occur in Montana collectively, but refer to them as being either natural or man-made.\textsuperscript{3}

Therefore, it is necessary to first articulate the definitions and conventions for these critical terms as they are used in this thesis. Since the original research project was designed to serve the needs of the Disaster and Emergency Services (DES) community in Montana, the definitions and conventions will be those most commonly used by them.

Definitions

Although taken from a variety of resources, the definitions listed below were found to be in common usage among the DES community in Montana.

**Risk.** Risk is the estimated impact that a hazard would have on people, services, facilities, and structures in a community or the likelihood of a hazard event resulting in an adverse condition that causes injury or damage. Risk may be stated in relative terms associated with the likelihood of occurrence, such as high, medium, or low. It may also be expressed in terms of potential monetary loss as a function of the intensity of the hazard.\textsuperscript{4}


Hazard. A hazard is best viewed as a naturally occurring or human-induced process, or event, with the potential to cause damage to property or loss of human life. In general, it is a source of potential danger or adverse condition.  

Disaster. A disaster is normally considered to be a hazard that has actually happened. It may take the form of a natural catastrophe, technological accident, or human-caused event that has resulted in severe property damage, deaths, and/or multiple injuries. From the perspective of the DES community, the magnitude of the disaster would dictate the associated extent of the response and recovery efforts required.

Conventions

There are two primary conventions that must be established for this discussion. The first is associated with the categorization of disasters and the second is that portion of the disaster cycle this research is directed toward.

Categories of Disaster. In reality, most events that are classified as disasters (hazard events that have occurred) have both natural and human (man-made) components. For example, a flood may be caused by higher than normal precipitation. However, the extent of the flood damage may be exacerbated by human-caused changes to drainage patterns, deforestation, or home construction in flood prone areas. Regardless of the cause of the disaster, some convention was required in order to categorize the map templates constructed during the course of this research. To satisfy this need, the hazard related map templates are separated into the categories natural or man-made disasters.

The Disaster Cycle. The disaster cycle is normally subdivided into four major steps: preparedness (or planning), mitigation, response, and recovery. Although the map templates discussed in the section titled Templates for County Pre-disaster Mitigation

---

Plans may have some utility during each of the steps on the disaster cycle, their primary focus is to serve the needs of DES personnel involved in the preparedness and mitigation portions of the cycle.

Diversity in Montana

Montana is a very diverse state. This diversity exists in many categories, including the areas of physical, economic, and human geography. Although detailed studies of these and other related categories of diversity are beyond the scope of this work, some critical aspects need to be examined here. Numerous books, journal articles, and other works have been compiled on these subjects. As an example, “coffee table” books depicting the natural wonders found in Montana, such as Glacier National Park, are relatively common in living rooms throughout the country. Another example is found in the book Roadside Geology of Montana, by David Alt and Donald Hyndman, who found it necessary to divide Montana into four distinct geological regions.\(^7\) In contrast to this, the Montana State Tourism website, http://visitmt.com/, divides the state into six separate regions because of the cultural and physical diversity found in the state.\(^8\) Likewise, the Montana Natural Heritage Program, just in the biological order of mammals, lists twenty-one different families of mammals that are found within Montana.\(^9\) However, one of the best sources of information regarding Montana’s diversity and its implications resulted from a collaborative work titled The Montana Challenge that was published on the Montana Fish, Wildlife, and Parks website in 2005.\(^10\)

A number of subject matter experts were commissioned to examine issues related to Montana’s natural resources, public policies regarding their use, and to outline demographic trends in order to determine what the future holds for our state. However, when viewed in the context of the topic of this thesis, their findings also provide insights regarding some of Montana’s vulnerabilities. The results of this and other works will be used to provide some insight regarding the manner in which Montana is vulnerable to natural and man-made disasters.

**Human Vulnerability**

In order to fully understand the potential risks for Montanans that are associated with natural and man-made disasters, some basic information regarding population growth and change must be examined. While Montana is the nation’s fourth largest state, it also one of the least populated. The U.S. Census estimated the 2005 population to be 935,670 people that are distributed over 147,046 square miles, making it one of the least densely populated states in the country. According to the U.S. Census of 2000, this data resulted in an average population density of 6.2 persons per square mile, as compared to the national average of 79.6 persons per square mile. Moreover, the situation is complicated because the population is not distributed evenly throughout the state. Of the fifty-six counties in the state, the two population extremes are Yellowstone and Petroleum Counties. Their 2004 U.S. Census population estimates were 136,717 and 492 respectively. And finally, Montana contains seven Indian reservations that encompass an area of 13,157 square miles. While not all of this land is owned by the various tribes, approximately 29,500 Native Americans live within the reservation boundaries. More importantly, when taken all together, Native Americans make up Montana’s largest minority population at approximately 6.2% of the total population.\(^\text{11}\)

George S. Masnick, a Senior Fellow at Harvard University’s Joint Center for Housing Studies, and contributor to the *Montana Challenge*, analyzed Montana’s demographic trends in this study. Masnick identified eight demographic changes, three

of which apply directly to this thesis. First of all, since 1850, the West has gained in share of the total U.S. population in every decade, and higher than average growth is projected to continue for the foreseeable future. More importantly, during the last decade of the 20th century and the first years of the 21st, the West’s eight state Mountain Division (MT-ID-WY-CO-NM-AZ-UT-NV) led the nation in percent growth. In its simplest sense, Montana will continue to gain population and subsequently have more people vulnerable to the natural and man-made disasters that occur here.

Secondly, Masnick’s research revealed that this population growth has not occurred evenly throughout the state. Western mountain counties in Montana have experienced high sustained growth on average in recent years, and many western counties including Flathead, Ravalli and Gallatin Counties, have experienced extremely high growth rates. Central Montana front-range counties have oscillated between positive and negative growth, and now appear to be in a slightly negative growth phase. Eastern plains counties have had sustained negative growth for the past two decades. This disparity in growth rates has been combined with the fact that the population in the West is spilling into the countryside. In Montana, the rate of growth of unincorporated and rural places during the 1990s was more than twice the rate of incorporated places.

Finally, Masnick identified another future demographic trend is. Barring some dramatic increase in mortality, Montana’s population is aging. This population aging trend is best demonstrated by comparing population pyramids for 1980, 1990 and 2000. For these measuring points, the age of the largest portion of the population has changed from the mid-20’s in 1980, to age 35 in 1990, and age 45 in 2000.12

Another characteristic of Montana’s population has to do with per capita income. According to the U.S. Census estimate for 2003, the average annual income for Montana residents was $25,920, as compared to the national average of $31,632. Because of this difference in average incomes, Montana was ranked 44th in the nation. In general, people that are more financially secure can more easily withstand the hardships, such as loss of

---

property, that are normally associated with natural or man-made disasters.\textsuperscript{13} This obviously puts many Montanans at a disadvantage, but it does not tell the whole story. Montana has also become the home, or second home, of a number of wealthy people who make additional demands on the capabilities of DES and other emergency services personnel throughout the state. As an example, a brief look at any of the real estate sales publications found around the state reveal numerous listings of multi-million dollar homes constructed in wildland-urban interface (WUI) areas. While these homes are obviously beyond the financial means of most Montanans, structures of this type are frequently more difficult to protect from fires. This is discussed in greater detail in the segment concerning wildland fires contained in the section titled \textit{Templates for County Pre-disaster Mitigation Plans}. The most extreme example is that Montana will soon have the most expensive home in the world. The 53,000 square foot structure, part of a gated community in a forested area near Bozeman, Montana, contains ten bedrooms and will cost $155,000,000.\textsuperscript{14}

\textbf{Ecological/Biophysical Vulnerability}

The diversity of Montana’s landscape and the resulting variety of disasters that have occurred here is also a matter of concern. The statement that Montana is often referred to as a land of extremes is given validity by some basic facts. Montana has an average elevation of approximately 3,400 feet above sea level, with a high point of 12,850 feet at Granite Peak and of low of 1,800 feet near Troy, Montana. The climate has similar extremes with the record high temperature of 117\textdegree{} F recorded near Glendive and a low of -70\textdegree{} F at Roger’s Pass, near Helena. Similarly, Montana has three distinct geographic regions: the broad, dry eastern plains, the western mountains, and the area in


between, which is often referred to as the Front Range. These are just a few of the variations in the landscape.

The research conducted for this project revealed that because of this diversity, Montana has experienced almost every type of natural disaster of concern to DES personnel, with the primary exceptions being tsunamis and coastal storms. Similarly, Montana is susceptible to virtually every type of man-made disaster except shipwrecks for two primary reasons. First of all, many of the activities that take place within Montana bring with them various risks. These include mining, petroleum production, chemical spills, the housing of strategic missile silos, and so on. These risks are compounded by Montana’s geographical location within the country. Major lines of transportation, such as highways, railroads, pipelines, and so on, pass through Montana. This transport infrastructure has inherent risks for hazardous events, such as spills of toxic materials, for items being moved through the state. The major disaster types are discussed in detail in the section titled *Templates for County Pre-disaster Mitigation Plans*, but the point to be emphasized here is that the people of Montana are susceptible to a wide variety of natural and man-made hazards.

### Summary of Vulnerability and Its Impact on PDM Planning in Montana

The results of these conditions that most concern DES personnel are that Montana is developing an older population that is less self-reliant than native rural Montanans and that lives in more remote areas. Associated with these concerns, conversations with various DES personnel around the state revealed two other related issues. First of all, emergency personnel recognize that they must be prepared to deal with the broadest possible range of disasters. This requires extensive training and the expenditure of oftentimes scarce resources. Secondly, and this is especially true in the less populated counties, emergency personnel are often volunteers, may work only part time, or have

16 Chief Scott Waldron, Frenchtown Rural Fire District, Frenchtown, MT. Interviewed by author September, 2006.
multiple responsibilities, some of which may not be related to emergency response. No matter how dedicated, their skill levels and availability may be inadequate. In any case, they are often performing functions that would normally be done by full time paid professionals.¹⁸

All of these vulnerability issues have a direct impact on the breadth and complexity necessary in PDM planning for Montana counties and Indian reservations. Plans must address a wide variety of potential disasters that can affect a population, dispersed in some areas and concentrated in others, that often has minimal capability of coping with disasters without assistance.

**Cartography and Thematic Mapping**

Although the use of maps and the science of cartography have developed over many centuries, thematic map products are a relatively new phenomenon. While a detailed history of cartography is beyond the scope of this project, it is important to outline some key points about thematic mapping, and its association with natural and man-made disasters, in order to demonstrate the importance of these products to the process of PDM planning.

**History of Thematic Mapping**

One of the best histories of thematic mapping was compiled by the noted geographer, Arthur H. Robinson. Historically, maps had been used for recording the location and identity of geographical features, were guides for travelers, and so on. Thematic maps did not appear until the late seventeenth century. Improved technology during first half of the nineteenth century made possible innovations in thematic concepts and symbolism. This made the first sixty years of the nineteenth century the period of most rapid development of thematic mapping, unparalleled for at least another 100 years. Robinson defined thematic maps as “…a map that concentrates on showing the

¹⁸ These concerns were compiled from notes taken during monthly meetings of the CISDM committee and phone conversations with Ron Knutson, DES Coordinator Hill County, Montana, during the months of January through April of 2006. Additional input came from participation in conversations and attendance at presentations during the Governor’s Emergency Summit Conference held in Billings, Montana, during May, 2006.
geographical occurrence and variation of a single theme….The number of themes is unlimited…including diseased population.”

From the literature, it appears that the association of thematic mapping with the portrayal of natural and man-made disasters did not evolve quickly. One of the first uses was to display and analyze the occurrence of a particular disease outbreak in Great Britain. This was accomplished by Dr. Alfred Havilland in Great Britain in 1892. Also, a more recent examination of the Map Division of the Library of Congress during research conducted by Mark Monmonier yielded few maps of hazards that were compiled before 1950. Despite this slow start, the association of thematic mapping and disasters has evolved dramatically since that time. As an example, one of the first attempts by the U.S. Government to present risk information in a map format was FEMA Publication 196 that was published in 1980. This was a state by state guide that displayed areas of risk to various natural disasters and nuclear attack and was published in the latter part of the Cold War. The individual map products were much generalized and the intent was to promote preparedness on an individual level. However, without question, thematic cartography and its use in portraying natural and human landscapes has developed dramatically in the last few decades. Numerous text and reference books, journal articles, guides by various government agencies, and so on, are available and have been used in the development of thematic map products associated with PDM plans. Some of the more important references that were used in the construction of map templates and the enumeration of applicable cartographic principles for this research are discussed in more detail in this thesis in the section titled Cartographic Products for Pre-Disaster Mitigation Plans.

---

The Science of Natural and Man-Made Disasters

A detailed investigation of the latest science of each type of natural and man-made disaster that occurs in Montana is dealt with to the extent necessary in the section titled *Templates for County Pre-disaster Mitigation Plans* of this thesis. However, for the purposes of framing the research problem, some preliminary points must be discussed here.

The first comprehensive national assessment of scientific research on natural hazards was conducted in 1972 at the Institute of Behavioral Sciences of the University of Colorado. This assessment was funded by the National Science Foundation and led by geographer Gilbert F. White and sociologist J. Eugene Haas. A complete report of the findings of this body was subsequently published by the leaders in 1975. Two important results of this assessment and the dialogue it generated are important for framing this research problem. First of all, this marked the beginning of the blending of many types of scientific disciplines in work related to hazards. Prior to this point, hazards assessment study had primarily been done within the purview of the physical scientists and engineers. Now, this area of study was expanded to formally include the social sciences and others. Secondly, the hazard assessment field of study expanded from being primarily concerned with response and recovery efforts to include studies on prevention and mitigation.23

Other types of assessments and developments were also occurring in the 1970s. One of the more important ones involved assessing the nation’s capability of warning its citizens of an impending nuclear attack or natural hazard.24 Another was the recognition of emergency management as a professional field of study and employment. By the end of that decade, most county and state governments had engaged professional DES personnel.25 All the while, as the population of the world increased, losses to natural and man-made disasters continued to grow, with the confirmation that hazards had become

---

more than a local or state issue. Although local planning, mitigation, and preparedness is critical, the potential extent of “mega-disasters” had become national and international in scope.\textsuperscript{26,27}

Consequently, a second national assessment was sponsored by the National Science Foundation in the mid 1990s. Work began in 1994 and the results were published in a number of works several years later. The major thesis of one of these works, \textit{Disasters by Design}, by Dennis Mileti, was “…losses from natural and related technological hazards-and the fact that the U.S. cannot seem to reduce them-are the consequence of narrow and short-sighted development patterns, cultural premises, and attitudes toward both the natural environment and even science and technology.” This work outlined the need for an overarching management strategy, the goal of which was to reduce hazard related losses of lives and property in each of the four stages of dealing with hazards: preparedness, mitigation, response, and recovery. Furthermore, “…implementation today relies on loss reduction activities…fostered at the societal level but carried out locally or individually.”\textsuperscript{28} Many of the results of this conference are embodied in the Disaster Mitigation Act of 2000 and its guidelines for pre-disaster mitigation planning that will be discussed in more detail later in this section and in the section titled \textit{Cartographic Products for Pre-Disaster Mitigation Plans}.

\textbf{The Development of Digital Cartography in the Hazards Field}

Without question, the development of digital cartography has had a tremendous impact on thematic mapping, scientific analysis of the natural and man-made landscape, and the portrayal of natural and man-made hazards. Several books and numerous articles have been published outlining the various methods and requirements for incorporating GIS into emergency management. A brief examination of the “Training and Education” portion of the ESRI website yielded five online courses and at least ten books that are directly related to GIS and natural or man-made disasters.\textsuperscript{29} One of the

\begin{thebibliography}{99}
\end{thebibliography}
best is *Confronting Catastrophe* by R. W. Greene. Several of these GIS and emergency management references were used in the research for this project and are discussed in more detail in the section titled *Cartographic Products for Pre-disaster Mitigation Plans*. Likewise, numerous types of GIS software specifically designed for use in emergency management have been developed over the years. Many of them, such as Hazards, U.S. (HAZUS-MH), the Consequence Assessment Tool 6.0 (CATS), Computer-Aided Management of Emergency Operations (CAMEO), and others have been made available for free by various government agencies. However, there are numerous disparities in the incorporation of GIS into the world of emergency management. Geographer Mark Monmonier, when conducting research for his book *Cartographies of Danger*, noted that while some emergency managers embrace new technology, many depend less on maps and are obsessed with lists of whom to notify, how to respond, and so on. More importantly, when evaluating the response to a hazardous liquid spill in Marlborough, Massachusetts, he noted that paper maps were utilized even though free emergency mapping software was on hand (CAMEO). This deficiency existed primarily because of a lack of funding. Local officials could not afford to purchase the required hardware or hire the staff to implement it.\(^{30}\) Essentially, there is a great disparity in how GIS is utilized in the general category of emergency management. This same situation exists in a variety of ways in Montana.

Conversations and interviews with DES and other personnel around Montana revealed a number of things. First of all, although almost all counties and reservations in the state use GIS for some purposes, there is little uniformity in its implementation or use. Very few have institutionalized it into a formal department, and many counties lack a formal IT department to aid in this process.\(^{31}\) When GIS is used actively, the problem of data availability exists. Many of the existing PDM plans reviewed for this project contained statements regarding the limitations of data availability for the county in question. And finally, even in those counties where a robust GIS capability exists, it may not be directly involved in DES activities.\(^{32}\) These local characteristics and cartographic (GIS) capabilities, combined with the diverse nature of hazards across the nation, have

limited the abilities of federal regulatory agencies to establish detailed specific guidelines for PDM plans.\textsuperscript{33} More current guidelines, such as FEMA’s Mitigation Plan Review, which was published in March, 2006, are similarly broad and general in character. The specific cartographic requirements of this PDM review guide are discussed in more detail in the section titled \textit{Cartographic Products for Pre-disaster Mitigation Plans.}\textsuperscript{34}

**Thematic Mapping and Its Impact on PDM Planning in Montana**

The various scientific efforts related to natural and man-made hazards have developed greatly in recent decades. Likewise, the capabilities provided by GIS to develop thematic maps, perform risk analysis, identify areas for mitigation by DES personnel, and so on have improved greatly during the same time frame. The potential to make use of these advances in pre-disaster mitigation planning varies greatly in Montana for many reasons, some of which have been identified here. First of all, because of the differences in county population, available funding, and priorities across the state, there is little uniformity in how GIS has been adopted by emergency management. Secondly, the availability of detailed and accurate data hinders those involved in emergency management. And finally, as it applies to the development of PDM plans, guidelines for related cartographic products are necessarily broad.

**Evolution of Emergency Management**

The involvement of the U.S. Government in various forms of disaster relief has existed almost since its inception. Federal troops were dispatched in 1786 to put down Shay’s Rebellion, an event of civil disobedience in western Massachusetts. The Congressional Act of 1803 provided disaster relief to Portsmouth, New Hampshire, which had suffered extensive fire damage. These are typical of the types of hazards that

\textsuperscript{33} Monmonier, Mark. \textit{Cartographies of Danger.}

are currently addressed in PDM plans.\textsuperscript{35} In the century that followed, federal relief was provided more than one hundred times around the nation to victims of earthquakes, floods, and hurricanes; each time with specific legislation. By the 1930s, there were a number of federal programs in existence that had disaster relief responsibilities. These included disaster loans available from the Reconstruction Finance Corporation, bridge and road repair funding provided by the Bureau of Public Roads, and flood control provided by the U.S. Army Corps of Engineers.\textsuperscript{36}

**Creation of the Federal Emergency Management Agency**

The 1960s brought massive natural disasters that required major Federal response and recovery operations. These included Hurricane Carla in 1962, Hurricane Betsy in 1965, the Alaskan earthquake in 1964, Hurricane Camille in 1969, and others. At the time, the national response was handled by the Federal Disaster Assistance Administration, which was part of the Department of Housing and Urban Development. However, federal activities in this area were too fragmented, with too many agencies involved. Concerns over this problem were the subject of a critical report published by the National Governor’s Association in 1978. As a result, the Federal Emergency Management Agency (FEMA) was established by Executive Order of President Carter in 1979. This was accomplished by consolidating seven existing disaster related programs into one agency. During the subsequent administration of President Reagan, much of the focus was on civil defense and nuclear war. However, with the end of the Cold War, FEMA’s focus turned fully to natural disasters.\textsuperscript{37} FEMA was subsequently incorporated into the newly formed Department of Homeland Security in March, 2003. However, it remains focused on natural and man-made disasters.\textsuperscript{38}


**Pre-Disaster Mitigation (PDM) Plans**

Major changes for FEMA took place in 1993 when President Clinton nominated James L. Witt as the new director. Witt, the first director with experience as a state emergency manager, instituted major reforms. One of the most important of these was a new emphasis on preparedness and mitigation, especially at the state and local levels.\(^\text{39}\) This ultimately resulted in the passage of the Disaster Mitigation Act of 2000 (DMA 2000), which requires that state, local, and tribal governments prepare and adopt jurisdiction-wide hazard mitigation (PDM) plans in order to receive various types of grant funding.

The DMA 2000 formalized the shift away from a reactive response and recovery approach to a new emphasis on identifying potential hazards and taking steps to minimize their impact.\(^\text{40}\) In turn, FEMA prepared an Interim Final Rule, published in 2002, which established more detailed planning and funding criteria for states, tribes, and local communities. It also gave county and tribal governments the option of preparing the PDM plans themselves or using Hazard Mitigation Grant Program (HMGP) funding to have them prepared by professional contractors.\(^\text{41}\) Additionally, FEMA has published numerous “How To” guides (listed in the section titled *Cartographic Products for Pre-disaster Mitigation Plans*) to assist local government in the development of PDM plans as well as “evaluation guides” for use by FEMA personnel in their evaluation. However, none of these documents establish specific requirements for the types of cartographic products necessary for a satisfactory PDM plan.

**PDM Plan Development in Montana**

At the time this research was conducted in 2006, all Montana counties and Indian reservations had compiled PDM plans. While some were still in the review process by FEMA, most had been approved and were actively being implemented (Figure 3-1). Some had been prepared locally while most had been prepared professionally by outside contractors. All of the PDM plans reviewed for this project contained some type of

---

\(^{39}\) History of Federal Disaster Mitigation: Evolution of the Federal emergency Management Agency.

\(^{40}\) *Disaster Mitigation Act.* Public Law 106-390. Sec.322.

cartographic products. A composite analysis of these cartographic products is shown in Table 3-1.

The immediate reason why this project became necessary was related to the content and types of the cartographic products included in PDM plans. Discussions with members of the Critical Infrastructure and Structures Data Model (CISDM) Committee prior to the formalizing of the Statement of Work revealed some of these concerns and desires. First of all, there was a desire to achieve some level of standardization in the cartographic products contained in PDM plans. Secondly, there was a desire to adhere more closely to basic cartographic principles and methods. And finally, there was a desire to provide a selection of cartographic products from which local emergency managers and others involved in compiling PDM plans could choose those that best met their needs.42

**Summary of Factors**

Three major groups of factors and events converged simultaneously and resulted in the need for this research. First of all, Montanans are a diverse group of people and live in a diverse landscape. As such, their lives and property are at risk from a wide variety of natural and man-made hazards. Secondly, knowledge of these hazards and our ability to portray and analyze them has advanced significantly over recent decades. This is especially true since the advent of GIS and digital cartography. And finally, one of the primary means of reducing this risk is through the development and implementation of comprehensive and thoughtfully compiled PDM plans that contain well developed cartographic products.

---

42 These needs were compiled from notes taken at four monthly meetings of the CISDM committee during the months of January through April of 2006. Additional input came from meetings with Ken Wall, owner of Geodata Services, Inc., of Missoula, Montana, and Mike Sweet of the College of Forestry and Conservation of The University of Montana that were held during the same time frame.
Problem Statement

The purpose of this project was to develop the methods to create standardized cartographic products that support pre-disaster mitigation plans for county and tribal governments.

Goals, Assumptions, and Context

In order to accomplish the purpose of this project, a number of individual goals and assumptions were set relating to the variety and quality of map templates that would be constructed. Additionally, the context of their applicability to individual counties and reservations needed to be established.

Goals

The goals listed here were established in order to provide a general outline of the sequence of events for the research.

Goal 1: Identify Standards set by Law. A beginning point was to study the Disaster Mitigation Act (DMA) of 2000 to learn what standards if any were in force for the inclusion of map information in the PDM plans. It was anticipated that the provisions made by the law would comprise the minimum standards for the inclusion of cartographic information. These minimum standards would supply the foundation or beginning point for recommending additional cartographic products.

Goal 2: Identify Cartographic Products Useful to Montana DES Personnel. The state has such diverse environmental, cultural, and economic characteristics that a wide variety of cartographic products would be needed in order to adequately plan for impending hazards. In some counties, wildfire is the major concern, in others it is earthquakes, in a few stored chemicals or petroleum products top the list, while some find tornadoes or severe winter storms compelling risks. It is the variety of these hazards that really determine which cartographic products would be most useful to county and tribal DES personnel, not national standards.
Goal 3: Identify Cartographic Principles and Methods for Building Disaster Mitigation Maps. Cartography is such a vast field that mastering its entire scope requires years of training and study. However, gaining a working knowledge the cartographic science necessary for creating maps that concern pre-disaster mitigation planning is a more manageable task. The concepts, principles, and methods necessary for this task can be digested into a reasonable number of pages. Thus it is another goal to provide a summary of just those elements of cartographic knowledge needed to build technically correct and accurate maps for pre-disaster mitigation planning.

Goal 4: Prepare Templates of Cartographic Products. It was understood from the very first that an actual map would have to be made for every potential map type that might be involved in pre-disaster mitigation planning. One alternative was to choose one county or Indian reservation and map it repeatedly until each type of cartographic product was demonstrated. Another alternative was to create a hypothetical map to be used repeatedly as the template. A final alternative was to choose whatever county or Indian reservation in Montana that best suited the topic for the template. Regardless of the alternative chosen, it was clear that building templates had to satisfy several sub-goals.

Sub-goal 1: Find Sources of Data. Sources of data had to be found that would allow the maps to be made in a timely manner. Moreover, steps for downloading, processing, and in cases analyzing that data had to be described in detail so that GIS personnel with a modicum of experience could replicate them for any county or Indian reservation. In addition, suitability of the data, data processing methods, and the results of analysis had to be comprehensible by local DES personnel so that the finished maps could be interpreted correctly.

Sub-goal 2: Build the Map Templates. So that it is clear to everyone from the beginning, it must be understood that the map templates were to be actual maps of counties, Indian reservations, or hypothetical areas. It was obvious from the outset that mere descriptions of maps and mapmaking processes would never satisfy the purpose of the report. Unless actual maps could be seen, the
perception of their usefulness would be difficult to comprehend. Consequently, it was a goal of the project to build actual maps just as they might appear in the pre-disaster mitigation plans.

Sub-goal 3: Describe the Map Building Process. Seeing a map is not building a map. By the time a map has ended up in printed form, it has undergone numerous processing steps. Cartographic processes have to be ground down to actual mouse clicks and key strokes on the computer that build the map one component at a time. A map that displays the results of data analysis may involve considerable conceptual maneuvering among generic tools present in the GIS software. For this reason it was determined that sets of instructions had to be provided with each map for its construction.

It is the premise of this research project that achieving the goals listed above would satisfy the purposes of the study. Counties and Indian reservations then would have the tools needed to create useful and insightful maps to complement their pre-disaster mitigation plans.

Assumptions

The methods described in this report are predicated on several assumptions that needed to be made clear at the outset.

Assumption 1: Maps Will Be Built With ArcGIS 9.1. A platform for work had to be chosen for the project, and that was ArcGIS 9.1. Consequently all of the map building processes right down to the individual keystrokes and mouse clicks all pertain to that specific piece of software unless otherwise indicated. (Some data processing involved Excel or SPSS)

Assumption 2: Template Maps Concern Montana. It is quite possible that this report may be circulated through parts of the DES community outside of Montana. However, map topics have been chosen that particularly concern Montana’s environment,
economies, and populations. Other states may involve hazardous events that would never happen in Montana. Hurricanes, shipwrecks, tsunami, and oil-tanker spills are examples. The creation of template maps in other states would have to take this limitation into account.

Context

Since Montana presents such a broad array of environments, economies, and cultures, templates that have been prepared during the course of this research must be considered and used in the appropriate context for each county. Circumstances may exist where certain templates may need to be modified in order to best suit local conditions for particular counties or Indian reservations; and beyond that there may be instances where useful maps may be produced that were overlooked during the course of this research.

County residents and officials know their county the best. They have knowledge of where things are located, their relative importance, and the strengths and weakness of their emergency preparedness better than anyone. They should be the ones choosing which maps to include and how the data should be manipulated and presented.

It must be understood that PDM plans are dynamic documents. Human landscapes, population densities, areas of responsibility, and potential sites for man-made hazards are continually changing. The process of creating useful PDM plans requires regular updates. Of course the associated cartographic products should be designed to accommodate this dynamic nature.

Consequently, the map templates produced in this work must be viewed as recommended models, not actual cartographic products to be implemented in their present form. The idea behind this work is to provide ideas of maps that might be produced and include as much information and instruction for their creation as possible. However, the character and specific appearance of the maps must be the product of county or Indian reservation DES personnel.
Section Summary

This section described the convergence of three sets of circumstances: the development of thematic mapping, the diversity of Montana, and the development of emergency management. The result of this convergence served to frame the purpose of this thesis which was to standardize cartographic products contained in PDM plans. Additionally, the assumption, goals, and context of the research were outlined. The following section will address the methodology utilized for this thesis.
METHODOLOGY

The methods used for conducting this research have been empirical when it came to choosing the list of templates to include, but theoretical and conceptual when it came to actually building them. It was necessary to research as many local sources, talk to as many people as possible, and examine numerous local pre-disaster mitigation plans in order to choose topics for templates. However, when it came to actually building the templates, that work depended on the theories, principles, concepts, and techniques of the disciplines of cartography and GIS. Methods used in the preparation of this research may best be organized around the goals, assumptions, and context listed and discussed in the preceding section.

Standards Set by Law

The logical beginning point to learn which cartographic products should be included in the pre-disaster mitigation plans was to research the law that requires the plans to be made and to consult any reference material that had been prepared by the government that laid out and discussed their design. It was anticipated that this material would prescribe the minimum standards set for the inclusion of cartographic materials. It was learned early on that virtually all of this material was easily accessible from Internet sources.

Identify Cartographic Products for Montana Pre-disaster Mitigation Plans

Logic determined that there were four potential sources for learning which cartographic products should be included in Montana’s county pre-disaster mitigation plans. These are listed below:

1. One source was the actual PDM plans that have been prepared to date. Maps included in them would help identify types of cartographic products already considered to be important enough to be included.
2. Another source was the county and state DES personnel who have prepared or are in the process of preparing of their PDM plans. Their preference for the types of maps would be based on either actual experiences they had encountered with emergencies in their counties or their study of disasters that might occur.

3. Periodic disaster and relief exercises are performed that involve county and state DES personnel reacting to hypothetical incidents such as a flood, an earthquake, or an outbreak of pandemic influenza. It was believed a professional cartographer observing such exercises would be able to identify types of cartographic products that might not occur to untrained participants.

4. Last was the literature that concerns disaster and emergency services and the vast body of literature that concerns cartography.

The methodology designed for learning which cartographic products to include was built around these sources as discussed in the sections that follow.

**Existing Cartographic Products**

Since there were two varieties of pre-disaster mitigation plans found in Montana (those prepared by commercial consulting firms and those prepared by the counties themselves) two methodologies had to be devised for their study. Virtually all of the commercially prepared pre-disaster mitigation plans could be accessed from the Internet. Copies were downloaded and examined. Lists of maps and other cartographic references were compiled so that the number and variety of products could be determined. Most county-prepared plans could also be obtained from Internet sources. These were sampled and their cartographic products were inventoried. A matrix was built that allowed counties to be cross-tabulated with the types of cartographic products found in their PDM plans. It was anticipated that repeated occurrence of particular map types would allow them to be assigned higher priority when it came time to build cartographic templates.

**Interviews with DES Personnel**

Actual interviews were chosen over questionnaires when it came to soliciting information from DES personnel. It was anticipated that the most complete list of cartographic products could be obtained through the interaction between trained DES personnel and the professional cartographer. This way the DES person could react to types of maps suggested by the cartographer and could counter with suggestions of his or
her own. Conversation would allow preferences to be expressed freely without being confined to checkmarks in a questionnaire. Interviews were conducted ad hoc either at professional meetings, at disaster and emergency exercises, or by telephone.

**Disaster and Emergency Exercises**

As many disaster and emergency exercises as possible were attended. Careful notes were taken during the process of observation particularly as concerns the types of maps that could have been profitably used. While many of these maps would have been best suited for the exercise itself, their topics are often suggestive of types of maps that might well fit into the PDM plans. Good map topics were added to the list of potential cartographic products as they were encountered.

**Project Literature Research**

This method concentrated mainly on researching the literature for disaster and emergency planning and relief with the end of finding what types of maps have been used elsewhere other than Montana to assist in disaster and emergency services. As documents were perused, potential map topics were noted and added to the list. Less time was needed for researching cartographic literature as most of the potential types of maps were already well known.

**Cartographic Principles for Building Pre-disaster Mitigation Maps**

While conducting the research, map templates were built that demonstrated concepts and methods. However, the actual maps will have to be created by either county employees or by professional GIS operators employed by consulting firms. In either case, a handy source of cartographic principles, methods, concepts, and techniques would be a useful addition to this report. Thus, it was determined from the outset to include a section that covered the cartographic essentials needed for preparing maps for the pre-disaster mitigation plans. The method employed was to initially review the cartographic methods by a brief perusal of the literature and select those methods that
seemed most appropriate. This set of cartographic principles, methods, and concepts was added to as additional problems were encountered during the course of the research.

**Templates of Cartographic Products**

Preparation of the templates involved addressing three areas of concern: 1) data sources, manipulation, and analysis, 2) compilation, assembly, and design of the map templates, and 3) instructions for conducting the work with ArcGIS 9.1 and allied software. Each of these areas of concern is covered in the subsections that follow.

**Data Sources, Manipulation, and Analysis**

As each template was created, care was given to record the sources of data used so that maps for PDM plans could be made for any county or Indian reservation in the state. Since datasets are not all available from one source it was deemed important to establish a priority list of sources at the outset. It was found when alternative sources were available, a set of standards, rules, and recommendations was necessary so that appropriate choices could be made. Further, reasonable standards had to be set regarding the availability of metadata, the ease with which data could be processed, and its appropriateness for analysis. Each of these concerns is addressed in the sections that follow.

1. **Prioritize Sources of Data.** Cartographic layers, including their attribute data were in the process of being assembled for the Critical Infrastructures and Structures Data Model (CISDM) project (parent for the current project) at the time of this writing. It was anticipated that this data would ultimately be housed in the Montana Department of Administration (DOA) and administered by the Information Technology Services Department (ITSD). Use of this data would be the highest priority for building maps for PDM plans since it would be maintained and periodically updated specifically for DES use.

   Of course CISDM data layers do not presently and may never contain all of the types of information that could be used to develop PDM plans. In these instances, it was determined that the second level priority for map data would be
the Montana Natural Resources Information Service (NRIS) housed in the Montana State Library. The web site maintained by NRIS is the official clearinghouse for GIS data for Montana and would be the logical second choice if information could not be acquired from the DOA.

In instances where data needed for pre-disaster mitigation plans did not exist at either of the above sources, it was determined that other local, state, or federal sources could be used. However, their use needed to be subject to a reasonable set of standards. Those standards are covered in the next section.

2. Standards for Data. Data to be stored for the CISDM project will ultimately all be governed by common set of standards. While those standards were still being set at the time of this writing, it was clear that they would come into play as the data layers were built. NRIS already has clear standards set for its data. Every geographic data layer has metadata already in place and all use the Montana State Plane, NAD 83 coordinate system in meters. All of the datasets have been examined and tested to ensure that they conform to standards set by NRIS. Unfortunately, no such governing structure has been devised for external data from other sources. Consequently, the following set of standards was established for building the cartographic product templates found in this project. The same set of standards is recommended to counties, Indian reservations, or private consultants as they build pre-disaster mitigation maps.

a. *Data must be taken from the original source or from as near to that source as possible.* The Internet has made it possible for either geographic or attribute data to be migrated from one source to another with incredible ease. Of course, every time the data is replicated and used in a new context the chances that it will become corrupted or altered to serve some new purpose increases. While even the original data may contain errors, they are likely to be fewer than if the data has been repeatedly manipulated.

b. *Data must be timely.* Since most map data is time sensitive, no attempt has been made to preserve external datasets that cover state for convenient use in preparing maps for pre-disaster mitigation plans. It was concluded
that it would be better for each county to download data from the Internet as it was needed for either creating a new plan or for revising an old one. This way map information would be the most up to date possible.

c. **The mapmaker must validate the data.** Some attempt must be made on the part of the cartographer to validate the data to ensure its accuracy. This may be done by consulting second or third sources to ensure they are consistent, or it may involve making actual checks by observation or by consultation with knowledgeable individuals.

d. **Metadata must exist.** Most geographic data (map coordinates, etc.) is not usable in a GIS unless metadata is present, and much attribute data has very limited utility. As data sources are found for PDM plan maps, metadata files must be sought out and preserved with the data. If the metadata file is missing, an alternative source should be found.

e. **Scientific content must be easily understood.** It is possible to make maps that are perfectly accurate but totally incomprehensible. When the data embodies information that is difficult to comprehend, additional resources may need to be included with the maps in order to make them useful.

3. **Appropriate for Analysis.** Most maps require some analysis in order for the data to be symbolized. Even before the data is gathered, the final map should be visualized and planned. Otherwise, data may be gathered that are inappropriate for the finished map. For one thing, the mapmaker needs to be cognizant of what if the operational taxonomic unit (OTU) chosen for mapping. If the OTU is building structures, for example, then both the geographic and attribute data should be for buildings. It is inappropriate to have geographic data for buildings but attribute data with individual identifiers for functions inside of those buildings. If the geographic data is for state and federal highways, it is inappropriate to have attribute data for local streets and county roads.

   A good plan is to create all of the conditions for the final map on paper including the various analytical steps. This way data can be gathered that will suit the finished map.
Creating Map Templates

Template maps were chosen from among Montana’s counties and Indian Reservations. One part of the design was to choose counties where the topic being mapped was a true potential problem. Thus, when the historical record of earthquakes was mapped, one of the counties near Yellowstone Park was chosen since that has been the area receiving the majority of earthquakes since record keeping began. When a map was made that showed tornadoes, a county was chosen that had experienced a significant number of them. In some cases, statewide maps were produced in conjunction with template maps when the thematic topic would benefit from data presented at that scale in addition to the county scale.

In general, the method was to employ the common features of ArcGIS 9.1 to produce all of the map templates. Where at all possible only the standard tools and utilities found there were employed. Only on several occasions were various ArcGIS extensions such as Spatial Analyst used to create specialized map layers. Attribute data was sometimes preprocessed in Excel or SPSS before being imported into ArcGIS.

Standardized base map features and symbols were used in the creation of the maps wherever possible. These standardized symbols were the result of research done during other phases of the overall CISDM research project.

Because all of the template maps had to be designed so that they could fit into the PDM plans, they were all designed in formats that would fit into the printed page. Of course template maps were drawn at a variety of scales since the various counties and Indian reservations are different sizes.

Many of the maps required considerable research in order to fully develop their topics. Sometimes this complexity carried over into the level of difficulty for interpretation. Items such as Richter and Fujita scales not only had to be researched and understood by the mapmaker but also needed to be expressed clearly to the map-reader. Consequently, the method involved going considerably beyond merely producing the maps, but also providing supporting definitions, tables, and explanatory text. If possible, this information was placed on the same page as the map, but in cases it had to be inserted into adjacent pages of text.
All of the template maps were given the same basic design. Where possible the same elements of marginal information were included, and the maps were given the same general appearance. However, it must be understood that the template maps are only that—templates. Because of the different scales of the individual county and reservation maps unique designs will have to be developed in order to make them well balanced and attractive.

**Instructions for Creating Cartographic Products**

A critical part of the methodology was to produce instructions for creating county or Indian reservation maps of the same topics as the templates. The instructions not only had to conform to work ordinarily done with ArcGIS 9.1, but they also had to be aimed at GIS technical operatives competent to make the software perform. It was assumed that the mapmakers would likely be better with regard to their GIS technical skills than their knowledge of the principles, methods, and concepts of cartography. Consequently, the instructions were slanted in that direction.

As each map template was created, copious notes were made of each step of the operations. After the map was completed, its construction was rehearsed in order to ensure that the most appropriate methods were employed. The refined notes were then used to create the steps for producing the map. Not every mouse click or button selected was included in the instructions; rather they assumed that mapmaker already possessed competent skills. If the procedures for creating one map were included in the instructions, but then encountered again in another map, they would were not repeated—merely referenced.

All phases of each map project were included in the project including data capture, data processing, geodatabase design, building and organizing map layers, conducting analytical procedures, generating map layout, designing the map, and so on. The order of presentation in the report was to begin with a description of each template map, then the map itself, and following the set of instructions for producing that map. This process was repeated again and again for as many map templates as were considered appropriate for inclusion in the report.
**Section Summary**

This section addressed the methodology utilized during the research conducted for the state of Montana and subsequently utilized for the development of this thesis. It was determined at the outset that legal standards for PDM plans would need to be examined and cartographic products suitable for use in plans developed for Montana would need to be identified. Likewise, cartographic principles applicable to PDM plans would need to be selected and outlined. And finally, map templates and the instructions for creating them would need to be developed. The next section discusses the process of identifying those cartographic products suitable for use in PDM plans.
CARTOGRAPHIC PRODUCTS for PRE-DISISTER MITIGATION PLANS

Mapping Standards Set by Law

The Disaster Mitigation Act of 2000 (DMA 2000) was signed by the President and became law (Public Law 106-390) on October, 30, 2000. The purpose of this legislation was to facilitate cooperation between state and local authorities in the area of disaster mitigation. Section 322 of the Act provided specific planning guidance, placed increased emphasis on the importance of pre-disaster mitigation planning, and promoted sustainability as the principle strategy for disaster resistance.\(^1\)

DMA 2000 provided additional, more specific, guidance for this process by defining “pre-disaster mitigation planning” as “the coordination taken prior to a hazard event to reduce injuries, deaths, property damage, economic losses, and degradation of natural resources during and following natural or man-made hazard events.” The act also provided broad clarification regarding the types of things mitigation can include. The various categories include physical projects, regulatory changes, and so on.\(^2\)

In order to implement the DMA 2000 requirements, FEMA prepared an Interim Final Rule that was published in the Federal Register in 2002 which established planning and funding criteria for states, tribes, and local governments. The purpose here was to provide meaningful background and guidance on the conduct of pre-disaster mitigation planning in order to comply with the various regulations. Furthermore, various deadlines were established for completion in order to qualify for funding for mitigation projects.\(^3\)

Local Hazard Mitigation Planning Guidelines

The DMA 2000 allowed significant latitude in the area of local hazard mitigation planning. For example, communities can be counties, local municipalities, and tribal

---


\(^2\) *Disaster Mitigation Act*. Public Law 106-390, Sec.322.

governments. In Montana, formal pre-disaster mitigation planning has been conducted primarily at the county and tribal level.

Basic guidelines were also established regarding the preparation and submission of the pre-disaster mitigation plans outlined in Section 322. These requirements were established in the broadest possible sense in order to give local governments the maximum flexibility in implementing them based on their needs. They are listed here.\(^4\)

1. Prepare and submit a local plan.
2. Monitor the progress of mitigation projects.
3. Review and update the mitigation plan every five years.

Similarly, the standards contained in the Interim Final Rule (the Rule) published by FEMA in 2002 are very broad and include only indirect references to cartographic requirements for local PDM plans. Section 201.6 (c), of the Plan Content Section for Local Mitigation Plans, is where most of these references are found. Examples are listed here with key words underlined for added emphasis.\(^5\)

1. Associated with risk assessment, “…a description of the type, location, and extent of all natural hazards that can affect the jurisdiction….shall include information on previous…hazard events…”
2. Associated with vulnerability, “…buildings, infrastructure, and critical facilities located in the identified hazard areas…”
3. Associated with financial vulnerability, “…estimate of the potential dollar losses to vulnerable structures identified (above)…”
4. Associated with land use, “…a general description of land uses and development trends…”

**State and Local Mitigation Planning How-To Guides**

The importance of the pre-disaster planning and mitigation process can be measured in a variety of ways. One of them is the amount and quality of the information and assistance provided by the government to implement this legislation. A series of

“How to” guides have been prepared that are available from FEMA, and can be ordered online at http://www.fema.gov/fema/planhowto.shtml. They provide detailed instructions for each step of the process. They also provide recommendations regarding map products, methodology, data sources, software recommendations, and so on. The overall goal of these books is to assist the local government in developing a PDM plan utilizing the best technology they have available. The guidebooks are listed below.\(^6\)

1. *Getting Started* (FEMA 386-1)
2. *Understanding Your Risks* (FEMA 386-2)
3. *Developing the Mitigation Plan* (FEMA 386-3)
4. *Bringing the Plan to Life* (FEMA 386-4)
5. *Integrating Manmade Hazards with Mitigation Planning* (FEMA 386-7)

**Cartographic Guidelines in the How-To Guides**

All of the guidebooks listed above were reviewed during the research for this project. They are written in a manner that provides a step by step process for all aspects of PDM plan development. Every possible category of risk, both natural and man-made, is identified and national maps are included to help the user begin the risk assessment process. In some cases, sample map products are shown. Additionally, subject matter expert resources are included, such as the U.S. Geological Survey (USGS), the National Oceanographic and Atmospheric Administration (NOAA), to assist users in locating additional information and data to determine specific risks and levels of vulnerability.

The cartographic guidelines contained in *Getting Started*, FEMA 386-1, for constructing or obtaining a base map are typical of those found in the remaining volumes. The opening paragraph is noteworthy in that it is written in a manner to accommodate those local governments that do not have a GIS capability. “…you should locate or create a base map so that you can show the areas that are subject to various hazards.”\(^7\)

---


A generic description of a base map and recommendations for content, such as hydrography and roads, is given. Also, other options for base maps, such as road maps and USGS Topographic maps are discussed.  

FEMA 386-1 also strongly recommends the use of Hazards U.S. (HAZUS) software, which is a GIS based risk assessment tool throughout the risk identification and assessment process. This software is distributed by FEMA at no cost. HAZUS was undergoing revision at the time the research for this project was conducted and the newest version, HAZUS-MH was not received in time to be fully evaluated. However, in addition to the evaluation and assessment tools, the software includes an additional data disk. This information is compiled and distributed regionally, so that each user only receives data for their four or five state area. Many different types of data are included, such as demographic information, building stock, medical care facilities, and so on. All of this data can be used for mapping and inventory analysis in the development of PDM plans. One item to note is that HAZUS-MH operates as an extension of ArcGIS 9.1 and requires the Spatial Analyst extension for developing flood models.  

Not every county or reservation in Montana has this capability.


The Mitigation Plan Review Reference Manual is utilized by FEMA personnel when evaluating PDM plans. As such, it is the composite reference of guidelines for PDM cartographic products. In order to accommodate the wide variety of DES mapping and analysis capabilities throughout the country, either inherent within the local governments or the contractors producing the PDM plans, the guidelines are broad in nature. To demonstrate this point, some of the specific criteria are listed here for demonstration purposes. It should also be noted that there are no example map products contained in the plan review guide.

1. Regarding map content, “…A composite map may be provided for hazards with a recognizable geographic extent, such as floods, coastal storms…”

---

8 Getting Started, FEMA 386-1.
9 Getting Started, FEMA 386-1.
2. Regarding scale, “Avoid using state or national scale maps.”

3. Regarding marginal information, “Provide a title and legend as appropriate for all maps.”

4. Regarding data limitations “Note any data limitations for profiling hazards and include in the mitigation strategy actions for collecting the data…”

Some special attention must be given to the notation on data limitations. Many of the PDM plans reviewed in this research contained comments regarding this issue, the impact it had on the planning process, and actions taken to overcome this problem. It should also be noted that one of the overall goals of the CISDM Committee, the sponsor of this project, was to gather and store data related to emergency management. In any case, this directly impacts the local government’s ability to develop cartographic products for PDM plans, regardless of the amount of detail in the guidance.

**Existing Cartographic Products**

One of the first steps necessary to develop cartographic products for PDM plans was to evaluate what was currently being done. The purpose of this section of the report was to discuss this investigation. To accomplish this task, the current status (April, 2006) of county and reservation PDM plans was examined. During this process, it was learned that contractors had produced some of the plans, while others were compiled by the counties themselves. Accordingly, a list of the contractors was acquired, and a sample matrix of the maps contained in the PDM’s was produced.

**Status of PDM Plans**

A meeting with Kent Atwood, of the Montana Department of Emergency Services, revealed at the start of this project that some thirty of the individual county and reservation PDM plans had been completed and approved by FEMA. All of the
The remainder had been compiled and were in some phase of the approval process. The figure provides a graphical representation of the overall status (Figure 3-1).  

**List of PDM Contractors**

There were ten companies identified that had produced county or reservation PDM plans at the time this report was written. Some of them had compiled plans for a number of counties and were actively seeking contracts to produce or review more. It was decided early on that it was not the function of the research team to critique, praise, or otherwise show an affinity for one method or contractor over another. Because of this, the list will not be reproduced here. Suffice it to say that all of the contractor or locally produced PDM plans that were reviewed during the research for this project were approved by the appropriate regulatory agencies and are in use today.

**Matrix of Map Products in PDM Plans**

Twenty county and reservation PDM plans were reviewed during this portion of the project. The focus of this review was to compile information regarding the types and content of the cartographic products they contained. Because of the diversity of the products, a comprehensive list of each map type contained within each county’s or reservation’s plan was compiled. These products were then catalogued and organized into specific categories to better illustrate the types of products that are commonly included in PDM plans. The products are broken down into the following categories:  

1. Base Maps: These are the underlying maps that provide the geographical context for the other layers. They include topographic and aerial photographs, road and transportation networks, and boundary maps of the jurisdiction. 
2. Emergency Services: This category includes maps that depict the locations and networks of emergency services, such as fire stations, hospitals, and police stations. 
3. Hazard Maps: These maps illustrate the areas prone to various types of hazards, such as floodplains, landslides, and earthquake zones. 
4. Evacuation Routes: Maps that identify evacuation routes and shelters. 
5. Mitigation Strategies: Maps that show the implementation of mitigation strategies, such as the placement of flood barriers or the construction of levees. 
6. Other: Additional maps that do not fit neatly into the aforementioned categories.

**Note:**

Montana, PDM plans from all parts of the state were selected. Likewise, every effort was made to include at least one plan from each contractor discussed above. There are significant differences in the number and types of maps contained in the various plans. There are also significant differences in the specific content of similar types of maps. One must keep in mind that this is at least partially due to the different natural and man-made characteristics of the counties and reservations across the state. Also, even when localities have similar characteristics, the perceived needs of the residents may differ greatly in this area. And finally, another reason for the differences has to do with the type of data available for the area. A composite of this review is shown in the following table. For the reasons stated above, the names of the counties and reservations are not shown (Table 3-1).

<table>
<thead>
<tr>
<th>A Composite Index of Maps Contained in Ten PDM Plans</th>
<th>Number Included</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location Map of Some Type</td>
<td>10</td>
</tr>
<tr>
<td>Fire Hazards of Various Types</td>
<td>8</td>
</tr>
<tr>
<td>Flood Hazard Maps of Various Types</td>
<td>7</td>
</tr>
<tr>
<td>Risk Associated With Earthquakes</td>
<td>7</td>
</tr>
<tr>
<td>Building Stock Dollar Exposure by Census Block</td>
<td>6</td>
</tr>
<tr>
<td>Total Societal Vulnerability by Census Block</td>
<td>5</td>
</tr>
<tr>
<td>Transportation Hazards by Census Block</td>
<td>5</td>
</tr>
<tr>
<td>Cumulative Hazard by Census Block</td>
<td>5</td>
</tr>
<tr>
<td>Various Types of Landcover and Vegetation</td>
<td>3</td>
</tr>
<tr>
<td>Location of Fire Stations</td>
<td>2</td>
</tr>
<tr>
<td>Location of Medical Facilities</td>
<td>2</td>
</tr>
<tr>
<td>Location of Law Enforcement Facilities</td>
<td>2</td>
</tr>
<tr>
<td>Location of Railroads</td>
<td>2</td>
</tr>
<tr>
<td>Annual Precipitation</td>
<td>2</td>
</tr>
<tr>
<td>Land Ownership by Type</td>
<td>2</td>
</tr>
<tr>
<td>Energy Production Infrastructure</td>
<td>2</td>
</tr>
<tr>
<td>City Inset Maps of Various Types</td>
<td>2</td>
</tr>
<tr>
<td>Dam Locations</td>
<td>1</td>
</tr>
<tr>
<td>Location of Airports and Heliports</td>
<td>1</td>
</tr>
<tr>
<td>Location of Major Bridges</td>
<td>1</td>
</tr>
<tr>
<td>Population Density by Census Block</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3-1, Composite of Maps in PDM Plans
Interviews with DES Personnel

The short-term nature of this project required that assimilation of the needs and concerns of the various people and agencies involved in disaster and emergency services be established as quickly as possible. The primary focus of this assimilation was to determine what types of map products would be most useful to the county or reservation in the pre-planning and mitigation portions of the disaster response cycle. Accordingly, a simple plan for interacting with DES Personnel was derived to achieve this end.

1. **Attend Appropriate Conferences.** During the course of the research, several conferences were attended throughout the state. Handouts containing contact information and a description of the project were distributed as widely as possible during each conference. Contact information was compiled for follow up meetings and phone calls. As they became available, officials were shown map products for inspection and comment. The major conferences attended were the Governor’s Emergency Preparedness Summit in May, 2006, the Montana Association of County Officials annual conference in September, 2006, and the Montana Association of Geographic Information Professionals Technical Session, also in September, 2006.

2. **Participate in Disaster and Emergency Services Exercises.** Participation in DES exercises was determined to be important for two reasons. First of all, the research team would gain a familiarity with how the DES process works. Secondly, some insight would be gained regarding potential map products and analysis that could be developed prior to the disaster occurring. The results of this process are discussed below.

3. **Contact DES Professionals Directly.** The CISDM committee prepared a letter of introduction that was distributed to DES officials at county and district levels throughout the state, thus allowing us to contact them as needed. A number of DES professionals were contacted at the federal level as well. Many informal interviews were conducted during the progress of the research.

4. **Contact Subject Matter Experts.** Experts in the various types of hazards were contacted in almost every subject area. These included officials at the local, state, and federal level. Meetings were also held with private contractors who had produced PDM plans for various counties in Montana. Additionally, several subject matter experts associated with the University of Montana were utilized.

5. **Get Feedback From CISDM Committee Members.** The CISDM Committee was the reviewing authority for the project. The results of the investigation
were presented to the committee for review at key points during the research in order to ensure it was progressing in the desired direction.

This basic plan worked well throughout the project research. A rough outline of the final report, along with a sample map package for one of the natural hazards was developed by July, 2006, and presented at the monthly CISDM Committee meeting. With minor modifications provided by the committee, these items served as the guidelines for the completed project.

**Disaster and Emergency Exercises**

The final Statement of Work for this project was signed and approved on June 1, 2006 of this year. However, since a limited number of these exercises are conducted each year, it was determined that participation in meetings and exercises was necessary prior to this point in time.

The first such exercise was called Northern Exposure and took place during February of 2006. The scenario was a pandemic flu outbreak in five counties in north-central Montana. GeoData Services, Inc., of Missoula, Montana, supported this exercise remotely and it was observed from their office. Additionally, various exercise reports and critiques were reviewed upon completion of the exercise.

A second exercise to be conducted at the State Government level in Helena, Montana, was scheduled for May, 2006. The scenario for this exercise was a large earthquake event that destroyed many of the state, local, and private facilities in the area. Unfortunately, the exercise was postponed until September, which prevented participation. This was not problematic in the sense that the research and work accomplished by then had matured significantly and the overall direction approved by the CISDM Committee.

**Project Literature Review**

This project required literature research in a number of areas. First of all, various publications on cartography were reviewed to identify those concepts, principles,
methods that were appropriate for building maps for pre-disaster mitigation plans. Secondly, several publications specifically covering methods of incorporating GIS into disaster response and homeland security were studied. Also, two ESRI online courses were completed in this effort. And finally, publications providing information on the science behind mapping and understanding each of these types of disasters were examined. Each of these categories will be discussed in detail.

**Cartography Publications**

The book *Elements of Cartography* by Arthur H. Robinson and others was the basis for study in this area.\(^\text{13}\) This textbook is a classic in the field of cartography and covers all of the cartographic principles and elements discussed in the next section of this thesis. These are enduring, whether the map is drawn by hand or produced digitally. Another textbook consulted in this project was *Thematic Map Design* by Borden D. Dent.\(^\text{14}\) This publication has become the foundation work of thematic mapping. The third textbook cited in this work was *Making Maps, A Visual Guide to Map Design for GIS* by John Krygier and Denis Wood.\(^\text{15}\) This book provides more up to date information specifically focused on using GIS software for making maps. It also outlines fundamental questions that need to be answered before making any map in order to provide focus for the work.

**Disaster Related Publications and Courses**

The two primary publications utilized in this area were *Confronting Catastrophe, A GIS Handbook* by R. W. Greene\(^\text{16}\), and *GIS for Homeland Security*, by ESRI Press.\(^\text{17}\) The publication by R. W. Greene focused primarily on natural hazards and was especially helpful. First of all, it outlined various methods for utilizing GIS in each of the disaster cycle steps. Although this report primarily focuses on cartographic products to be used during the planning and identification, and the mitigation processes, important insights

---


were gained from the other sections. Sources of data and potential problem areas were covered in detail. Other types of useful software and ArcGIS software extensions were also introduced and discussed.

The ESRI publication focused more on the area of man-made disasters. The process of geographic decision-making was introduced and explained in detail. The importance of building a local foundation of GIS data and then sharing it with all levels of government was stressed throughout the book. Also, various large-scale data models were portrayed. Both of these books were important in that they were easy to understand. It also contained extensive glossaries, sources of additional information, and provided detailed examples of what is being done currently in this area of GIS.

A third publication utilized was *Disaster Response, GIS for Public Safety* by Gary Amdahl.\(^{18}\) This book was very helpful because it contains numerous step-by-step examples of modeling and analysis of actual disaster situations from around the country. Additionally, the examples covered both pre-disaster risk assessments, how GIS can be utilized for assessing response methods during a disaster, and for post disaster analysis.

In addition to the above, two online ESRI courses were completed as part of the preparation for this project. The first was *Spatial Analysis of Geohazards Using ArcGIS 9*.\(^{19}\) This course was devoted entirely to the area of natural hazards. Of the five hazards covered in the course, four commonly occur in Montana. Detailed introductory information was provided for each as concerns their causes, characteristics, and potential damage. The various terms and methods of measurement for each were explained in detail. Data manipulation, analysis, and map building were integral components of each segment of the course. Moreover, references and sources for additional data and information were provided.

The second course, *Solving Disaster Management Problems Using ArcGIS 9*, was a direct compliment to the first, and would be an invaluable experience to anyone working in this area.\(^{20}\) While much of the course focused on the response and recovery

---


portions of a disaster: planning, risk assessment, and mitigation were covered as well. More importantly, the course walked the student through the complete disaster cycle, demonstrating a variety of ways that a robust GIS program can assist communities in performing disaster related activities.

**Other Publications**

The publication *Natural Hazards and Disasters* by Donald and David Hyndman was so helpful that it has a category of its own. The two authors are both professors of geology at the university level and have earned numerous awards in their field of study. This text discusses virtually all of the natural disasters that occur in North America. The large and small-scale natural processes, along with man-made influences, are covered in a simple but effective manner. Various public policy issues and options are put forth as well.

**Results**

Many of the cartographic products contained in the PDM plans reviewed were very good. The content was portrayed in a manner that could be easily understood by anyone, whether familiar with the area or not. Because of this, several of the templates presented in this report utilized methods, ideas, or data sources developed in these plans. Additionally, the process of reviewing these plans enabled the research effort in developing at least two general criteria to use in this work.

The first was to focus as much as possible on cartographic templates that work best when used at the county or reservation scale. Likewise, the content and purpose of each template would be based whenever possible on the stated desires of local officials.

The second concept was initiated during the review process and matured during subsequent research. There are a number of other government programs in existence whose aims are complimentary to those of the PDM plan process. An example was the development of the Community Wildfire Protection Plan, which is discussed in detail in the section titled *Templates for County Pre-disaster Mitigation Plans*. Most of these

---

programs have their own cartographic requirements and processes. Because of this, it was determined not to duplicate those efforts here. Rather, they were referenced when appropriate and complimentary map templates were developed.

The results of the review and research process are contained in the section titled *Templates for County Pre-disaster Mitigation Plans*. The cartographic templates developed are divided into groups similar to those in most of the PDM plans. This was done for organizational purposes, with no suggestion of relative importance intended. In many cases, a secondary purpose of the individual template was to demonstrate the general type, or content, of map that could be created. This was especially true when using Computer Assisted Mass Appraisal (CAMA) data. In all cases, individuals involved in the PDM plan development process should decide which maps would best serve their needs.

**Section Summary**

This section begins with an examination of the legal standards and associated “How to” guides for the development of PDM plans and the cartographic products they contain. Following this is a discussion of the investigation of existing plans and breakdown of the maps they contain. Additionally, the results of interviews, participation in DES exercises, and the project literature review are outlined. The following section will discuss those cartographic principles that pertain directly to PDM map products.
CARTOGRAPHY FOR PRE-DISASTER MITIGATION PLAN MAPS

Since the template maps built and described in this project are designed to be models for many different cartographic products, the cartographic principles, concepts, and methods involved in their creation should be discussed at least briefly. Many of the template maps embody these concepts and methods in ways that are easy to overlook when striking out to build maps for counties or Indian reservations other than those described in this document. The purpose of the following section is to provide a brief summary of the most critical cartographic topics that are of concern. While these topics are not a glossary, they are given subheadings so that they can be easily found when questions arise while building the actual maps that will go into pre-disaster mitigation plans.

Format

Format concerns the manner in which the map is placed on the printed page of the plan. To date all of the pre-disaster mitigation plans for Montana have been prepared on 8 ½” X 11” paper, so the following remarks assume those dimensions (Figure 4-1). Standard margins for text and figures on 8 ½” X 11” pages are 1” on each side except for the side that is to fit into the binding of the report, which should be 1 ½”. This means that all of information of the map must fit into the 6” X 9” area that remains. This is the format area.

The map can fit into this area in one of three ways, in portrait format, landscape format, or as part of a page. In portrait format, north or “up” on the map will point toward the top of the page. Since it is possible to orient the map in directions other than north at the top, “up” refers to the orientation of text on the map in the readable position. In landscape format, north or up points toward the binding margin. This way the map is in the position closest to the reader when the book is rotated for reading. Maps can also
be placed on part of a page with text either above, below or surrounding them. In this instance, north or up always points toward the top of the page.

**Map Components**

Two general components are found in a completed map—the mapped area and the marginal information. The mapped area is the specific geographic area that is the subject of the map. As regards pre-disaster mitigation plans, the area will be either the county or the Indian reservation that is involved. However, there may be cases where the subject matter of the map is such that only a part of the county or Indian reservation is mapped. In other cases, an area larger than the county, perhaps even the entire state, may be needed. The marginal information is all of the printed and graphic information that is placed outside the mapped area and act in support of it. This would include items such as the map title, legend, scale, etc. Both the mapped area and marginal information are discussed more in detail in the sections that follow.

**The Mapped Area**

Since this is the subject or focus of the map, the mapped area should be given a position of prominence in the layout area. In order to preserve the best scale possible, it should be as large as can be while still preserving adequate space for all of the marginal information that must surround it. It should be positioned with an eye toward artistic balance among all of the components of the map. Balancing items around an optical center of the map somewhat similar to balancing is a lever on a fulcrum (Figure 4-2). The size of the objects being balanced is not as important as is their visual weight, which is a matter of perception. In the figure, A and C are balanced.

![Figure 4-2, Balance map elements as on a fulcrum.](image)
Mapped areas come in several types depending on the kind of map being made. The types that are germane to pre-disaster mitigation plans include location maps and thematic maps. Location maps are general-purpose maps that serve to show the location of a wide variety of features. In the case of location maps for disaster and emergency services, layers that are particularly important include topography, hydrography, transportation facilities, towns, landmarks, and some historical features. Thematic maps are needed to display critical structures and infrastructures, at-risk populations, potential hazards, the location of existing emergency facilities, and the like.

As these and other features appear in the mapped area they take on two forms—map symbols and text or annotations (Figure 4-3). Together, these comprise the stuff that makes the map. Symbols are conveniently subdivided into point, line, and polygon features since these agree with the topological structures. Annotations are mostly delivered as attributes to features that are otherwise symbolized on the map, although spurious annotations can be added that have no actual connectivity to the data being mapped. In the following discussion, map symbols will be examined first and annotations second. Different principles apply to point, line, and area symbols, so they will be dealt with separately.

There are two types of feature point symbols, geometric and mimetic. Geometric point symbols are entirely abstract symbols consisting of dots, circles, triangles, squares, etc. (Figure 4-4). Since there are a virtually limitless variety of such geometric symbols, finding ones that are distinguishable should be easy. The problem with geometric point symbols is that their appearances are seldom suggestive of the feature being represented.
Mimetic point symbols are those that we naturally associate with their feature attributes (Figure 4-5). They are more desirable on location maps than geometric symbols when they are unambiguous and easy to understand. However, some mimetic symbols are so intricate or obtuse that it is difficult to differentiate among them (Figure 4-6). But well-chosen mimetic symbols can provide a very effective means for presenting point information on a map.

Line feature symbols also come in two varieties, visual variable shape and visual variable size. Here are some examples of lines of differing visual variable shape (Figure 4-7). Again the variety of lines of this type is great. The concern is to choose symbols that are easily distinguishable.

In the case of visual variable size, the lines are solid, but the width is adjusted. Adjusting the visual variable size of line symbols is an excellent way of emphasizing or de-emphasizing line features on the map. The method not only contributes to the clarity of the map, but it adds visual drama, making the map more interesting to look at. The width of lines should match the hierarchy of importance of the features they represent (Figure 4-8). The circled areas on the line variable width diagram identify good choices that will produce map areas that are crisper and more interesting than those with lines of less contrast (Figure 4-9).
Visual variable size and visual variable shape can be used in combination to clarify maps that have particularly complicated varieties of line symbols. Area symbols need contrast just as much as point and line symbols if not more. There are three major categories of area symbols—screen tints, patterns, and colors. Each has its own set of advantages and problems so far as visualization is concerned.

Screen tints translate into shades of gray or monochromatic graded color. In pen-and-ink cartography, screen tints were actual film sheets filled with black dots on a clear background or clear dots on a black background, all the same size arranged in a rectangular pattern (Figure 4-10). The same arrangement is done with the computer today, except film is not used. Each screen tint is specified by its percentage and its ruling. The ruling is the number of lines per inch. In traditional cartography screen
rulings of 65, 86, 100, 120, 133, and 150 lines per inch were commonly used. Today the computer sets the ruling in lines per inch. A 65 lines per inch screen is considered coarse since the individual dots can be seen with the naked eye, while a 150 lines per inch screen is considered fine since no pattern is visible and only smooth tone results.

Screen tints are ordinarily in 10% increments. It is a matter of perception that the eye is able to discern better between the lighter tints than the darker ones. This has the effect of substantially reducing the number of usable screen tints for any one map. Five or six tints are the maximum number that can be used even with black and white employed.

Repetition of basic graphic elements (marks) produces an areal graphic effect called “pattern.” Pattern exhibits the characteristics of arrangement, texture (spacing), and orientation (Figure 4-11).

Texture—refers to the size and spacing of the component marks that make up a pattern.

Orientation—refers to the directional arrangement of parallel rows of marks of the pattern.

Arrangement—refers to the shape and configuration of the component marks of the pattern.

Figure 4-11, Pattern characteristics.

It is possible to increase the number of identifiable classes considerably by using patterns as opposed to screen tints. The samples shown in the figure give numerous identifiable patterns, and more would be possible (Figure 4-12). The trouble with
patterns is that they are often mono-tonal and require a lot of attention on the part of the map-reader to ferret out geographic distributions. Since the ability to distinguish depends upon the pattern rather than the relative darkness or lightness, pattern combinations can occur that are bland (Figure 4-13). A careless choice of pattern can entirely alter the effect of the map.

Color is the third category of area symbol. Color extends the graphic limits (types of media) of area symbol mapping to the extreme. Figure 4-14 shows eight different color schemes, each employing seven different color classes that could be used in mapping (Figure 4-14). This diagram is from a web page created by Cynthia Brewer titled ColorBrewer (http://www.personal.psu.edu/faculty/c/a/cab38/ColorBrewer/
Figure 4-14, Color schemes from *ColorBrewer.*

colorBrewer_intro.html). It is one of the most useful devices for helping to choose colors for maps that have been created to date. Numerous pre-designed color combinations have been made that can be worked with interactively to change the number of categories, choose sequential, diverging, or qualitative legend designs, and to evaluate the usefulness of the choice for various types of maps and media.

Much more can be accomplished if color can be employed in the creation of either location or thematic maps than if the work is limited to either screen tints or patterns. More categories can be shown, the maps are easier to read, and the product is more attractive. The disadvantage of color is the increased cost of printing. This is true regardless of the media employed—color computer printer, Xerox, offset press, or what have you.

The mapped area would not be complete without annotation or text. Similar to the other marks on a map, text is a symbol. It may not be as direct in showing the location of features as the other symbols, but its manner of symbolism is actually more complex. Text can be used as a literal symbol, a locative symbol, a nominal symbol, or an ordinal symbol.

*Literal symbol.* When text is used on the map to name features it is used as a literal symbol. This is perhaps the most useful purpose for having lettering on the map. Features without names are generic; the process of naming them individualizes them.
**Locative symbol.** Text can also function as a locative symbol. First, by its position, it helps to indicate the location of points (for example cities or towns). Second, its spacing can be used to show linear or areal extents (mountain ranges or oceans). When use to help locate area symbols, the lettering is usually spread out across the areas. For linear symbols, the letters are grouped into words, but the words are repeated along the feature (See Figure 4-3).

**Nominal symbol.** By systematically using design attributes, such as upright or italic, serif or sans serif, bold or light faced, and color, the type of lettering can be used to show nominal categories of features. For example, lettering in blue might show hydrographic features, and within that category, open water might be lettered with upright letters and running streams with italic letters. The lettering for county seats may be underlined, while other towns are not.

**Ordinal symbol.** Text can also serve as an ordinal symbol on the mapped area, showing hierarchy among geographical phenomena. Varying the size, tone, boldness, or choice of uppercase or lowercase letters might accomplish this. This would allow features to be ranked with respect to size, importance, productivity, and so on. For example, all uppercase letters might be used for cities and lower case with initial capital letters for towns.

Because of the many functions of lettering, the topic needs to be learned by mapmakers. Choosing type as a symbol on the map should employ the same rigor as choosing all other symbols. Choice of the text needs to be incorporated into the objectives of the map similar to the choice of any other symbols. Following are some cartographic principles for using text on the mapped area:

1. Names should be either entirely on land or on water—they should not cross over between the two.
2. Lettering should be oriented to match the orientation structure of the map (Figure 4-15). On large-scale maps, this means that type should be parallel with the upper and lower edges of the map; in small-scale maps, type should be parallel with the parallels of the graticule.
3. Names of rivers should parallel the course of rivers; contour numbers should split the contour lines.
4. Names should be letter-spaced as little as possible. That is there should not be wide spaces between the letters in a name. The only exception to this rule is when names of mountain ranges or other map areas are spread to show the location of the range or the other area.

5. Where the continuity of names and other map features, such as lines and tones, conflict with the lettering, the map features, not the names, should be interrupted.

6. Lettering should never be upside down.

7. Names for points should be positioned according to the following set of priorities (Figure 4-16).

[Diagram showing priorities for lettering point symbols]

Figure 4-16, Priorities for lettering point symbols (1 is high, 8 is low).

It may help to see examples of a correctly lettered map as opposed to a poorly lettered map. An example of a correctly lettered map is shown below (Figure 4-17).
**Base Layers**

Base layers (sometimes called framework layers) are those collections of features that would be included in the mapped area that would give the map enough structure that the map-reader can determine where things are located. For a map of Montana, the base layers might include the counties, stewardship lands (National Forests, National Parks, State Parks, BLM Land, etc.), towns, major transportation routes, hydrography, and the like. County maps provide special challenges when choices are made when deciding which base layers to include because the area is smaller and there are fewer types of features that provide good locational frameworks. County administrative sub boundaries include such things as wards and voting districts or census tracts, block groups, and blocks, none of which are familiar enough for map-readers to use for locating other geographic features such as emergency facilities, critical structures, or potential natural or man-made hazards. Even the graticule for longitude and latitude or township and section boundaries of the Public Land Survey System are of little help. Base layers that are of help, however, include things like topographic information (shaded relief and contours), hydrography (streams and water bodies), and transportation features (roads, railroads, transmission lines, pipelines, etc.). These layers are more useful to the map-reader at the county level because they consist of features that can be actually seen in the landscape.

Particularly in mountainous western Montana, topographic information is useful. Either contours or shaded relief, or a combination of the two can be used (Figure 4-18).
Shaded relief and contours may not work well as a base layer for all maps. This is true particularly regarding thematic maps that carry a lot of detail such as census blocks or land ownership. The various tones of gray in the shaded relief may mix with the various chloropleth colors used to fill the areas making them appear darker in places and lighter in others, thus interfering with the map-readers ability to interpret the map.

Hydrography is another layer that can make a useful base layer on the map. To get all hydrographic features actually involves adding two layers to the map—the water bodies layer and the streams layer. At present, the National Hydrographic Database (NHD) is the best source for this data. The hydrographic layer is critical to a location map. Partly, this is because streams, lakes, and rivers are such prominent landmark features in the landscape. But importantly, it can be an essential framework layer on the base map that helps map-readers to determine locations. If all of the streams are kept, they tend to crowd location maps at the county scale. This may make it necessary to eliminate some of the lowest order streams when they are classified and leave them off of the map (Figure 4-19).
Transportation makes a very useful base layer for county scale maps since almost all map-readers from the local area are familiar with the layout of roads and railroads. This layer should be used even if shaded relief is present since it allows map-readers to pinpoint locations on the map very specifically. If all of the roads are included in this layer, the possibility exists that they may overwhelm the map, particularly in western Montana where the Forest Service has built so many roads to access forested lands (Figure 4-20). Once the attributes of the road layer have been used to classify the roads and once the Forest Service roads have been omitted, the road layer makes a very useful framework layer for helping the map-read to determine the position of things on the map (Figure 4-21).

At the county scale, towns are problematic since the road features are compressed together to the point that the lines run together as a blob. The obvious solution is to map urban area polygons over the streets and roads. The problem is that many Montana counties do not have towns large enough to be classified as Urban Areas by the Census Bureau, and as a consequence the convenient polygons created by that organization for
larger towns are missing. The recommended solution is to group census blocks over the streets of the smaller towns, and then dissolve them into urban areas (Figure 4-22).

Undoubtedly, more base layers could be added to the map; however, the most common mistake made with most location maps is to load them with too much information. Additional information is all right until the point is reached that it interferes
with the ease of reading. The best plan is to build the map to suit the map-reader’s purpose.

**Base Layers for Thematic Maps**

On occasion, certain layers of information will have to be added to the map that are too detailed or too complex to be added to the base layers of the location map. In these cases, thematic maps will have to be built. Thematic maps are maps that concern a certain specific topic or theme. The principles for including base materials on thematic maps are different that those for location maps. Of course, the rule for location maps is to put as many layers on the map as would be useful to the map-reader but at the same time not interfere with the readability of the map. The principle for thematic maps is to include only the minimum amount of base information on the map that will allow the theme to be located and interpreted correctly. This way the attention of the map-reader is directed toward the thematic topic of the map and away from the base information.

Mapping thematic information on county-level maps presents special challenges since no easily recognizable administrative sub-units exist. When mapping at the state level, the county layer can be used as the framework for supporting thematic information. At the national level, the state layer can be used. Unfortunately, a parallel does not exist at the county level. It would be possible to use the township layer from the Public Land.
Survey System (PLSS). However, very few people are familiar enough with the PLSS, even county residents, to use it as a locational framework (Figure 4-23).

As it turns out, the transportation network layer is the best locational framework that can be used for county thematic maps. It would be possible to use the hydrography layer, but not all people who live in a county have learned the names of even a majority of the streams and lakes found there. Topographic information (contours or shaded relief) is helpful in some situations but can interfere with some types of thematic symbols. To a great degree, the type and variety of framework layers that can be used depends on the type of thematic symbols being used. In general, thematic point symbols leave space-rich maps (the exception being dot maps). More base layers can be included, and may need to be included, to allow them to be adequately interpreted. In the case of the CISDM research project, mapping critical structures leaves lots of room except in towns and cities. Following is the Critical Structures map for Sanders County (Figure 4-24).
The point symbols not only work well with the various base layers that are included in the map, but they enhance the topic by providing critical locational information. The only problem is that the symbols tend to pile up badly in towns to the point that some of them are hidden altogether (Figure 4-25). This problem can be partially resolved by breaking the critical structures into their functions and mapping one function at a time as is shown in the Emergency Shelters map below (Figure 4-26).
But even in these cases some overlap may exist (Figure 4-27). The best solution has been to create inset maps for the individual towns and cities. In this instance, the decision has been made to use stacked symbols that will allow all of the functions to be displayed at one time, a method that eliminates a lot of the separate map sheets needed in order to map one type of critical structure at a time (Figure 4-28).

Figure 4-26, Emergency Shelters of Sanders County.

Figure 4-27, Stacked functions.
Thematic line symbol maps are still space rich, but less so than point symbol maps. As it turns out, there are not a lot of critical structure or infrastructure layers that get mapped thematically as lines or flow arrows in the project. Even where the principal theme is lines, such as roads, the critical information often gets mapped as points, not lines. For example, one of the critical infrastructure features for the transportation layer is the bridge layer. However, when bridges are mapped at the county scale they are mapped as points, not lines (Figure 4-29). In the case of the map of bridge capacities, it seemed reasonable to leave both the roads and the hydrography as base layers since both were germane to the topic.

Area thematic symbols mostly tend to leave the map, space poor. In general, the fewer base layers included the better. When the area symbol maps are presented in the form of choropleth maps, it is possible to use the boundaries of the choropleth units as the base layer. This is certainly a possibility as concerns maps employing census data. But other interesting possibilities exist. The problem is that boundaries of census areas mean little to most map-readers other than census takers. Instead of using the census boundaries, why not leave the boundaries out, let the choropleth colors end where the missing boundaries would be otherwise, and use the roads layer as the base layer instead? The map that follows of Hill County has employed this technique (Figure 4-30).
Figure 4-29, Capacity Rating of Bridges map using point symbols.

Figure 4-30, At-Risk Populations, Hill County, Montana.
The map concerns the part of “at-risk population” that is sixty-five years and older. Other maps would display the very young populations. Since the Census Bureau often used roads for the boundaries of their census areas, many of the Census Blocks appear to be bounded. But that is not always the case. There are many areas where the choropleth colors change without a road being present. Most map-readers would not even notice that the census area boundaries were missing (Figure 4-31).

Since choropleth maps are being dealt with it should be pointed out that some of the most common mistakes concerning thematic maps have to do with choropleth maps and most of these have to do with the ways data is handled. The choropleth technique should be selected only when the form of data is appropriate. Typically, and appropriately, they are constructed using discrete data that are summarized for enumeration units. For example, area units used by the Census Bureau or administrative political subdivision areas such as those for cities, counties, school districts all work correctly. On the other hand, geographic phenomena that are continuous in nature (weather patterns or elevations) should not be mapped by the choropleth technique because their distributions are not controlled by political or administrative subdivisions.

Enumeration data for choropleth maps may be of two kinds—total values and derived values. The number of people living in a census tract is an example of a total value. The number of people is totaled to produce the value. Average annual income
conversely, is an example of a derived value. Incomes for all of the people are totaled and then averaged in order to produce the value. It is not acceptable to map total values when using the choropleth technique. One of the principals of cartography is, “**Never use total values for choropleth mapping.**” The reason is that in most choropleth mapping situations, enumeration areas are not the same size. The varying size of areas in conjunction with their mapped total values will alter the impression of distribution. In the case of the example below, the larger of the two areas would be mapped with a darker shade indicating a higher degree of concentration than the smaller area if their total were used (500 persons as opposed to 100 persons). This would happen even though the densities of population in each of the areas were the same (10 persons per square kilometers). Actually the two areas have the same degree of population concentration and thus should be mapped with the same fill symbol (Figure 4-32). Mapping with data totals masks the even densities because the areas are of unequal size (the first panel). Mapping with derived values allows the map-reader to see that the densities are the same even though the sizes of the areas and the number of people are different (the second panel).

![Figure 4-32, Choropleth mapping must be done with derived values.](image)

**Marginal Information**

After the mapped area, the second component of the map is the marginal information. Marginal information is all information included in the design of the map that appears outside the mapped area. Usually, the marginal information is confined inside the boarder of the map if a border is used; otherwise it is confined to the area reserved for the format of the map. In this regard, marginal information must not be
allowed to penetrate the margins of the page. Marginal information includes items such as borders, titles, legends, graphic scales, representative fractions, north arrows, and notes and credits. Each of these topics will be dealt with briefly.

**Borders and Neatlines**

Neatlines and borders are not the same thing. The neatline usually encompasses the outside edge of the mapped area, or the area reserved for it. The border encompasses both the mapped area and the marginal information; it usually (but not always) coincides with the format area.

A neatline is a fine line that provides a definite frame or edge at which the various elements of the mapped area terminate. Neatlines are not always necessary—it is up to the cartographer to decide if and when one is needed. It is possible to simply to terminate the map along an edge without having an actual bounding line. It is also possible to have the map run completely off the page, so the edge of the page itself is the termination line. This unusual treatment is called a “bleed.”

A border is an additional line or set of lines, drawn outside the neatline and usually parallel to it. It is usually heavier than the neatline and may range from a simple single, solid line to a complex treatment of decorative lines. While there are many styles of borders that can be made, the tendency in modern cartography is to use relatively simple ones (Figure 4-33).

Figure 4-33, Examples of map borders.

One special type of border that is useful consists of alternate black and white bands. When properly used, the change in color indicates the graticule spacing. A banded border of this sort is particularly useful for navigational charts or location maps since it highlights the lines of latitude and longitude.
Neatline and border arrangements may be drawn to accommodate the numerals for longitude and latitude in a variety of ways. For example, numbers can be placed either inside or outside the neatline (Figure 4-34).

Figure 4-34, Longitude and latitude placement relative to the neatline.

Map Titles

Map titles must be complete and accurate. If they are not, there is a real risk that the map-reader will be misled regarding the content of the map. At a minimum, the title should identify the region being mapped. On thematic maps, information about the topic displayed and the date of the data are usually needed.

There is, however, an opposing need to avoid using excessive amount of map space for titles. Thus an economy of words is desirable. For example, there may be circumstances, such as when the map appears in a book or an article about a specific topic, in which the context makes it unnecessary include some information. Including the name of the county on every map that appears in a pre-disaster mitigation plan would be undesirable.

Titles are generally the most important of the marginal elements and should therefore have the largest font size and be placed in a prominent position. Parts of the title can be subordinated if desired and then assigned smaller font sizes. In the figure that appears below, the subject of the map is population density, thus the region and the date are subordinated (Figure 4-35).

Montana
POPULATION DENSITY
2000

Figure 4-35, Parts of a title subordinated.
Spacing, font sizes, and position for titles all need to be considered by the map designer. When three lines of type are used, and the middle line is the largest, the lower line must be a bit smaller than the top line if it is to appear the same size. Concerning letter spacing, there is an actual cartographic principal involved (Figure 4-36). “

Lines consisting of letters of the same size in the same arrangement must, under all circumstances have the same letter spacing.”

Figure 4-36, Do not vary letterspacing of titles.

Either centered, left justified, or right justified can be used depending on the overall design of the map (Figure 4-37).

Figure 4-37, Titles can be either centered, left justified or right justified.

There are no set rules regarding where map titles are to be placed. Regardless of the location, the title should be given the highest visual priority of all of the marginal map elements (Figure 4-38).

It is hard to generalize about what information should go into a title. It depends entirely on the map, its subject, and its purpose. However, it is a good rule to only place information in the title that is necessary for the map-reader to comprehend its purpose. If
the map appears in a report, such as the pre-disaster mitigation plans discussed here, much can be left out since the location of the mapped area and possibly even the date can be left out since they are made obvious from their context.

Map Legends

Legends are indispensable to most maps since they explain the symbols and the ways in which the data was manipulated in making the map. In theory, any map symbol that is not self-explanatory should be explained in a legend. In practice, cartographers take a great deal for granted when creating a map legend since it is assumed the map-reader is knowledgeable. At least, we should be able to assume that the map-reader will be familiar with the general concepts and practices of using maps.

Still creating legends must conform to some set standards. When symbols are included in the legend, they should appear exactly as they look on the map, produced in precisely the same size and manner. If an analogy between map symbols and language is accepted (map symbols are the language of maps), legends are like dictionaries. In that case, the symbols should come first, and their explanations second as words come first in a dictionary and their definitions second (Figure 4-39).

Figure 4-39, Place symbol definitions to the right of the symbols.
The arrangement of parts of a legend, such as the series of color patches or point and line symbols, needs our attention. When there is an array of values, they should be displayed in order. Whether the highest value is placed at the top or the bottom is the cartographer’s choice. The map topic may suggest the order. If the legend is arrayed horizontally, care must be taken to see that the symbols and definitions are clearly paired (Figure 4-40).

The items making up a legend should also be positioned so as to achieve visual balance. In the case of complex legends, items should be grouped into logical categories (political boundaries, hydrology, transportation, thematic, etc.).

### Inset Maps

Small areas inside the border of the map that are set aside to hold an additional map are called “inset maps.” There are three instances when inset map are used: 1) First, when a small-scale map is needed to show where the principal map area is located. 2) Second, when there is so much detail in a portion of the main map that it is necessary to enlarge that area. 3) Third, when there is a protuberance of the main map that hampers its display of the entire map at an adequate scale. In the first case, the inset map is at a smaller scale than the principal map. In the second, it is at a larger scale. In the third case, the map is ordinarily at the same scale as the principal map so that both parts are comparable.

Inset maps need to conform to the same rules and practices as the principal map. They need to be centered on their central meridians. They should be given a scale,
particularly if it is important to interpreting the information of the map. They should be given appropriate neatlines in order to separate them from the main map and the rest of the marginal information.

**Map Scales**

There are three types of map scales: representative fraction, verbal, and graphic. Representative fractions are ratios or fractions that describe the relationship between the map and the world. An example would be 1:24,000 or 1/24,000 where one unit of measurement on the map represents 24,000 of the same unit of measurement on the ground. Verbal scales are oral expressions of the relationship, for example, “One inch represents one mile,” or alternatively, “A one-inch map.” Verbal scales are not usually employed on maps, but they are used to describe maps in conversation. Graphic scales are drawn devices on the map that display the scale in pictorial form (Figure 4-41). Map units are

![Figure 4-41, A graphic scale.](image)

The advantage of representative fractions is that they work for any units of measurement—miles, feet, meters, kilometers, etc. The units must be defined for graphic scales, but the advantage is that the map and the scale can be enlarged or reduced together without affecting the accuracy of the scale.

Most general location maps and virtually all thematic maps employ graphic scales. Usually, if the map does provide a representative fraction, it will also have a graphic scale. Graphic scales are more functional than representative fractions. There are a large variety of styles of graphic scales from which to choose (Figure 4-42).
North Arrows

North arrows have been used on maps since the Middle Ages. Originally, they tended to be very ornate, matching the elaborate artwork of the maps of the time. North arrows of this type are called “compass roses” (Figure 4-43). A few years ago, the cartographer was on his or her own when it came to creating north arrows. Now, one can find entire type fonts devoted to them (Figure 4-44). Choosing a north arrow for a map is similar to choosing the style for a graphic scale. It should suit the function and design of the map.

Figure 4-42, Different styles of graphic scales.

Figure 4-43, Compass roses.

Figure 4-44, Entire type fonts are devoted to north arrows.
The purpose of north arrows is to indicate which way is north on the map. This is more complicated than it first sounds, particularly in the event of maps that have been projected with meridians that are oriented in several different directions. In that event, the north arrow should be oriented with the central meridian, and that meridian in turn should be oriented with the page.

North arrows are useful for map areas that might not be well known by all map-readers. They are essential for maps that are not oriented with north toward the top of the page. However, in most instances, the use of the north arrow is optional. If the area is recognizable to virtually all prospective map-readers, they will be able to correctly orient the map without any aid. Only in those instances where there is uncertainty is the north arrow required.

Notes and Credits

There are no limits set for notes and explanatory text on the map. Sometimes, however, the legend and other marginal information are insufficient to explain about the map. Notes, graphs, and even tables can be added as necessary. The principle involved is that the map is a communication device, and the cartographer is the communicator, and thus is responsible for what can be gleaned from the map.

Credits fall in to two types—those given to others and those that refer to the cartographer. Credit to others fall in the realm of citing sources when necessary. Much of the geographic information compiled as base data—such as coastlines, rivers, transportation networks, and administrative boundaries—may be classed as general knowledge. This information has been mapped many times and does not need to be cited. However, if the portrayal of the map differs significantly from the way things have traditionally been mapped, then it is helpful to the map user to include the sources. Examples might include recent boundary changes or the use of some very new source, such as a new survey or new remotely sensed imagery. In these cases, it may not be complying with copyright laws that are important so much as just providing helpful information to the map-reader.
Safely assume, however, that most thematic maps and large scale specialized reference maps will contain data that are not common knowledge. In these instances, give the source, and if important, give the date of authorship or origin.

The other side of the coin is notes that concern authorship on the part of the mapmaker. It is recommended as a matter of standard practice that the name of the mapmaker, contact information, organizational affiliation and the date be included as a note on the map. Maps have a way of becoming disconnected from their parent documents. In these cases the note of authorship is the only claim that the cartographer has to his or her work.

**Priorities**

Elements of the map need to be organized and presented in priority order with highest visibility being assigned the element with highest priority and least visibility being assigned to the element with lowest priority. This way the most important things are emphasized and the least important are de-emphasized.

Of course, the mapped area is the focus of the map and automatically is assigned highest priority. It should be prominently positioned where the eye will be drawn to it first. Borders and neatlines are important too, as are grids and graticules, but these are optional items that should carry less emphasis.

Elements of marginal information should be rigorously prioritized in a hierarchical manner that will cause the map-reader’s attention to be directed to those things that are most important. The list of marginal information elements that follows is given in descending priority order. They should either be placed on the map in a way that conveys that order of priority or otherwise be give visual emphasis or de-emphasis that does the same.

1. Map title
2. Legend
3. Inset maps
4. Graphic map scale
5. North arrow
6. Notes
7. Sources and credits
8. Authorship
Section Summary

Designing good maps involves not only creating pleasing visual images, but also building strong communication devices that share valuable information with the map-reader. In order to do this, care and attention needs to be given to every detail—the size and placement of the mapped areas, the layers of information that are included, the symbolism chosen, and even the annotation or lettering that is placed on the map. Well designed maps do not stop with the mapped area; an equal amount of care needs to be given to the marginal information so that the map is enhanced with well crafted titles, legends, graphic scales and the like.

Only some of the elements and principles of cartography have been covered in this section. However, the intent has been to provide information, concepts, and principles of map making that will help to improve the quality of pre-disaster mitigation plans for Montana counties and Indian reservations. Other information can be found from the following sources:


The next section is the most extensive in that it contains all of the map templates constructed for this thesis.
TEMPLATES FOR COUNTY PRE-DISASTER MITIGATION PLANS

Process For Making Maps

The purpose of this section of the thesis is to outline the general process by which the templates were constructed. Procedures and conventions are discussed here in order to assist the reader in understanding and implementing the map templates.

Acquire Statewide Information

The first step in construction of map templates was to establish the method of acquiring and organizing statewide information and the construction of a common base map. Additionally, the spatial reference system had to be set in ArcCatalog and conventions regarding symbology established. All of the base information was acquired in shapefile or geodatabase format from the CISDM project and NRIS. Both raster and vector data were utilized in the construction of map templates. The steps discussed here outline the construction, organization, and conventions utilized throughout this project. Additionally, base map content will be covered.

Geodatabase Construction and Conventions

Mapmaking accomplished during this project required the use of nine geodatabases. Some of the data, such as the Hill County Cadastral and CAMA data were obtained in this format and used as is. Also, it quickly became apparent that multiple geodatabases would be required for organizational purposes as the number of map types, varieties of data, and areas mapped increased dramatically during the project. The geodatabase development process followed the general rules outlined below (Figure 5-1).

1. General statewide information that could potentially be utilized in all maps was compiled into the MT_Template_Base_Data.mdb geodatabase, which contains thirteen feature datasets.

2. Separate geodatabases were constructed that paralleled the general categories of maps to be produced. These are the MT_Template_Natural_Disasters.mdb, MT_Template_Man_Made_Hazards.mdb, and Hill_Cty_Inventory
Asset.mdb geodatabases. At risk populations and raster data were given their own geodatabases.

3. In each geodatabase, the general process was to develop a statewide feature dataset, such as MT_Tornadoes, analyze the data, and then construct a county or reservation feature dataset, such as Valley_Cty_Tornadoes.

4. A separate geodatabase was constructed for all of the raster data used in the template project. In this case, all of its contents were either statewide or county specific raster datasets. Similar naming conventions were used for its contents.

![Geodatabases_All](image)

**Figure 5-1, Geodatabase Structure**

**Spatial Reference System**

Most, if not all, data acquired from NRIS came in the Montana State Plane coordinate system, NAD 83 (meters). This coordinate system works well for maps made of any portion of Montana and the area immediately surrounding it. All of the feature datasets and associated feature classes were constructed using these parameters. Additionally, the Min X: and Min Y: values of the X/Y Domain were set at 0 and the Precision was set to 1000. This means that each point is measured from the origins of the State Plane Coordinate System and stored precisely to 1/1000th of a meter, or 1 millimeter. The details of the spatial reference system for statewide data are shown in the figure below (Figure 5-2).

The Lambert Conformal Conic Projection works well for states in the mid latitudes, such as Montana. It is constructed by superimposing a cone over the sphere of the earth, with two standard parallels secant to the globe and intersecting it. Distortion is thereby minimized when a three dimensional surface is projected onto the two dimensional map. The projection is conformal, which means that there is no angular
deformation around points. The spatial reference values of the coordinate system for individual county or reservation maps were re-projected accordingly in ArcMap using the Coordinate System Tab of the individual Data Frame Properties dialog box in order to rotate the area mapped so that north is toward the top of the page.

Symobology

The symbology portion of the CISDM project was not established and promulgated at the time of this writing. The only existing symbol system discovered during the research for this project that is commonly used for disaster and emergency services was created by the Homeland Security Working Group (HSWG). Therefore, the majority of the symbols used in the creation of these maps are from the ArcGIS 9.1 symbol files. HSWG symbols were used where appropriate.

Basemap Content

It was necessary to answer the fundamental question of what specific features the base map should contain before development of the map templates could continue. A partial attempt to resolve this issue was to attend sessions with county and district DES personnel hosted by GeoData Services, Inc., which were devoted specifically to answering this question. The result of this research is that currently there is no hard and fast answer regarding base map content. For this project, the features that appear in the Location Map for Hill County best display the most common conventions.
**Acquire Thematic Data**

The next step in the template construction process was to identify and acquire the thematic data used for the construction of specific map templates. In most cases, this information was acquired as raw data from the most authoritative source available. An example of this was the tornado data acquired from the National Oceanographic and Atmospheric Administration’s (NOAA) National Weather Service Storm Prediction Center. In the case of Natural Hazard information, every effort was made to find information covering the longest time period possible in order to portray the most complete historical record. Detailed processing instructions were included where necessary. As for man-made features, the most current information available was utilized and appropriate remarks were made regarding the timeliness of the data.

**Process the Data**

Once statewide information was acquired and portrayed, it was necessary to select an appropriate county or reservation for template construction. In most cases, this selection process involved determining that part of Montana most frequently afflicted by the particular disaster. Once this selection was made, various methods were utilized to extract just the specific base map and disaster information needed for that county or reservation. The convention in this thesis has been to **bold** items where actual computer operations or steps are required. The objects acted upon are *italicized*.

**ArcGIS Data View**

The next step focused on analysis of the data and was generally conducted within ArcGIS’s Data View. This often involved joining tables, summarizing information, calculating various values of attributes, and so on. The goal here was to derive information in a format that would be useful to county or reservation PDM planners. Additionally, various types of explanatory information useful to the map reader were developed. An example of this was the compiling of information describing the Fujita Scale, a method of measuring tornado intensity.
**ArcGIS Layout View**

The final step in the process was to use the features to construct the actual map. All of the cartographic principles covered in the previous section were incorporated into this process. It should be noted that many of the elements of the maps, such as background, font type, and so on, were standardized for this project. It should also be emphasized that these are not the only options. However, standardization of appropriate elements is generally considered correct for a folio of maps.

**Location Maps**

Just as the purpose of a map is to communicate information, the purpose of a location map is to give a generalized overview of a geographical area. Moreover, it must be capable of communicating this information clearly to audiences that are not familiar with the area. More than one map may be required to achieve this end. This section of the thesis describes the considerations and construction processes involved in building a location map. To begin, some basic questions regarding the construction of any set of maps must be answered. Then, thought must be given to some issues regarding the content necessary to adequately tell the area’s story. The final section will pertain to the actual construction of location maps. The basemap data acquisition and download processes are described here and a variety of content options are discussed and portrayed.

The first issue is to clarify the goal or intent of the map. In this case, both general and specific information regarding the location of natural and man-made features need to be utilized. Due to the variety of scales and extent required to portray this information, sample inset maps may need to be used.

The next question is to identify the intended audience. Because of the public nature of pre-disaster mitigation plans and the wide variety of users, these maps must work in the broadest possible sense. Even though the location map may portray state, county, or reservation level information, it will be reviewed and used by all levels of government as well as the general public. Much of the information contained in the maps will be common knowledge to the residents of the area. However, this may not be the case for everyone that needs to make use of pre-disaster mitigation plans. Moreover,
adequately telling a story on a map to an audience not familiar to the area is especially important when seeking funding from various agencies or for involving higher levels of government in mitigation projects.

The final question to answer prior to dealing with actual content has to do with the medium used to display the map. This has been discussed previously, but is stated again here for emphasis. All of the maps that appear in this thesis, not just this section, are designed to be printed in color on standard sized 8 ½” x 11” inch paper in thesis format.

The potential number and specific content of maps in the location map category is limited only by the needs and desires of the user, and this should be the fundamental criterion in their development. Additionally, just as the counties and reservations across the Montana landscape vary greatly, so will the content requirements for location maps. County or reservation location and size, topography, general population characteristics, major lines of communication, natural characteristics, aerial imagery, and public lands are just a few of the items that may be desired. Examples of most of these are included here. Hill County was chosen as the subject area for most of the maps constructed in this part and the Inventory Asset portion of this thesis. Public lands are also covered in that portion.

**Location Map Methodology**

This section expands upon the data acquisition and processing steps introduced earlier. Additionally, the specific steps used in actual map construction are covered.

**Data Acquisition and Processing for Location Maps**

Most of the data utilized in these templates was obtained through the NRIS website at http://nris.mt.gov/gis/. Numerous types of information can be obtained here and the overall content is expanded and updated frequently. Along these same lines, the download procedures discussed here apply to other websites as well. A procedure for acquiring a single dataset will be discussed, although multiple datasets may be downloaded simultaneously. On the website’s home page, **Click on GIS Data List** and then **scroll down** the list until you reach the **Counties, U.S. Census Bureau**. **Click on the**
data button and choose the shape file type. This will download all the county boundaries in the shapefile format in the NAD 1983 Montana State Plane coordinate system in a zip file. The metadata will normally come in the zip file, but can be examined and downloaded separately. Once unzipped, the shapefile can often be imported directly into the appropriate feature dataset of a personal geodatabase because it contains a .prj file. This informs ArcCatalog what spatial reference system is used. Occasionally, especially with the raster data downloaded from this site, the spatial reference system will need to be defined in ArcCatalog. In either case, for raster or vector data, the procedure for defining the spatial reference system is much the same.

The process utilized for shapefiles will be described here. Open ArcCatalog and navigate to the shapefile just downloaded. Right click on it and select properties, which will open the Shapefile Properties Dialog Box. Select the Fields Tab and click on the field named Shape. This will bring up the Shape Field Properties in the lower portion of the dialog box. Click on the button to the right of the Spatial Reference heading. This will invoke the Spatial Reference Properties Dialog Box. Use the Select button to choose the appropriate Coordinate System taken from the metadata and Click Add. The appropriate spatial reference information should appear in the Details section of the Spatial Reference Properties Dialog Box (Figure 5-3). Click OK on this box and the previous one and the appropriate information should be registered in ArcCatalog. This can be verified by checking the information contained in the Spatial Tab of the Metadata Tab for the shapefile. The shapefile can now be imported into a geodatabase.

The metadata for each dataset should be examined for other items as well. All metadata obtained from this website conforms to the Federal Geographic Data Committee (FGDC) metadata content standards, which specify the format and content. More detailed information about metadata can be obtained from the FGDC website at http://www.fgdc.gov/. One of the more important segments of the metadata is the Horizontal Position Accuracy Report. In the case of our County Boundaries file, the horizontal accuracy is approximately fifty-one meters. Usage constraints are also normally provided; in this case it is not for use at scales greater than 1:100,000. This information regarding the precision and accuracy of the data should be considered carefully for each intended use.
Information regarding the source, processing method, and date of acquisition are also be provided in the metadata. Some of the questions to be answered when examining it include: is the data current enough, does it contain the necessary attribution, and did it originate from a credible source?

Mapmaking-Location Map of Hill County

This is the most basic map of the series. Two data frames are provided; one that shows where the county is located in Montana and the other is the county base map itself. The Montana data frame enables the map-reader to quickly identify the geographic context of the main map. Keeping in mind the potential audience for pre-disaster mitigation plans, it is very possible that many of the readers are not familiar with the location of Hill County. One can also easily see the balance and symmetry achieved by placing the legend and inset map together on the right side of the page. The reader’s eye flows naturally over the map from left to right, taking in all of the map elements, and then remains focused on the most important part of the map, which is Hill County. The map also demonstrates the suitability of the Lambert Conformal Conic projection for use in this context.
No special processes were used in the construction of this map. Most of the data, including the MT_Hillshade layer, was acquired from NRIS in the form of zipped shapefiles containing statewide information. Once all of the information was downloaded, a straightforward process was utilized to transform it into feature classes within our MT_Template_Base_Data.mdb geodatabase. A number of feature datasets were constructed in order to organize it all properly and provide the framework for adding more data (Figure 5-4). The major exception to this was the transportation features, which were acquired in the form of a personal geodatabase from the CISDM website.

Once Hill County had been chosen as the subject for the location map, the Clip tool, found in ArcToolbox under Analysis Tools and then Extract, was used to create feature classes containing only data for Hill County. The segment of the MT_Hillshade layer covering Hill County was extracted by importing the feature and setting the data frame extent of the Hill_Cty_Location Data Frame Properties dialog box to the boundary of Hill County. This was accomplished by Enabling the Clip to Shape function and specifying the Hill_Cty_Boundary layer as the shape. This segment of the MT_Hillshade was then exported to form its own raster dataset within the MT_Template_Raster_Data.mdb (Hill_Cty_Hillshade). Finally, the Hill County portions of the feature classes containing major roads, railroads, towns, major hydrographic features, and the Rocky Boy Reservation were added to the map. This is the limit of what can be portrayed before the map becomes cluttered. The reservation feature class was set to display at 40% transparency in order to allow the Hill_Cty_Hillshade layer to be seen. We should
also note that a significant portion of the Rocky Boys’ Reservation is located in Chouteau County to the south (Map 5-1).

Mapmaking: Geographic Coordinates Map of Hill County

It is a simple matter to add a grid coordinate system, or graticule, to a map. This process will be demonstrated using the previous Location Map of Hill County (Map 5-1). The graticule will be developed in geographic coordinates (degrees, minutes, and seconds), but the process can be used for other coordinate systems.

Start by opening the Hill_Cty Data Frame Properties Dialog Box and Select the Grids Tab. Click on New Grid to open the Grids and Graticules Wizard. In this section, we want to create a graticule, or a map divided by meridians and parallels. Select the appropriate button and give the Grid an appropriate name (such as LatLong). Click Next to move to the Create a Graticule window. Leave the default Graticule and labels button selected. Some experimentation is required to determine the appropriate Interval to set for the parallels and meridians. For the extent of Hill County, settings of 0 degrees, 20 minutes, and 0 seconds worked well for both fields. Click Next and Select appropriate Axes and Labels. Click Finish on the Create a graticule dialog box. This completes the process of creating a new grid. Ensure the box next to LatLong is checked and it will be displayed over the Hill County map in the Layout View only. Experiment with the Grid properties on this tab in order to select the font, line colors and weights, tick marks, and so on. An example is shown on the following map (Map 5-2). It should be noted that at this scale, the graticule is appropriate for orientation purposes only, not for deriving specific geographic coordinates for a particular feature in Hill County.

Mapmaking: Selected Natural Characteristics of Hill County

The NRIS website contains vast amounts of data that fall into the general category of natural characteristics. More importantly, old datasets are updated and new datasets are added to the library on a continuous basis. In our location map series, this type of information may be needed to give the pre-disaster mitigation plan reader more general information about the area. Most of these datasets are distributed as statewide features and need to be clipped using the processes described in the previous section. Also, the
Map 5-1, Hill County Location Map

Hill County
- U.S. Highway
- County Highway
- County Road
- Railroad
- Rocky Boy's Reservation

Bruce A Koerner
Department of Geography
The University of Montana
Location Map Series
September 6, 2006
Map 5-2. Geographic Coordinates of Hill County
metadata needs to be examined carefully to ensure the data is compatible with its intended use. As an example, the metadata for precipitation states that the information covers the period of 1971-2000, which should be sufficient for a PDM plan. The map displayed here depicts Climax Vegetation and Average Annual Precipitation for Hill County. Some of the other types of datasets available at the time of this writing include the following.

1. Conservation Districts
2. FWP Regional Fisheries Boundaries
3. FWP Regional Wildlife Boundaries
4. Soils data - 1:250,000 scale STATSGO
5. Various Types of Wildlife Distribution
6. Various Fish Species Native Ranges
7. Climax Vegetation
8. Land Use from USGS - 1:250,000 scale

Two data frames are used in this map. The Hill_Cty_Boundary feature was used to clip the subject layers to the proper size. The output feature classes, Hill_Cty_Climax_Veg and Hill_Cty_Precip, were exported to the Hill_Cty_Features feature dataset. The attribute tables for both new feature classes were inspected to ensure they were complete. For annual precipitation in Hill County, it should be noted that although the majority of the county falls into the ranges of ten to thirteen inches of precipitation per year, some segments of the county receive as much as thirty-four inches per year. The Group Values Function of the Symbology Tab in the Hill_Cty_Precip layer properties dialog box was used to group some of the precipitation values (Figure 5-5). This simplifies the map and reduces the number of sequentially color-coded values from fourteen to six, a number that the human eye can comprehend. In order to focus attention completely on the natural characteristics subject matter, almost all other map features were removed (Map 5-3).

Mapmaking: Aerial Imagery of a Portion of Hill County

There are numerous types and sources of remotely sensed imagery available for Montana. One of the best types currently available for Location Maps is the National
Agricultural Information Program (NAIP) imagery. This was compiled by the U.S. Farm Services Agency (http://www.apfo.usda.gov/NAIP.htm), and is designed to meet the standards of the U.S. Department of Agriculture for conservation and planning. These data are comprised of color digital aerial photos taken in 2005. They consist of 2,703 12x12-kilometer tiles that cover the entire state of Montana. They are orthorectified natural-color MrSID images with a ground resolution of one meter, and are registered to the Montana State Plane coordinate system, NAD83, units meters. The figure provides a sample of a portion of the tiles that can be acquired for Hill County (Figure 5-6).
Selected Natural Characteristics of Hill County

Climax Vegetation

- Montane Forest
- Intermountain Grassland
- Plains Grassland
- Water

Annual Precipitation

- 10-11
- 11-12
- 12-13
- 13-18
- 18-24
- 24-34

Map 5-3, Natural Characteristics of Hill County

Bruce A Koerner
Department of Geography
The University of Montana
Location Map Series
September 6, 2006
The download process for the NAIP imagery has been discussed previously. The appropriate tiles were acquired, unzipped, and their spatial reference systems defined in ArcCatalog. They were then imported into the MT_Template_Raster_Data geodatabase.

For the location map described in this section, it was necessary to assume that providing details of Fresno Reservoir was important in the PDM planning and mitigation process. This dam is owned and operated by the U.S Bureau of Reclamation and used for irrigation, flood control, and supplying water to the area. Two data layers were included that show the general area and the NAIP imagery. MT Fish, Wildlife, and Parks property is displayed in both data layers. In this case, the central focus of the imagery is the dam and spillway area (Map 5-4).

**Location Map Summary**

The location map section served a variety of purposes. It provided the first example of using the processes, procedures, and conventions outlined in the first part of this section. Base map data was acquired and processed into the formats necessary for use in the map-making process. Thematic data necessary for communicating the required information about Hill County was gathered and manipulated using the same procedures. Although location maps usually do not involve much analysis, it was still necessary for the mapmaker to make use of selection and generalization processes in order to determine which map elements to portray. Much of this work was accomplished in ArcGIS Data View. Once completed, the actual map layouts were compiled in the ArcGIS Layout View. It was here that many standards of style, format, font types, and other map elements were established, thus simplifying the mapmaking process. Finally, the most important concept of this thesis was reinforced. The map templates constructed here are meant to provide ideas and concepts, demonstrating some of the products that can be produced to aid the pre-disaster planning and mitigation processes.
Fresno Reservoir on the Milk River, Near Kremlin, MT

Fresno Reservoir Area
- U.S. Highway
- County Road
- Fish, Wildlife, and Parks Land

Fresno Reservoir, Dam, and Spillway Area
2005 NAIP Imagery
Color, 1 Meter Resolution

Bruce A Koerner
Department of Geography
The University of Montana
Location Map Series
September 6, 2006

Map 5-4, NAIP Imagery of Fresno Reservoir
Inventory Asset Maps

Purpose

Maps discussed in this section display the inventory of assets and population within a particular county or reservation. Just as each county differs greatly in these areas, so will the nature of the cartographic products that are useful. Counties and Indian reservations each have their own special natural and man-made assets, population demographics, and concerns. Because of this, it is critical that county residents, first responders, and county officials work together to determine the features that should be portrayed. In this section, a series of maps will be constructed the purpose of which will be to demonstrate a variety of mapping possibilities at the county, reservation, and community level.

Subject Areas and Data Sources

The general subject areas of the map products are: property and structures, critical facilities, high potential loss facilities, total population, and at-risk populations. It should also be noted that while the maps portrayed here are for pre-disaster planning and mitigation, they would also be beneficial for disaster response. These functions, and their associated cartographic products, are frequently opposite sides of the same coin. A separate personal geodatabase entitled Hill_Cty_Inventory_Assets.mdb has been constructed to contain the data for this portion of the project. The exception to this is the section on dams, which is one of the types of high potential loss facilities. Lincoln County is utilized for that template because it contains one of the two dams located in Montana that is operated by the U.S. Army Corps of Engineers.

It is appropriate to briefly discuss the data sources that will be used for this series of maps. The user should start with data provided through the state’s Critical Infrastructure and Structures Data Model (CISDM) project. This is a work in progress, with new information being added all the time. Because the Inventory of Assets group of map templates has much to do with land, land ownership, and the characteristics of the man-made features present on the land, extensive use was made of the Cadastral and Computer Assisted Mass Appraisal (CAMA) system data available through the state at
either the http://gis.mt.gov/ website or the Montana Natural Resource Information System (NRIS) website. The Montana Cadastral and CAMA databases are also works in progress, as well as being dynamic in nature. Finally, the population information originated with the U.S. Census Bureau, but was acquired from their American Fact Finder website.

As always, the mapmaking capability is limited by the availability and quality of the data available. This issue was especially important in this group of map templates. In most cases, data for building footprints was not available at the time of this writing. Also, for security reasons, data for various infrastructures deemed critical was not available to the general public. These factors hindered the mapmaking process throughout this section.

**Property and Structure Inventory Asset Maps**

Hill County, Montana, was utilized to produce this series of maps. The appropriate cadastral and CAMA layers were downloaded from the State website in the form of personal geodatabases. As stated earlier, these databases are works in progress and many of the tables contain no information at this time. This situation, to one degree or another, is common for many of the counties across the state. An extensive set of metadata documents describing the spatial and tabular data was also acquired from the same location. Some of the more populated counties in Montana have elected to manage these databases themselves, while the others are handled at the state level.

Several sample property ownership maps were produced for this segment of the thesis. While the processes and data included are discussed in detail later, it should be noted that the completeness of the data limits what can be portrayed. For example, the cadastral data distinguishes between the various types of property owned by the U.S. Government. The individual parcels are identified as belonging to the Department of Defense, Department of Interior, U.S. Government, and so on. However, within the category of U.S. Government, one can not easily distinguish between parcels occupied by the U.S. Postal Service, Federal Court Houses, or other entities. Other procedures, such as address matching, ground truthing, or local knowledge would be needed to make this distinction. Likewise, at this time, only land parcel demarcations are available. While
there are some exceptions to this, actual structure footprint data is generally not available.
Various agencies at all levels of government are taking steps to acquire this data, but this
is a work in progress as well. One substitute method might be to overlay the parcel
boundary(s) on NAIP imagery. If desired, the building footprints could be digitized and
the data developed from this product. Once again, the amount of effort expended in
acquiring this data and making the associated cartographic products should be based
primarily on the needs of the individual county and the benefits to their pre-disaster
planning.

**Inventory Asset Map Methodology**

This section covers the methodology involved in producing templates of various
types of assets. It should be emphasized that in this section, more than any other, the
templates represent concepts of what could be done.

**Data Acquisition and Processing: Property and Structure Inventory Asset Maps**

No special techniques are required to create the first inventory asset map. The
cadastral and CAMA data are downloaded by navigating to the state website,
http://gis.mt.gov/, and selecting the folder for Hill County. Opening the folder reveals
two .zip files (HiCama.zip and Hill.zip). Save and unzip both of these. Also download
the folder entitled Documentation, which is located in the same place as the county
folders. The Documentation folder contains three .zip files (CamaDOC.zip,
CamaSchema.zip, and WebTutorialPowerPoint.zip) that contain detailed information
(hereinafter called metadata) on the structure and purpose of cadastral and CAMA data.
Download and open these files as well. We should note that the Cadastral and CAMA
data is available in either the ESRI geodatabase or shapefile format from the NRIS
website. The information comes in the personal geodatabase format with spatial
reference systems that are recognized by ArcCatalog.

**Problems with Cadastral Data.** In addition to being a work in progress, problems exist
with the Cadastral Data for much of the Western United States. Much of the digital data,
such as parcel boundaries, that has been constructed in recent years does not line up with
its actual location on the ground. The graphic below shows this visually (Figure 5-7).
The U.S. Bureau of Land Management (BLM), working with the individual states, has
the lead in correcting this problem. The overall process involves creating and updating
the Geographic Coordinate Data Base (GCDB), which is used essentially to georeference
the Cadastral Data. It is anticipated that this process will be accomplished for key
portions of Hill County in 2007. The same work will progress for all counties in
Montana as time and money become available. As it exists right now, the data is off by
as much as two hundred feet in the area around Havre in Hill County. The data is still a
valuable tool and can be used in making some maps and conducting certain types of
analysis.

Figure 5-7, Cadastral Vs. Road Layers

Inventory Asset Mapmaking with Cadastral Data

Two cadastral maps depicting land ownership characteristics are shown here. The
primary difference between them is one has an inset map depicting land ownership in the
vicinity of Havre and the other has a table showing a breakdown of land ownership for
the county. The mapmaking process for both will commence with the layout constructed
in the previous Location Map section (Map 5-1). The symbology utilized for the
Location Map works satisfactorily with these maps. The Hill_Cty_Hillshade feature
class is not included in the construction of the Cadastral Maps because the shaded tones
can interfere with the colors used to depict land ownership.

1. Use the Add Data button to add the OwnerParcel feature of the ParcelFeatures
feature dataset from the Hill_Cty_Cadastral geodatabase to the map. Initial
examination of the OwnerClassification field of the OwnerParcel attribute
table reveals that ownership is initially broken down into approximately
eighteen general categories, with all of the privately owned land lumped into a single classification.

2. The first objective will be to group the ownership categories in order to achieve a recognizable number of colors. Open the OwnerParcel Layer Properties Dialog Box and select the Symbology Tab. Under the show button, select Categories and then Unique Values. In the Value Field, select Owner Classification and then Add All Values. This will result in all layers being depicted with a color from the default Color Ramp. These are difficult to distinguish and will be grouped in order to make the number of colors more manageable.

3. Hold down the Control Key and select all those categories belonging to the U.S. Government. Scroll up or down as necessary. Right Click in the highlighted area and select Group Values. Continue this process as necessary until the different categories are grouped into the following: U.S. Government, Tribal Ownership, State Government, Local Government, Private, and Right of Way. Change the Labels to reflect these categories. Remove the categories of Water and Undetermined.

4. Since it is the largest category, white was selected for privately owned parcels. The Color Brewer website (http://www.personal.psu.edu/cab38/ColorBrewer/ColorBrewer.html) was used to select five qualitative colors for the other categories.

5. The next step is to construct and add a table to the map showing the distribution of land ownership throughout the county. The procedure outlined here is one of several ways to accomplish this task. Open the attribute table of the Owner_Parcel feature, right click on the OwnerClassification field and select Summarize. In the Summarize dialog box expand the GIS_acreage field and check Sum. Save the table in dBASE format in an appropriate location and name it (Ownership for example). Click No when asked if you want to add the table to the map. Close the OwnerParcel attribute table.

6. Open the Ownership table in Microsoft Excel. The number of parcels and acres in each category should be summarized as specified. Adjust the font, column widths, and headings as desired. The table can now be pasted into the map (Map 5-5).

The second Cadastral Map is similar to the previous one, with the exception that an inset map of the Havre area is included instead of the table. No special processes are used in the construction of this map. The symbology and associated legend used for the county map works for the inset at well. The inset is made by copying and pasting the
Map 5-5, Land Ownership in Hill County
County Data Frame back into the same map. The name of the second Data Frame was changed to Havre_Area to avoid confusion (Map 5-6).

**Mapmaking: Inventory Asset and Analysis Using CAMA Data**

The mapmaking and analysis capabilities using CAMA data are endless. The challenge is to determine the type of information that would be most useful. The two examples provided here will provide ideas as to the type of maps and analyses possible. Since Hill County experiences tornadoes on a somewhat regular basis, it is necessary to determine how many structures in the county have full or partial basements. The theory is basements provide shelter for the residents during any tornado event. Likewise, since Montana has issues with wildland fire, CAMA data can be used to determine what type of roofing materials are most commonly used in the county. Simplify the process by doing a Save As with the last Cadastral Map and start from that point, since the majority of the required features are the same.

*Note*: Only inset maps of selected residential areas are shown here that illustrate the relative distributions of basements and roofing material types. The graphic display of this information in a map would require many pages to cover the entire county.

1. The general process is to join several tables to the OwnerParcel feature class. Once accomplished, the individual parcels may be symbolized according to basement type in one data layer and roof type in another. In both cases, the results are exported, forming a new permanent feature class. Also, the appropriate fields of the attribute tables are summarized and added to the map.

2. Once again, starting with the Hill_Cty_Cadastral_II Map, remove the Havre_Area data layer. Work with the Hill_County data layer to start with. Use the Add Data Button to add the BASEMENT, RESIMPDWELL, AND ROOFMAT Tables from the Hill_Cty_Cama.mdb to the map.

3. The key to successful joins is finding the correct fields for joining the tables. Right click on OwnerParcel, select Join and Relate, then select Join. The figure below shows the entries for each field (Figure 5-8). Click OK.

4. Open the Attribute Table of OwnerParcel to ensure the Join was done correctly. The two fields that will be important in the next steps are RESIMPDWELL.ROOFMATL and RESIMPDWELL.BSMT.
Land Ownership in Hill County and Havre

Ownership Categories
- U.S. Government
- Local Government
- Tribal Ownership
- Right of Way
- State Government
- Privately Owned

Map 5-6. Land Ownership in Hill County and Havre
5. The next step is to **repeat** the *Join* process for the OWNERPARCEL feature class and the BASEMENT Table. **Use** the BASEMENTID field in the BASEMENT table to **conduct** the *Join*. **Open** the Attribute Table of OWNERPARCEL again to insure the process was completed correctly. You should now have a field entitled BASEMENT.BASEMENTDESC.

6. **Use** the *Export Data tool* to **create** a new **feature class** in the Hill_Cty_Features feature dataset entitled Hill_Cty_Basements and **click yes** when asked to add it to the Map. **Open** the *Layer Properties Dialog Box* of the new feature class and **select** the *Symbology Tab*. The figure below shows one method to symbolize the feature class (Figure 5-9).

7. It should be noted that the parcels, regardless of size, will be displayed on the map according to the color coding of their basement type. **Close** the *layer properties dialog box* and **open** the *attribute table*. 
8. **Right click** on the `BASEMENTDESC` field and **Select Summarize**, which will open the Summarize Dialog Box. **Set up** the fields as shown in the following figure (Figure 5-10). **Save** the resulting *dBASE file* in an appropriate location and **name it** `(BasementType.dbf)`. 

![Figure 5-10, Basement Summarize Dialog Box](image)

9. The easiest way to correctly format and display the table in the map is to **use** the *data export tool*, **export** it as a *dBASE file*, and then **open** it in Microsoft Excel. **Use Excel** to set column width, font, and so on as desired. Then **paste** it into the map. The figure below shows basement types for a selected residential area of Havre, Montana. The table does the same for Hill County (Figure 5-11) (Table 5-1).

![Figure 5-11, Basements](image)
The basic steps above can also be used to determine the roofing materials used for structures in Hill County. Once again, only a portion of the county will be portrayed in the figure, but the table will give numbers for the entire county.

1. Begin the process by **copying** the *Hill_Cty_Basement Layer* and **pasting** a copy of it into the map. **Change** the name of the new layer to *Hill_Cty_Roof_Type*.

2. **Right click** on the *OwnerParcel layer*, **Select Joins and Relates, Remove Joins**, and then *BASEMENT*. This will remove the selected table, but leave RESIMPDWELL joined to OwnerParcel. At this time, **follow** the procedures above to join the ROOFMAT table and summarize the data.

3. Now, the map can be constructed in the appropriate format. Displaying the associated tables is sufficient. The figure and table below provide the information derived for basements and roofing materials (Figure 5-12) (Table 5-2).

![Figure 5-12, Roofing Material](image)
**Table 5-2, Roofing Material**

<table>
<thead>
<tr>
<th>Roofing Material Used In Hill County</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Shingle</td>
<td>2,845</td>
</tr>
<tr>
<td>Wood Shingle</td>
<td>985</td>
</tr>
<tr>
<td>Slate</td>
<td>7</td>
</tr>
<tr>
<td>Tile</td>
<td>28</td>
</tr>
<tr>
<td>Metal</td>
<td>77</td>
</tr>
<tr>
<td>Wood Shake</td>
<td>58</td>
</tr>
<tr>
<td>Composition Roll</td>
<td>270</td>
</tr>
<tr>
<td>Tar and Gravel</td>
<td>45</td>
</tr>
<tr>
<td>Asbestos</td>
<td>162</td>
</tr>
</tbody>
</table>

**Inventory Asset Maps of Critical Structures**

The CISDM project is developing critical structure data, including building footprints, for the entire state. While presently the best source of this type of information, it is limited primarily to point data for schools, law enforcement, fire departments, emergency shelters, health care facilities, and so on. Also, the attributes generally do not include specific characteristics such as the number of hospital beds, numbers of police officers, or types of fire fighting equipment at the location. All of this information could easily be added to a map in a variety of ways if the information were available. However, the information currently available has value in that at a minimum, it allows a visual analysis for pre-disaster planning and mitigation.

The transportation layer developed by the CISDM project contains detailed information on roadways and bridges around the state and has a great deal of utility because of this. While many of these characteristics are well known to the emergency managers within their respective counties, this may not be the case for those outside the stricken county or reservation who are attempting to route supplies and equipment to the disaster site. A sample map of bridge widths will be included for this reason.

As for other critical facilities such as military bases and utility systems, much of that data does not exist or is not available to the general public. Some agency officials have indicated existing data would be made available to county emergency management officials on a case-by-case basis. Regardless of the situation, the mapmaking procedures demonstrated in this thesis can be used to produce workable maps utilizing whatever data...
can be acquired. In cases where this is not possible, NAIP imagery could be portrayed with parcel boundaries in order to serve this need. Generally speaking, the various emergency management agencies have established agreements, procedures, and training processes for dealing with disasters affecting these types of facilities in their area of responsibility.

Inventory Asset Mapmaking: Law Enforcement Facilities and Fire Stations. The acquisition of the Critical Structures data from the CISDM website was described previously. Once acquired, a series of Select by Attribute functions were performed to isolate those facilities located in Hill County. Each of these was exported into separate feature classes of the Hill_Cty_Critical_Structures feature dataset in the Hill_Cty_Inventory_Assets geodatabase. In this case, the process was accomplished in a blank ArcMap. Once completed, they are available for use as desired.

Any number of maps could be constructed in this section. The first set of instructions provides one example of how to portray law enforcement and fire station facilities in Hill County. A second map displays all of the bridge sizes, clearances, and load capacities. These procedures can be used to map shelters, schools, medical facilities, or any other structure type desired by a county or reservation.

1. Most of the elements needed are already contained in the Hill_Cty_Cadastral_II map. Open this and do a Save As with an appropriate name. (Hill_Cty_FIRE_POLICE.) The general process will be to create a map with four data layers: Hill County Fire, Hill County Law Enforcement, Havre Area Fire, and Havre Are Law Enforcement. Copy and past one more of each of the two existing layers in the map. Rename all of the data layers as listed previously.

2. Use the Add Data button to add the Hill_Cty_Fire_Station and Hill_Cty_Police_Station features to the appropriate data layers. The symbols for a fire station and law enforcement were acquired from the Homeland Security Working Group website at http://www.fgdc.gov/HSWG/index.html. In this case, the symbols are difficult to see on the map. The Symbol Property Editor was utilized to create red and blue backgrounds, respectively (Figure 5-13).
3. The remaining step is to label the law enforcement and fire facilities in the Havre Area. **Right Click** on the *Hill_Cty_Fire_Station* feature in the Havre_Fire inset data layer and **Select Properties**. This will open the Layer Properties Dialog Box. **Go** to the *Labels Tab* and **set up** the *Method, Label Field, and Text Symbol* as desired. **Click** on the *Label features* in this layer box to select it, and **Click OK**. **Repeat** this process for the *Havre Police* inset map. Both Havre Insets should be labeled at this point. **Adjust** the font size if necessary. The following map shows the results (Map 5-7).

### Inventory Asset Mapmaking: Transportation Features

Routing vehicles, especially those carrying heavy equipment, can be frustrating when leaving a major highway. Road and bridge load bearing capacity, overhead clearance, or width may be less than required. While this type of information is often common knowledge for emergency managers and first responders working in their own county, the situation is quite different when utilizing assistance from outside the local area. When examining the types of emergencies that are likely to occur in an area, information regarding transportation routes becomes critical, especially in the more remote rural areas common in Montana. Additionally, these routes need to be evaluated from at least two perspectives. First of all, will they support equipment available locally? The other question is: will they support equipment likely to be sent in from outside the area? The next process will portray the bridges in Hill County cartographically and index them to a table.
Map 5-7, Law Enforcement and Fire Stations in Hill County
More detailed information on bridges is available from the Montana Department of Transportation website http://www3.mdt.mt.gov:7783/db-pub/pontis40_site.htm.

1. Two data layers are required for this map. Do a **Save As** of the Hill_Cty_FIRE_POLICE map, give it an appropriate name (Hill_Cty_Bridges), and remove two of the four data layers. Use the **Add Data** button to add Hill_Cty_Bridges to both remaining data layers. Rename the data layers if necessary (Hill_Cty_Bridges and Havre_Area_Bridges).

2. **Open** the attribute table of Hill_Cty_Bridges. According to the metadata, all linear measurements are in meters and CAPACITY_RATING is in pounds. The first step is to establish a simple numerical method of identifying bridges. **Click** on the **Options Tab** and **Select Add Field**. Use the **Add Field Dialog Box** to add a **Text Field** entitled BRDGE_NMBR with a Length of ten characters. **Click** on **Start Editing** on the Editor Toolbar. **Insert** sequential numbers (1 through 49 in Hill County) in the blocks under the BRDGE_NMBR field in the attribute table. The individual bridges now have an identifier that can be used for labeling purposes.

3. **Open** the Hill_Cty_Bridges Layer Properties Dialog Box and **Select** the **Labels Tab**. **Select** “Label features in this layer” and **choose** the **Method** of “label all the features the same way.” **Select** BRDGE_NMBR as the Label Field. **Choose** an appropriate **font**. **Click** on the Placement Properties button to open the Placement Properties Dialog Box. **Select** the **Placement Tab** and **Select** the **Place label on top of the point option**. **Click OK** to close the Placement Properties Dialog Box. **Select** the **Symbol button** in the Text Symbol box of the Layers Tab. Then **Select Properties** on the Symbol Selector Dialog Box. **Select** the **Mask Tab** of the Symbol Editor Dialog Box. **Select** the **Halo Button** and **choose** an appropriate **color** for the background. Go back to the Symbology Tab of the Layer Properties Dialog Box and **Delete** the Symbol. **Click OK**.

4. Examine the Hill_County_Bridges data layer. Most counties will have a concentration of bridges in some area. In this case they are concentrated in the vicinity of Havre and some of the labels overlap. **Convert** the Labels to Annotations and **add them** to the Hill_County_Bridges data layer. **Start** an **Edit Session** and **move** the labels for those bridges outside of the Havre as required to eliminate the overlaps.

5. **Click and drag** the Hill_Cty_BridgesAnno feature into the Havre_Area_Bridges data layer. **Zoom in** to the appropriate extent and **repeat** the Edit process to ensure all labels are visible. At this time, a layout can be constructed of both data layers and other appropriate information (Map 5-8).
Map 5-8, Road and Highway Bridges in Hill County
There are too many bridges in the county to include the table in the map. The numbers provide an index method of portraying them in a separate table that can be included in the text of the PDM plan or printed on the back of the map sheet. One of the easier ways to do this is to export the attribute table of Hill_Cty_Bridges feature class as a dBASE IV file and then open it in Microsoft Excel. The individual entries can then be manipulated as desired. A portion on a finished table is shown below (Table 5-3).

Table 5-3, Hill County Bridge Specifications

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>STATE</th>
<th>FEATURE CROSSED</th>
<th>OVERHEAD (FT)</th>
<th>CAPACITY (TONS)</th>
<th>ROADWAY WIDTH (FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>L210605+09001</td>
<td>FRESNO RES (MILK RV)</td>
<td>UNLIMITED</td>
<td>14</td>
<td>16.79</td>
</tr>
<tr>
<td>6</td>
<td>L21604+03001</td>
<td>BEAVER CREEK</td>
<td>UNLIMITED</td>
<td>16</td>
<td>16.01</td>
</tr>
<tr>
<td>7</td>
<td>L211650+07001</td>
<td>CANADIAN COULEE</td>
<td>UNLIMITED</td>
<td>18</td>
<td>23.29</td>
</tr>
<tr>
<td>8</td>
<td>L214280+09001</td>
<td>BIG SANDY CREEK</td>
<td>UNLIMITED</td>
<td>18</td>
<td>19.59</td>
</tr>
<tr>
<td>9</td>
<td>L21600001+00001</td>
<td>BEAVER CREEK</td>
<td>UNLIMITED</td>
<td>18</td>
<td>29.00</td>
</tr>
<tr>
<td>10</td>
<td>L210110+02001</td>
<td>SAGE CREEK</td>
<td>UNLIMITED</td>
<td>19</td>
<td>23.94</td>
</tr>
<tr>
<td>11</td>
<td>L21014002+07001</td>
<td>FRESNO RES SPILLWAY</td>
<td>14.75</td>
<td>19</td>
<td>17.97</td>
</tr>
<tr>
<td>12</td>
<td>L21600002+06001</td>
<td>BEAVER CREEK</td>
<td>UNLIMITED</td>
<td>19</td>
<td>29.19</td>
</tr>
<tr>
<td>13</td>
<td>S004480002+01001</td>
<td>BIG SANDY CREEK</td>
<td>UNLIMITED</td>
<td>19</td>
<td>24.30</td>
</tr>
</tbody>
</table>

Inventory Asset Mapmaking: High Potential Loss Facilities - Dams

The failure of a large dam due to natural or man-made acts represents one of the worst case scenarios for a “high potential loss” facility. Other facilities in this category may include military bases, hazardous material storage and processing facilities, some types of research facilities, key government structures, and so on. Unless data for actual structure or facility footprints is available, most of this information will be in the form of point data or parcel boundaries. For the purposes of template construction, the basic cartographic methods of identifying and locating dams outlined here will apply to most of this type of facility located within a county or reservation.

High Potential Loss Facilities – Dams-Information. Chapter fourteen of the Administrative Rules of Montana, titled Dam Safety Rules (hereafter referred to as Rules), defines a dam as “any artificial barrier, including appurtenant works, used to impound or divert water with an impounding capacity of 50 acre-feet or greater measured
at the crest of the dam embankment.”¹ The Dam Safety Rules are available to the public online from http://dnrc.mt.gov/wrd/water_op/dam_safety/damsafetyrules.asp. According to Dam Safety Officials of the Montana Department of Natural Resources (DNRC), this is the guidebook for issues involving dams administered by Montana. Regulations established by various other government agencies, most commonly the Federal Energy Regulatory Commission and the U.S. Army Corps of Engineers, proscribe the safety regulations for federally controlled dams located within the state.

There are currently well over 3,000 dams located in the State of Montana that serve a variety of purposes. One of the best databases of dams in Montana is available through NRIS and currently lists 3,667. This data was compiled from two datasets: the National Inventory of Dams (NID), which is maintained by the U.S. Army Corps of Engineers and the USGS Geographic Names Information System (GNIS) dams feature class. According to the metadata, this database is current as of February of 2002.² We should note that the numbers of dams in Montana change constantly as old dams fail or are removed and new dams are constructed. The DNRC also maintains its own database listing of dams in Montana that was used to construct the maps in this thesis. The processes that will be described are the same for both databases. The figure below provides general information regarding the ownership and locations of dams in Montana (Figure 5-14).³

For emergency managers, the most important issue involving dams is their potential for failure and the resultant loss of life and property. It is not known how many larger dams (in excess of one hundred acre-feet storage capacity) have failed in Montana. However, DNRC officials have stated that two or three of the smaller dams (fifty acre-feet or less storage capacity) fail each year. For these smaller dams, the most common cause of failure is overtopping. This occurs when water enters the reservoir at such a rate that the outflow mechanisms of the dam are overcome. Water flows over the

³ Michele Lemieux, P.E., Dam Safety Program/Civil Engineer, MT DNRC. Interviewed by author August, 2006.
top of the dam, washes out the spillway and other support structures, and eventually causes the dam to fail. Extreme storm events, especially when combined with heavy spring runoff from snowmelt, can lead to this situation.\(^4\)

Sub-Chapter two of the Rules provides the procedures and criteria for determining the hazard classification of a dam regulated by the State of Montana. It is important to note that a high-hazard classification is based solely on “…the consequences of dam failure—not the condition, probability, or risk of failure… A dam must be classified high-hazard if the impoundment capacity is 50 acre-feet or larger and it is determined that loss of human life is likely to occur within the breach flooded area as a result of failure of the dam.”\(^5\)

Dam hazard classification is determined in the following manner. The owner of any dam impounding more than fifty acre-feet of water is required to make an application to the DNRC for a hazard determination. In turn, the DNRC follows guidelines in determining the potential effects of flood inundation, should a failure occur. If

\(^4\) Michele Lemieux interview.  
\(^5\) Montana Department of Natural Resources, “Dam Safety Rules.”
designated a high hazard dam, the rules further require that the dam operation plan include emergency procedures and warning plans. These are developed in cooperation with local DES coordinators, law enforcement, and other appropriate officials. Pertinent portions of the plan, such as maps of the evacuation area and the evacuation plan are filed with these same officials. Federally regulated dams located in Montana utilize similar criteria and procedures. At the present time, there are approximately 150 high-hazard dams in Montana.

Conversations with both Federal and State officials revealed two similar situations that are of importance to emergency managers at the local level. The first has to do with the breach flooded area, which the Rules define as the area downstream from a dam that would be flooded if the dam failed. As mentioned earlier, there are several ways that the extent of this area can be determined. Because of the number of variables involved, dam safety officials typically take a more conservative, or safer, approach when establishing the evacuation area and associated evacuation procedures. The evacuation area, which will be the focus of emergency managers, will normally be of a greater extent than the inundation area.

The second situation has to do with the current status of maps of the evacuation and inundation areas. At both levels, efforts are ongoing to construct digital maps compiled by engineers and other experts that portray more exact inundation areas, rates of water flow, and so on. However, at the present time, the inundation and evacuation areas in the plans are typically portrayed on standard 1:24,000 scale USGS quadrangle maps. For this reason, the mapping processes described in the next section will focus on the locations of dams and not their associated evacuation areas. When preparing a pre-disaster mitigation plan, officials will need to consider the inundation areas and evacuation areas that fall within their boundaries, not just the dams themselves.

High Potential Loss Facilities: Dams - Data Acquisition and Processing. The shapefile containing information on dams in Montana was acquired from the NRIS website. Use

---

7 Michele Lemieux interview.
8 Ernest Gomez Jr. interview.
the procedures outlined previously to download the data, unzip it, and import it into the MT_Dam_Failure feature dataset of the MT_Template_Man_Made_Hazard geodatabase.

High Potential Loss Facility – Dams - Mapmaking. The mapping process is straightforward and no special procedures are required. The goal of this section is to construct two county level maps showing dam ownership and storage capacity. The base map layers for both maps are essentially the same.

1. **Open** a new empty map in ArcMap and **bring in** the layers *MT_Boundary, Counties_All, and MT_Dams_NRIS*. The individual dams should appear as points distributed throughout the state.

2. Experiment with the Symbology Tab of the Layer Properties Dialog Box of the MT_Dams_NRIS feature class. The points can be symbolized in many different ways, depending upon which characteristic are most important. In Figure 5-13 above, the Owner Type field was used to indicate ownership of the individual dams.

3. A spatial join was performed in order to associate the MT_Dams_NRIS feature class with Counties_All. The result is that ArcMap will join the dam locations in the MT_Dams_NRIS feature class to the individual county polygons in the Counties_All feature class. Ensure that you export the resulting feature class to the appropriate feature dataset and name it (MT_GCDB_CNTY_DAMS_Join). Graduated colors with four classes were used to show the number of dams in each county (Figure 5-13).

Lincoln County was chosen as the demonstration county for this section. A Select By Location step was performed to capture the dams located there. A new feature dataset entitled Lincoln_Cty_Dams was created in the MT_Template_Man_Made_Hazard geodatabase in which to store all of these features. Various other feature classes, scales and legends were added in order to provide adequate information to the map reader. The first map, Dams in Lincoln County, uses Graduated Symbols in order to demonstrate the approximate storage capacity of each dam (Map 5-9). The second map, Purposes of Dams in Lincoln County, uses Unique Values to display the primary purpose of the various dams in the county (Map 5-10).
Storage Capacity of Dams in Lincoln County

Map 5-9, Storage Capacity of Dams in Lincoln County
Map 5-10, Purposes of Dams in Lincoln County
Inventory Asset Mapmaking: At Risk Populations

The most detailed mapping of at-risk populations can be done at the census block level. They can be mapped either as dots on dot maps or color tones on choropleth maps. While there are a variety of data sources for such mapping, the two identified here will be Montana’s Census and Economic Information Center (CEIC) and the U.S. Census Bureau’s American Fact Finder. Both of these sources are available on line from Internet sites. CEIC has geographic data available for census areas including blocks. However, population attribute data attached to the blocks is sparse. On the other hand, very detailed population data can be obtained and downloaded using American Fact Finder.

Census geographic data available from CEIC can be linked to through Montana’s Natural Resource Information Service (NRIS). The link through NRIS is actually the quickest way to the data since it eliminates all of the census geographic types (counties, tracts, block groups, etc., and links directly to the block data.

Data for the 2000 Census available by using American Fact Finder are limited to attribute information available either through Public Law 94 (PL94, created to facilitate congressional redistricting) or from Summary File 1 (SF 1). SF 1 will be used for mapping at-risk populations since it contains detailed breakdowns of the population by age. While American Fact Finder appears to be a robust utility for viewing and downloading census data, it is not for the inexperienced or faint-hearted user. It has been common for seminars and workshops to be held during the last five years for the expressed purpose of teaching the use of American Fact Finder. The solitary researcher learning American Fact Finder on his own has his work cut out. Hopefully, some of the mystery will be dispelled by the instructions that follow.

At Risk Population: Data Acquisition and Processing - NRIS. Instructions for accessing and downloading data from NRIS has been covered previously in this document so will not be repeated here. At the point where the GIS Data List is displayed, use the search items window to search for 2000 Census Blocks. Choose the data set that has the description Census Blocks with population data—2000, and click the data download button. When the Layer downloads dialog box appears, click on the shape button in the type column. The result will be to link directly to CEIC’s web page titled Montana 2000.
TIGER Data. Set the window named, Select Data Format to Download to read Census 2000 Blocks with Population and Housing data, shapefiles, State Plane coordinates, then choose Hill County either from the map or from the list found below the map. When the File Download dialog box appears, click the Save button and save the data to the directory that you have prepared in advance. The result will be to save a zipped file into that directory. Unzip it to find the block data for Hill County.

At Risk Population: Data Acquisition and Processing - American Fact Finder: A direct route to American Fact finder is given with the following web site address: http://factfinder.census.gov/home/saff/main.html?_lang=en. When the Fact Finder page appears, click on the button to the left that reads DATA SETS. Now perform the following operations:

1. 1. The data sets are listed on the page that appears after choosing DATA SETS. Choose the data set titled, Census 2000 Summary File 1 (SF1) by clicking on its radio button.

2. When the data set is chosen, a list of options appears alongside to the right. Choose Custom Table from this list. This will lead to a new page titled Select Geography.

3. Under the Choose a selection method heading, select the tab that reads geo within geo. The screen will refresh; be patient–this may take a moment.

4. When the page is refreshed, make the following settings to the chain of commands: (Please be aware that the page will take time to refresh between each action. Working ahead of the refresh process does not seem to work well.)

   a. Set Show me all to read Blocks.
   b. Set Within to read County.
   c. Set Select a state to read Montana (substitute the name for your state).
   d. Set Select a county to read Hill County (substitute the name for the county you have chosen to work on).
   e. Set Select one or more geographic areas to read All Blocks and click Add. It will take several moments for the page to refresh this time. When it has, all of the blocks of your county will appear in the table called Current geography selections:
f. Now **click Next**. When the page refreshes once again, by default a list will appear titled **Select a table** and **click ‘Go.’** Choose **P12 Sex by Age (Total Population)** from this list by **clicking on it** and then **select Go.**

g. When the screen refreshes again, a table will appear headed **Select one or more data elements** and **click ‘Add.’** This table will allow you to choose the exact columns of data you want to download. Unless you know exactly which age groups you need to collect in order to gather figures for at risk populations, you should check all of the boxes for both Male and Female. This way the data can be combined to meet your needs later on. Once all of the boxed have been checked, **click Add.**

h. Another table will eventually appear headed **Current data element selections.** I guess the purpose of this table is to confirm your selections. **Check the boxes** once again in order to confirm your selections and **click Next.**

5. At this point a new page will appear titled **Select Filters.** **Click the button titled Show Result.** The name of the table that you have requested will appear along with a count of the number of rows.

   a. Use the menu bar that appears above the table to **select Print/Download** and **choose Download** from the drop-down menu.

   b. A dialog box will appear named **Custom Table>Download.** Make sure the **Microsoft Excel (xls)** radio button is **chosen, do not remove** the check mark from in front of **Include descriptive data element names,** and **click OK.**

6. **Use the File Download utility** to save the table to your Zip folder. Be sure to rename the zip file that is produced so that the county name is included. Otherwise, every time you download a county, the downloaded file will be named **output.zip** and will overwrite the preceding download.

7. Processing the data can take place in either Excel or in ArcMap. It is probably better to at least redo the column headings in Excel before transporting the data into ArcGIS, since they will make a mess otherwise. In the process of massaging the data it will be necessary to build new columns to hold the at-risk population age groups. Various age groups may need to be combined and certainly male/female differences will have to be totaled.

At-Risk Populations: Mapmaking. At least two problems exist regarding mapping at-risk populations. One is in defining what at-risk populations are. The other concerns how they should be symbolized. Logic would determine that at-risk populations would
include the very old and the very young as a minimum. Other at-risk populations might include the physically handicapped and mentally impaired. While data for the very old and very young are easy to come by from the census, data regarding the handicapped and impaired may be more difficult to find. Mapping to this point concerns only the data that comes from the census. Whether or not data for the handicapped can be found remains an important question.

Work so far has determined that an inset map or maps is necessary in order to allow all of the displayed information to be visible to the map-reader. Hill County was not hard in this sense since Havre is the only town of any size. I chose to map both the inset map and the main map with the same map legend, but experimentation with using different classifications for each might be productive.

Mapping the very old and the very young can be symbolized in at least two ways—either with choropleth symbols or as a dot map. When symbolizing as a choropleth map there are several considerations: 1) In addition to the choropleth symbols, sufficient additional locational information is needed to ensure that map-readers can determine their location on the map. I decided to remove identifiable lines from between the choropleth areas. This allowed areas of the same color to blend with one another. It also allowed information about highways, county roads, and streets to use as base information. I also included streams and lakes on the inset map. 2) The number of choropleth categories must be kept small. Otherwise, they become difficult for the map-reader to differentiate. I chose to use four categories. 3) Absolute values cannot be used to build choropleth maps. This is particularly true when a sub-set of a group is being mapped. The location of the total population tends to mask the group otherwise. All that you find is that the 65 years and older population is concentrated in the same places where concentrations of the total population are found. In addition, choropleth mapping with absolute values should not be done where there is considerable difference in the size of the enumeration areas. This adversely impacts on the map-reader’s perception of density. One option is to map the 65 years and older population as a percentage of the total population. This was rejected in favor of mapping the group as a rate of population 65 years and older per 1000 total population of the county. Of course the reason is that
the numerical figures appearing in the legend are larger and thus easier for the map-reader to interpret. This was accomplished by first calculating the total population by calculating the statistics of the TOTPOP field of the At_Risk_Blocks feature (16,673 people). A new float field titled Sr_Per1000 was then added to the attribute table. Values were calculated using Field Calculator and the formula shown in the figure below (Figure 5-15) (Map 5-11).

![Field Calculator Image]

**Figure 5-15, Calculating Sr_Per1000 Values**

Mapping with dots rather than choropleth areas should be experimented with. The most satisfactory way to do this is to map with dots based on the census block areas, but fail to map the block boundaries. Again, additional base information will be necessary to help the map-reader locate patterns or concentrations. Depending on how the map scale is handled or how insets are included, it might be possible to set the dot value to one, or one person per dot (Map 5-12).

Similar processes were utilized to map the young at risk populations. The data was broken down by sex and then by age group. In this case, the age groups of less than 5 years old, ages 5 through 9, and ages 10 through 14 were chosen. These fields for males and females were totaled and then converted to the same rate of population, 14 years or less per 1000 total population, utilized in map 5-11 (Map 5-13).
Map 5-11. At Risk Population, 65 Years and Older
Map 5-12, Total Population Dot
Inventory Asset Mapmaking Summary

The map templates produced in this section of the thesis displayed various methods of portraying the natural and man-made assets and the population of a county or reservation. Although standardized in their method and format, the templates fulfilled a secondary purpose of stimulating ideas regarding the content of cartographic products that best serve the needs of the county or Indian reservation in the area of pre-disaster mitigation planning. These needs will be as diverse as the landscape and population of Montana.

The general subject areas included were property and structures, critical structures, high potential loss facilities, and population characteristics. The basic process outlined at the beginning of this section was utilized to construct the templates. Throughout the section, every attempt was made to illustrate the various problems encountered, ways of overcoming many of them, and areas where more work could be done. Additionally, various innovative methods of utilizing existing information were introduced. Finally, although these templates are designed to serve the needs of pre-disaster planning and mitigation, many of them will be useful for various response and recovery operations.
**Natural Hazard Maps**

**Tornado Natural Hazard Maps**

The purpose of this series of maps is to cartographically portray the historical occurrence of tornadoes in Montana. The text will describe the acquisition and processing of data for the entire state and the selection of an appropriate county to be mapped. Additionally, state inset maps will be provided as appropriate.

**Tornadoes**

Tornadoes are narrow funnels of intense wind, usually rotating counterclockwise, which descend from the cumulonimbus clouds of thunderstorms and can cause extreme damage on the ground. The storms that lead to tornadoes are normally created through the collision of warm humid air moving north from the Gulf of Mexico with cold air moving south from Canada. These air masses collide across the southeastern and midwestern United States, often resulting in thunderstorms and occasionally in tornadoes.

An average tornado path on the ground is generally less than one kilometer wide, but can be up to thirty kilometers long. While typical wind speeds across the ground range from thirty to fifty miles per hour, internal winds can be as high as 320 miles per hour. Most experts believe that these severe winds and the associated flying debris cause most of the damage from tornadoes. The internal winds are utilized to classify the severity of a tornado using the Fujita Tornado Scale that was developed by Dr. T. Fujita at the University of Chicago (Table 5-4). This scale segregates tornado wind speeds into a six-point nonlinear scale from F0 to F5, and delineates the wind speeds and potential damage associated with each.¹

**Tornado Data Source**

The National Oceanographic and Atmospheric Administration’s (NOAA) National Weather Service Storm Prediction Center proved to be the best source of tabular historical data for tornadoes in the United States. Their website,

http://www.spc.noaa.gov/archive/, has data available for download that covers the period from 1950 to 2004.

Table 5-4, Fujita Scale of Tornado Categories

<table>
<thead>
<tr>
<th>F-SCALE</th>
<th>WIND SPEED (MPH)</th>
<th>TYPICAL DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>&lt; 73</td>
<td>Light damage. Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.</td>
</tr>
<tr>
<td>F1</td>
<td>73-112</td>
<td>Moderate damage. Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.</td>
</tr>
<tr>
<td>F2</td>
<td>113-157</td>
<td>Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; cars lifted off ground.</td>
</tr>
<tr>
<td>F3</td>
<td>158-206</td>
<td>Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground.</td>
</tr>
<tr>
<td>F4</td>
<td>207-260</td>
<td>Devastating damage. Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.</td>
</tr>
<tr>
<td>F5</td>
<td>261-318</td>
<td>Incredible damage. Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters.</td>
</tr>
</tbody>
</table>

Tornado Map Methodology

The methodology used was to look at data acquisition and processing and then to actually build the maps. Instructions are provided as necessary.

Tornado Data Acquisition and Processing. To acquire the raw data, navigate to the NOAA website and scroll down to the title Individual severe weather report elements. The data is retrieved by right clicking on Tornado and saving the file ONETOR5004 as a text document. This Storm Prediction Center (SPC) database comes in the form of an ASCII text, comma-separated value (CSV) file that contains tornado data for the United States. You also need to download the MS Word document (hereafter referred to as Metadata) listed on the same webpage. This document identifies, or is the key, for each column of data in the file. Information regarding State Federal Information Processing Standards (FIPS) Codes (the code for Montana is 30) is available from the website too.²

There are a number of ways to prepare the data for importation into ArcMap. The steps below outline one of the simpler processes.

1. **Open** the ONETOR5004 file in Notepad and do a **Save As**, changing the file extension to `.csv`. **Close** the new file.

2. **Open** the new file in a blank Microsoft Excel Worksheet. The Metadata information says that column C contains the state FIPS code. We only want the data for Montana, so **select** any cell in that column and **click** on the **Sort Ascending** tool. **Scroll down** and **select** all the rows where this value is 30 (tornadoes in Montana). **Copy** these rows into a new blank worksheet and **save** it with an appropriate name, such as *Tornadoes*. If necessary, **close** the ONETOR5004 file.

3. The next step is to **insert** a new empty row at the top of the worksheet. Use the Metadata information to determine the appropriate column headings for all of the columns. Column headings should be all capital letters; no more than eight characters, and have no spaces.

4. According to the Metadata, column 15 (O) contains the Longitude for the touchdown point of each tornado. Longitudes in the Western Hemisphere are negative numbers and the data comes as positive numbers. Remedy this problem by **inserting a new column** and **giving** it a logical heading, such as BESTLONG. **Insert** the formula `=sum(J2*-1)` in the first cell. Upon selection of another cell, the correct negative longitude should appear in the cell. Once this is done, **select** the cell again and **left click and drag** the button in the lower right hand corner down to the bottom row of your data. Correct values should appear in all the cells at this point. This process can be repeated for Column 18 (R), if you choose to retain the data for the tornado lift-off point. **Note:** The lift off point data is not complete and has limited usefulness.

5. The final task is to format the cells of each column appropriately. **Right clicking** the letter above each column and **selecting Format Cells** can accomplish this. **Use** the **Number Tab** to choose the appropriate category for each column. The logical choices are: **Number** for numbers such as year, latitude, and so on, **Text** for codes such as the number of the month, and **Date** for complete dates. When using the number code, ensure the appropriate numbers of decimal places are selected as well. The location data comes with a two decimal place level of precision. In Montana, this results in latitude location accuracies of 1.11 km. When all this is completed, **save the file** again in two formats: once again in Microsoft Excel Workbook format and DBF 4 (dBase IV).
Note: at the time of this writing, the latitude and longitude values were in decimal
degrees, which is appropriate for importation into ArcMap.

The entire dataset of tornadoes in Montana can be kept as is and imported into
ArcMap. However, not all of the columns are necessary, or even useful. Listed below
are the items of information considered most essential to retain and use for this set of
maps. The Metadata file should be studied prior to making decisions on which parts of
the data to retain.

1. Year. The year in which the tornado occurred.
2. Month. This data should be retained in order to determine the tornado season
   for Montana.
3. Stlat. The latitude of the touchdown point of the tornado.
4. Stlon. The longitude of the touchdown point of the tornado.

Note: The data for the end points of the individual tornadoes is incomplete and
therefore of limited value.

5. Fatal. The number of fatalities caused by each tornado.
6. Inj. The number of injuries attributed to each tornado.
7. Damage. This is a code that corresponds to a specific dollar amount range of
damage caused by the tornado.
8. F. Fujita’s F-Scale damage classification rating.

Tornado Mapmaking. From this point, the remainder of the work is done in ArcMap and
the steps are covered in sequence.

1. **Open** up a new empty map in ArcMap and bring in the layers MT_Boundary
   and Counties_All. Additional layers can be added as desired later. **Check** the
   attribute table to ensure that the Counties_All feature class contains data for
   the area in square miles for each county. If not, a new short integer field can
   be added and X-tools used to calculate the values.

2. **Use** the Add Data button to add the Tornadoes.dbf table to the Table of
   Contents of the map. The Add XY Data tool from the Tools menu is then
   used to add the points to the map. When invoked, the Add XY Data dialog
   box is opened. The LONG (or BESTLONG, depending on how it was labeled)
field is chosen for the X Field and LAT for the Y Field (Figure 5-16). Click OK, and the points will be added to the map.

![Add XY Data Dialog Box](image)

Figure 5-16, Add XY Data Dialog Box.

3. By NOAA’s own admission, the data is not perfect and some of the tornadoes may appear outside the state boundary. The best way to deal with this problem is to use the Select By Location function to select those tornadoes that are completely within the MT_Boundary feature. Once selected, the data should be exported to your Geodatabase as a new feature class with an appropriate name, such as MT_Tornadoes. At this point, the original table and intermediate layer can be removed from the map. At the time of this writing, 346 tornadoes were identified.

Some experimentation with the MT_Tornadoes Layer Properties Dialog Box yielded interesting information. As an example, selecting the Symbology Tab and Categories-Unique Values allowed setting the Value Field on various attributes. Selecting F-Scale revealed that of the 346 tornadoes, only five reached the F3 intensity level while fifty had no reading available. In the same way, selecting Month revealed that most tornadoes have occurred during the months of May through August. Any of these characteristics could be mapped.

4. A Spatial Join was performed in order to associate the MT_Tornadoes feature class with Counties_All. The result was that ArcMap joined the tornado locations in the MT_Tornadoes feature class to the individual county polygons in the Counties_All feature class. The procedure was to Select Counties_All in the Table of Contents, right click, and select Join, which opens the Join Data Dialog Box (Figure 5-17). In the pulldown menu, choose Join from another layer based on spatial location. Use the pulldown folder to navigate to the MT_Tornadoes feature class. Use the bottom window to navigate to the Tornado Feature Dataset in the geodatabase and give the new feature class an appropriate name, such as NumberTorndadoCty, and click Ok.
Once the NumberTornadoCty layer is added to the map, some decisions can be made. An inspection of the attribute table of this layer will show if the particular county of interest has experienced any recorded tornadoes. For some counties, the number is zero and the mapmaker may wish to stop at this point. Others may wish to map all the tornadoes across the state. An example of the results of this process is shown below (Figure 5-18).
Similarly, a thematic isarithmic density map could be constructed utilizing the Spatial Analyst extension. This process creates a raster grid of values that can be used to create isolines of equal density. The resulting map is similar to the choropleth map, but depicts distributions and numerical densities across the state much more precisely. An example is shown below (Figure 5-19).

![Isarithmic Density Map](image)

Figure 5-19, Isarithmic Density Map

The attribute table for the NumberTorndadoCty layer reveals that Valley County experienced the largest number of tornadoes (twenty-eight at this writing) during the period covered by the data. For this reason, the actual county map production will describe the procedure for mapping tornadoes in Valley County. Since this is a larger scale map, more information will be included.

Valley County was selected from the Counties_All layer and exported to form a new feature class called Valley_Cty and then added to the map. A basic Select By Location process was used to identify those tornadoes that have their centers in the
boundary of Valley County. The *selected features* were exported to form a new feature class entitled ValleyCty_Tornadoes, which was also added to the map. At this point, the Table of Contents can be cleaned up a bit by removing all of the features except the two just created.

Decisions need to be made regarding what type of additional information would educate the user as to the distribution of tornadoes in Valley County. For the sample map, roads, hydrography, urban areas, and a background hill-shade were used to best illustrate this distribution. These were each constructed using the selection and export processes described earlier from feature classes/raster datasets that cover the entire state. A listing of these statewide features and the resulting clipped or selected features is shown below.

<table>
<thead>
<tr>
<th>Feature</th>
<th>New Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT_Road</td>
<td>ValleyCtyRoads</td>
</tr>
<tr>
<td>MT_NHD_Streams</td>
<td>Valley_Cty_NHD_Streams</td>
</tr>
<tr>
<td>MT_NHD_Lakes</td>
<td>Valley_Cty_NHD_Lake</td>
</tr>
<tr>
<td>MT_Urban_Areas_2000</td>
<td>Valley_Cty_Towns</td>
</tr>
<tr>
<td>Mtshade</td>
<td>ValleyCtyHillshade</td>
</tr>
</tbody>
</table>

Since this is a much larger scale map, more information can be included to provide the user with a better understanding of the distribution and levels of intensity (F-Scale). Experimentation revealed that the best method to portray location and intensity levels simultaneously was to use appropriately colored *Graduated Symbols*. *Manual classification* was used to choose four classes that corresponded to the F-Scale rating. The *labels* were changed to equate to the appropriate F-Scale number, or No Data as appropriate. The Homeland Security Working Group symbol for a tornado was downloaded from their website, http://www.fgdc.gov/HSWG/index.html, and utilized in the map. In the example, tabular data with F-Scale definitions has also been incorporated into the map in order to provide a description of the potential damage tornadoes can cause (Map 5-14).
Tornadoes in Valley County
1952-2004

<table>
<thead>
<tr>
<th>F SCALE</th>
<th>WIND ESTIMATE (MPH)</th>
<th>TYPICAL DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>&lt; 73</td>
<td>Light Damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Some damage to chimneys, branches broken off trees, shallow-rooted trees pushed over.</td>
</tr>
<tr>
<td>F1</td>
<td>73-112</td>
<td>Moderate Damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peels surface off roofs, mobile homes pushed off foundations or overturned, moving autos blown off roads.</td>
</tr>
<tr>
<td>F2</td>
<td>113-157</td>
<td>Considerable Damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Roof torn off frame houses, mobile homes demolished, large trees snapped or uprooted, cars lifted off ground.</td>
</tr>
</tbody>
</table>

F-Scale Measurement

- No Data
- 0
- 1
- 2

Bruce A Koerner
Department of Geography
The University of Montana
Tornado Series
July 12, 2006

Map 5-14, Valley County Tornadoes
Winter Storm Event Natural Hazard Maps

The purpose of this set of maps is to portray the historical occurrence of winter storms and the associated loss of life and property damage. Unlike some of the other types of natural hazards, winter storm events seldom affect counties or reservations individually. More likely, they will frequently encompass larger portions of the state simultaneously. For this reason, only statewide maps will be developed in this section.

Winter Storms

Hazards associated with winter weather affect Montanans every year. While statistics are difficult to obtain, dozens of people die nationwide each year due to exposure to cold, associated vehicle accidents, fires, serious health issues, and so on. A major winter storm can last for several days and is normally accompanied by high winds, freezing rain or sleet, heavy snowfall, or cold temperatures.

Because of the paralyzing nature of winter storms on infrastructure, whole areas of the state may be immobilized. Highways and airports are often closed, thus stopping the movement of first responders and supplies, and making relief efforts more difficult. Accumulations of snow and ice often knock down trees and power lines, causing power outages for days or even weeks. Homes in rural areas may be isolated for extended periods of time, putting both people and livestock at risk. The cost of snow removal is normally a large portion of state, county, and community budgets. Moreover, lost business and damage repairs may result in additional severe economic impacts.

Three key components are required for the formation of a winter storm. First of all, for snow and ice to form, the temperature of the air mass must be below freezing. Secondly, there must be an adequate supply of water vapor in the atmosphere. This will often be supplied by air masses moving across the ocean or large lakes. And finally, the moist air mass must be lifted, causing a temperature drop resulting in the formation of clouds and precipitation. This may be caused by the moist air mass flowing up a mountainside or colliding with a cold air mass and being forced to rise. The figure below
shows a classic example of this process, resulting in snow over the Rocky Mountains and Great Lakes Regions (Figure 5-20).  

**Figure 5-20, Winter Storm Formation**

### Winter Storm Methodology

Two examples will be provided here. The data obtained from the National Atlas of the United States website, http://www.nationalatlas.gov/, will be used in the first example. This data was acquired from the database compiled by the University of South Carolina as part of their Spatial Hazard Events and Losses Database for the United States (SHELDUS). This is a county-level data set for a variety of hazards and was compiled from several sources, including the National Climatic Data Center (NCDC), the Storm Prediction Center, and others. The data covers the period of 1995-2000 and contains those events that were reported to the NCDC with a specific damage amount. According to the metadata, this dataset is designed for display and analysis of large regional areas and is most appropriate when used at scales of approximately 1:2,000,000 or smaller. The second example will consist of data acquired directly from the SHELDUS website.

---

Winter Storm National Atlas Data Acquisition and Processing. This section will outline the process of acquiring the data, processing, and importing it into ArcMap.

1. Navigate to the website shown above and Select the Mapping Professionals button in the upper right hand corner of the page. Scroll down and Select Raw Data and then Select Climate on the Raw Data Download page adjacent to Climate and Spatial Hazard Events and Losses for the United States, 1995-2000. Download the Raw Data Documentation titled November 2004 and the data titled sheld0t.tar.gz. Unzip the file. Open the DBF file titled shel18t in Microsoft Excel. This file contains the winter storm information reported for all states during this period. Copy the column headings and the rows for Montana into a new Microsoft Excel workbook and save it with a new name (MT_1995_2000_Data).

2. The goal is to create a table in dBASE IV format that can be joined to our MT_Counties_All feature class using the county FIPS codes. The fields STATE, COUNTY, and STATE_FIPS can be deleted from the table at this time. Create a new number field titled CTY_FIPS. Under the CTY_FIPS heading insert an appropriate formula to concatenate the state + county FIPS code into just the county code. Apply this formula to all rows. Save this file in dBASE IV format with an appropriate name (Final_MT_1995_2000_Data).

3. Open ArcCatalog and navigate to the MT_Template_Natural_Disasters geodatabase. Create a new feature dataset for this natural hazard (MT_WinterWeather) and import the spatial reference settings from one of the other feature datasets.

4. Open a new map in ArcMap and add the MT_Counties_All and MT_Boundary feature classes. Add the table Final_MT_1995_2000_Data as well. Right click on MT_Counties_All and Select Joins and Relates and then Join. Fill out the fields in the Join Data Dialog Box to join the table to this feature using the County FIPS code as the join field. Click OK. Open the attribute table of MT_Counties_All to check the join. Close the attribute table.

5. Right click on MT_Counties_All, select Data and Export Data in order to make the join permanent by creating a new feature class. Use the Saving Data window to navigate to the MT_WinterWeather feature dataset and name the new feature class (MT_Winter1995_2000).

Winter Storm National Atlas Data Mapmaking. In this case, the mapmaking process is concerned primarily with how to symbolize the Winter Storm data in order to portray the information correctly. According the metadata, if the storm event covered multiple
counties, the dollar losses, fatalities, and injuries were equally divided among the affected counties [emphasis added]. This complicates the process further in the sense of “how do you portray a portion of a fatality?” Additional features will be added to provide location detail to the map.

1. **Add** the layers MT_County_Seats and MT_NHS_Roads to the data frame. **Create a copy** of the existing data layer in the same layout. Examination of the attribute table of the MT_Winter1995_2000 feature reveals that property damage and fatalities are more meaningful than injuries. This is what the two data frames will portray. **Use the General Tab** of the Data Layer Properties Dialog Box to give them each an appropriate name, such as MT_Prop_Damage and MT_Fatality.

2. **Use** the Symbology Tab of the MT_Winter1995_2000 feature to choose an appropriate method to symbolize the death rate and property damage in the two data layers. In the example, four sequential graduated colors were used for each (red for fatalities and green for property damage). The Classification Dialog Box of the Symbology Tab was used for both feature classes to exclude zero values, set appropriate breaking points, and select the appropriate classification methods.

3. **Symbolize** the MT_County_Seats and MT_NHS_Roads features appropriately. Their purpose is to provide additional location information for the readers unfamiliar with Montana.

The following is an example of what the finished map should look like. (Map 5-15) Some caution should be used, however, when interpreting the map. First of all, the period of 1995-2000 covered by the data is not long enough to reflect any change in weather patterns. Moreover, it isn’t long enough to ensure the more severe winter storms are covered. It is, however, a long enough period to provide a snapshot view. We can also infer from looking at the property damage map that this characteristic of winter storms is not always associated with more densely populated areas. The northeast portion of the state has a relatively small population and yet experienced some of the most severe property damage. However, this was not true for fatalities, many of which are associated directly or indirectly with vehicle travel and accidents. Missoula County, one of the more populated areas of the state, had the greatest number of fatalities.
Cumulative Property Damage and Fatalities Due To Winter Storm Events, 1995 - 2000

Location Information
- County Seats
- Interstate Highways
- U.S. Highways

Property Damage in Dollars
- 1,400 - 5,000
- 5,001 - 50,000
- 50,001 - 250,000
- 250,001 - 550,000

Fatalities
- None
- Less Than One
- 1.00 - 1.50
- 1.51 - 2.18

Note: Fatalities resulting from storm events that affect more than one county are divided among the affected counties equally.
Winter Storm SHELDUS Data Acquisition and Processing. This section outlines the process of acquiring and processing the SHELDUS data, and importing it into ArcMap. There are several advantages to using this information. First of all, it covers a greater time span, thereby providing a longer historical record. Additionally, reported crop damages are included. And finally, it distinguishes between the various types and characteristics of winter storms.

1. **Navigate** to the SHELDUS website (http://go2.cla.sc.edu/hazard/db_registration), enter your email address in the registration block, and select Submit. This invokes the Damage by County download screen.

2. **Select** Winter Weather under Hazard Type, January 1, 1970 to January 1, 2005 under time frame, and Montana and All Counties under area of interest. **Select Submit.** This will invoke the next screen that will contain a sample of the data and download instructions. **Choose “Tab Delimited”** and follow the instructions to acquire the data. **Save it** as a .txt file with an appropriate name. (haz_utils1970)

3. **Open** haz_utils1970 in Microsoft Excel and work through the steps in the Text Import Wizard. The most important portion of this process is Step 3 of 3, formatting each column of data. **Select General** for numeric data, **Text** for text, and **Date** for date. Click finish. Expand the column widths as necessary to view the data. A brief examination of the date columns reveals what most Montana residents already know. Winter storms can occur in almost any month of the year. Also, under the column HAZARD_TYPE, the classifications of winter weather, severe storm, thunderstorm, and wind are used.

4. Follow the processes used in step two of the previous data acquisition and processing section in order to create a satisfactory table in dBASE IV format.

Winter Storm SHELDUS Data Mapmaking. The processes used here are similar to those used with the National Atlas data. **Do a Save As** with the previous map in order to preserve the layout and then **import** the haz_utils1970 table. The join process is slightly different and will be explained here.

1. In the previous map, the Final_MT_1995_2000_Data table was joined to the MT_Counties_All feature class in a one-to-one relationship. One row of data in the table was matched up with one polygon (county) in the counties feature
class. The situation here is that of a many-to-one relationship. Some counties have experienced numerous storm events.

2. Because of the nature of what we are trying to accomplish, the sequence of events is to summarize the INJUR, FATAL, PRP_DAM, AND CRP_DAM fields of the table based upon the CTY_FIPS field. Right Click on the CTY_FIPS heading of the attribute table and Select Summarize. Expand the fields listed and put a Check in the Sum Category for each. Save the output table and give it an appropriate name (SumStormByCty). Click Yes when asked to add it to the map.

3. The new table can now be joined to the MT_Counties_All feature using the steps outlined above. Use the same procedures to export the data and form a new feature class (MT_Winter1970_2004SHELDUS) and add it to both data layers of the map.

4. Use the same procedures to symbolize the two data layers using graduated colors. In the example shown below, the same color scheme was utilized in order to allow a better comparison of the results.

It is important to note that the longer period covered by the data provides greater validity. However, it was interesting to note that the pattern of damage and fatalities across Montana was relatively consistent in both. The addition of major highways and county seats provided enough general location information to orient the reader not familiar with Montana (Map 5-16).

One additional point must be made regarding the completeness of the data contained in both winter storm maps. Essentially, the data contains information reported and attributed directly to a particular storm event. Given the nature of these events and the lengthy Montana winters, some information must inevitably be missing. Complete damage assessments to buildings or infrastructures, losses of livestock, and so on may not be completed until spring. The impact of winter weather on the aged or infirm may be cumulative, but not fatal until some later date. Also, some areas of the state may have a better capacity to deal with this type of hazard. However, they do provide an indication of the historical susceptibility to winter storm events.
Cumulative Property Damage and Fatalities Due To Winter Storm Events, 1970 - 2004

Note: Fatalities resulting from storm events that affect more than one county are divided among the affected counties equally.

Property Damage in Dollars
- 142,160 - 520,000
- 520,001 - 900,000
- 900,001 - 1,275,000
- 1,275,001 - 1,700,000

Location Information
- MT_County_Seats
- Interstate Highways
- U.S. Highways

Fatalities
- None
- Less Than One
- 1 - 2
- 2 - 3.3

Bruce A Koerner
Department of Geography
The University of Montana
Winter Storm Series
October 15, 2006

Wind and Thunderstorm Natural Hazard Maps

The purpose of this series of maps is to cartographically portray the historical occurrence of high winds and thunderstorms in Montana. The text will describe the acquisition and processing of data for the entire state and the selection of an appropriate county to be mapped. Additionally, state inset maps will be provided when appropriate.

High Winds and Thunderstorms

Thunderstorms occur frequently throughout Montana. These storms often include numerous lightning strikes that may be accompanied by hail or tornadoes. The storms discussed here and depicted on the associated maps are an attempt to display thunderstorms and occurrences of high winds only. Instances of hailstorms and tornadoes have been addressed as separate issues. As with any type of weather event, the data was compiled from those storms that are reported to the appropriate agencies. Because of the large amount of unpopulated land in Montana, we must assume that some storms have taken places that were not reported.

Thunderstorms form as warm moist air rises rapidly into colder air, which causes the moisture to condense. This condensation process releases heat, which causes the warm air to continue to rise at an even faster rate in the form of updrafts. If the updrafts push air high enough into the atmosphere, the water droplets freeze in the upper portions of cumulonimbus clouds with the wide, flat anvil-shapes typical of thunderstorms. This upper portion is where lightening and thunder form.

Thunderstorms produce a number of different hazards across the country and in Montana. Lightening strikes kill an average of eighty-six people per year nationwide. In addition to potential loss of life in Montana, lightening is frequently responsible for wildland and structural fires. Strong winds often blow down trees, power lines, and can cause structural damage to buildings.4

High Wind and Thunderstorm Data Sources

The National Oceanographic and Atmospheric Administration’s (NOAA) National Weather Service Storm Prediction Center proved to be the best source of tabular historical data for wind and thunderstorms in the United States. Their website, http://www.spc.noaa.gov/archive/, has data available for download that covers the period from 1955 to 2004. We should note that data for some parts of the state starts much later than 1955 and is somewhat spotty until the 1980’s. This phenomenon is a function of the official weather observation and reporting capabilities in certain portions of the state at that time. Storms were occurring that are not necessarily reflected in the data.

High Wind and Thunderstorm Methodology

The processes for data acquisition and processing are discussed first. They are followed by the methods for actual template construction and use.

High Wind and Thunderstorm Data Acquisition and Processing. The processes used here to acquire and process the data are similar to that utilized in the section on tornadoes. To acquire the raw data, navigate to the NOAA website and scroll down to the title, Individual severe weather report elements. The data is retrieved by right clicking on Damaging Tstm Wind and saving the file FWIND5504 as a text document. This Storm Prediction Center (SPC) database comes in the form of an ASCII text, comma-separated value (CSV) file that contains hail data for the United States. You also need to download the MS Word document (hereafter referred to as Metadata) listed on the same webpage. This document is the same one acquired earlier for tornadoes and identifies each column of data in the file. Read it carefully to identify those columns of data that apply to wind and thunderstorms.

The concept for processing the data and preparing it for importation into ArcMap is the same as that used for the Tornado data. However, the size of the file caused some issues that had to be dealt with in the same manner as that for hailstorms. For this reason, these initial steps will be included in their entirety.
1. The file FWIND5504 contains all of the storm records for the United States and was too large to be imported directly into Microsoft Excel. The Statistical Program for the Social Sciences (SPSS) software was used first in order to extract the data for Montana from the file. Start SPSS and then open FWIND5504. This will invoke the Text Import Wizard dialog box. Accept the default settings for each of the six windows and click on finish. This will bring in the hailstorm data with the column values separated where the commas were located in the text file.

2. Click on data and then click on select cases in the drop down menu. This will invoke the Select Cases Dialog Box. In the Select window, select the If condition is satisfied button. Then click on the If button. This will open the Select Cases: If dialog box. We want hailstorms in Montana (FIPS code 30), which are listed in column (variable) V3 in the file. Click on V3 in the left window and move it to the window on the right. Then use the computer mouse to click on the appropriate buttons to make the condition V3=30 appear in the right window. Click on Continue. Once back in the Select Cases dialog box, in the Output window select Copy selected cases to a new dataset and give it an appropriate name (montanahail).

3. A new SPSS Data Editor screen will appear that contains only Montana hailstorms. Click on File and Save As. In the Save Data As dialog box, name the file (Montana_W_T_Storms) and save it as an Excel (*.xls) file. Close SPSS.

From this point on, the remainder of the data preparation will be done in a Microsoft Excel Workbook. The steps are almost exactly the same as those outlined in the section on tornadoes and will not be repeated here. They include changing the longitude values to negative numbers. Many of the columns will be blank and some are not required. After looking closely at the data, it is recommended that you delete the empty columns and keep the rest. In this case, all of the date and time information is important because these storms occur more frequently than tornadoes. In some cases, the same general area was affected two or more times in the same day. Knowing exactly when the data was recorded allowed confirmation of individual events.

High Wind and Thunderstorm Mapmaking. Once the work in Microsoft Excel is completed, the DBF 4 (dBase IV) file (Montana_W_T_Storms.dbf) was imported into the Table of Contents of ArcMap. Continue following the steps and procedures used in the Tornado section. Once again, the Spatial Join process was used to associate the storm
locations with the individual counties. The inset map shown below portrays the distribution of reported storms around the state (Figure 5-21).

Figure 5-21, Montana Wind and Thunderstorms

The attribute table of the resulting feature class, MT_Wind_TStorms_Cty_Join, listed 119 storms that occurred within the boundaries of Cascade County. This area was chosen for the wind and thunderstorm map template. The various statewide feature classes were clipped to extract information for Cascade County. The Homeland Security Working Group symbol for thunderstorm was used in the map. Some experimentation revealed that graduated symbols worked just as well here as they did for the Valley County Tornado map (Map 5-17).
Wind and Thunderstorms in Cascade County

Period Covered: 1955-2004

Damage in Dollars
- None
- Less Than 50,000
- 50,000 - 5,000,000
- 5,000,000 - 50,000,000

Bruce A. Koerner
Department of Geography
The University of Montana
Wind and Thunderstorm Series
August 6, 2006

Map 5-17, Wind and Thunderstorms in Cascade County
Hail Natural Hazard Maps

The purpose of this series of maps is to cartographically portray the historical occurrence of hailstorms in Montana. The text describes the acquisition and processing of data for the entire state and the selection of an appropriate county to be mapped. Additionally, state inset maps are provided when appropriate.

Hailstorms

Nationwide, hail causes approximately $2.9 billion damage annually. In Montana, the majority of this damage is to automobiles, roofs, crops, and livestock. Hailstones normally appear when warm humid air in a thunderstorm rises rapidly into the upper atmosphere and freezes. Ice crystals are carried up in the strong updrafts, collecting more and more ice until they are heavy enough to overcome these updrafts and fall to the ground. While hailstones six inches in diameter have been recorded in Montana, 1.5 inches or less are much more common. Hailstorms occur most frequently in the early spring and summer when the extreme temperature difference between the ground’s surface and the jet stream promotes the strong updraft winds necessary to create hail.\(^5\)

Hail Data Sources

The National Oceanographic and Atmospheric Administration’s (NOAA) National Weather Service Storm Prediction Center proved to be the best source of tabular historical data for hailstorms in the United States. Their website, http://www.spc.noaa.gov/archive/, has data available for download that covers the period from 1950 to 2004. It should be noted that data for some parts of the state starts much later than 1950 and is somewhat spotty until the 1980’s. This phenomenon is a function of the official weather observation and reporting capabilities in certain portions of the state at different time periods. Hailstorms did occur that are not necessarily reflected in the data.

Hailstorm Methodology

The method for acquiring, processing, and mapping hailstorms is very similar to that for tornadoes, and wind and thunderstorms. Detailed instructions will be provided for those areas that differ.

Hailstorm Data Acquisition and Processing. The data acquisition and processing steps used in this section were the same as those used in the previous section. This time, download the file titled HAIL5504 and process it in the same manner as before.

Hailstorm Mapmaking. Once the work in Microsoft Excel is completed, the DBF 4 (dBase IV) file (montanahailFINAL.dbf) can be imported into the Table of Contents of ArcMap. Continue following the steps and procedures used in the Tornado section. Once again, use the Spatial Join process to associate the hailstorm locations with the individual counties. In this case, the Spatial Join process was repeated with the MT_NA_Reservations feature class in order to associate hail storms with the Indian Reservations in Montana. The attribute table of the resulting feature class, MT_Res_Hailstorms, shows that the data contained 122 hailstorms that occurred within the boundaries of the Fort Peck Indian Reservation. Therefore, this area was chosen for the sample hailstorm map (Map 5-18). The same procedures were used to select or clip the from various state wide feature classes just that information pertinent to the area of Fort Peck Indian Reservation. Because of the configuration of the reservation boundary, a landscape view was used for the layout. The Homeland Security Working Group symbol for hail storm was downloaded from their website and incorporated into the map. Some experimentation revealed that graduated symbols work just as well here as they did for the Valley County Tornado map.
Earthquakes Natural Hazard Maps

The purpose of this series of maps is to cartographically portray the historical occurrence of earthquakes in Montana. The text will describe the acquisition and processing of data for the entire state and the selection of an appropriate county to be mapped. Additionally, state inset maps will be provided where appropriate.

Earthquakes

Montana is one of the most seismically active States in the Union. Since 1925, the State has experienced five shocks that reached intensity VIII or greater (Modified Mercalli Scale). During the same interval, hundreds of less severe tremors were felt within the State. Montana's earthquake activity is concentrated mostly in the mountainous western third of the State which lies within a seismic zone that also includes southeastern Idaho, western Wyoming, and central Utah.\(^6\)

An in depth discussion of how and why earthquakes occur is beyond the scope of this work. However, the United States Geological Survey’s (USGS) Earthquake Hazards Program website, http://earthquake.usgs.gov/, contains a great deal of information on this subject. Instead, this report concentrates on the types of damage earthquakes cause, methods of measuring their magnitude and intensity, and the current status of predicting earthquakes. It should also be noted that the Montana Bureau of Mines and Geology has done exhaustive work regarding earthquakes. Their Special Publication 117, *Probabilistic Earthquake Hazard Maps for the State of Montana*, contains an extensive set of maps and a detailed discussion of earthquakes in Montana.

“Earthquakes don’t kill people-falling buildings and highway structures do.” This loss of life often includes portions of structures falling on and killing the people in vehicles located near the structures. “Land use planning and building codes are the best defenses against deaths, injuries, and property damage in earthquakes.”\(^7\) The purpose of

---


\(^7\) Hyndman, Donald, and Hyndman, David. *Natural Hazards and Disasters*. California: Thomson Brooks/Cole, 2006
the template is to aid the individual counties in assessing the likelihood of an earthquake occurring and the manner in which lives may be lost or damage incurred. The development and implementation of appropriate building codes and land use practices at the state and local levels is beyond the scope of this project.

Earthquakes also cause loss of life due to their effect on lakes, mountains, dams, and other natural or man-made features. The largest earthquake in Montana's history was the magnitude 7.3 Hebgen Lake earthquake of August 17, 1959. At 11:37 p.m., Mountain Standard Time, the earth beneath Hebgen Lake suddenly warped and rotated, generating waves in the lake over one meter in height for about 1 1/2 hours. The first few waves were large enough to flow over Hebgen Dam, a concrete core earth filled structure that was completed in 1914. Although the dam's concrete core wall cracked in 16 places, only a minor amount of seepage occurred. The surface of the lake, which contained 324,000 acre-feet of water at the time of the earthquake, dropped more than three meters because of the violent geologic changes.

The main tremor triggered a major landslide in the Madison River Canyon, about nine kilometers downstream from Hebgen Dam. An estimated eighty million tons of rock (approximately forty million cubic yards of material) jarred loose by the earthquake slid down the south wall of the canyon. The slide formed a natural dam in Madison Canyon which blocked the flow of the Madison River and created a new lake. This lake filled to a depth of sixty meters within a few weeks and extended almost to Hebgen Dam. Damage to roads and timber was estimated at over $11 million.8

There are two primary methods of measuring earthquakes. The Italian seismologist Giuseppe Mercalli formalized the oldest method in 1902, before the invention of the seismograph. It was based upon how strongly people felt the shaking and the amount of damage caused. This is also referred to as the “intensity” of the earthquake. A modified version of the Mercalli Scale is still in use today. The Richter Scale, developed by Dr. Charles Richter, is the best known scale for measuring the magnitude of earthquakes. The scale is logarithmic, so a recording of seven indicates a disturbance with ground motion ten times as large and containing thirty-three times the energy as a recording of six. Earthquakes with a value of six are considered major and a

8 USGS, Earthquake History of Montana.
value of eight makes it a great earthquake. The chart below gives a comparison of the two methods (Table 5-5).³

Table 5-5, Comparison of Richter Magnitude and Mercalli Intensity Scale

<table>
<thead>
<tr>
<th>Richter Magnitude</th>
<th>Mercalli Intensity</th>
<th>Effect on People and Buildings</th>
<th>Velocity of Back and Forth Shaking (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>I - II</td>
<td>Not Felt By Most People</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>III</td>
<td>Felt indoors by some people</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>IV-V</td>
<td>Felt by most people. Dishes rattle and break.</td>
<td>1 - 8</td>
</tr>
<tr>
<td>5</td>
<td>VI-VII</td>
<td>Felt by all. Many windows and some masonry breaks/falls.</td>
<td>8 - 31</td>
</tr>
<tr>
<td>6</td>
<td>VIII-IX</td>
<td>People frightened; most chimneys fall; major damage to some structures.</td>
<td>31 - 116</td>
</tr>
<tr>
<td>7</td>
<td>X-XI</td>
<td>People panic; most masonry structures and bridges destroyed</td>
<td>116 - 150</td>
</tr>
<tr>
<td>8</td>
<td>XII</td>
<td>Nearly total damage to masonry structures, major damage to dams, bridges, railroad tracks</td>
<td>&gt;150</td>
</tr>
<tr>
<td>9</td>
<td>&gt;XII</td>
<td>Nearly total destruction; objects thrown into the air; ground surface moves in waves.</td>
<td></td>
</tr>
</tbody>
</table>

Earthquake forecasting involves attempting to determine the location, the magnitude, and the frequency of earthquakes. Generally speaking, forecasting earthquakes implies a timeframe of decades or longer. This becomes important when choosing sites and construction methods for major structures such as dams, power plants, and so on. These forecasts are generally based on past earthquake activity and are statistically relevant to this discussion. Earthquake predictions involve attempting to

determine exactly when an earthquake will occur. Predictions of this sort are not possible at this time.\textsuperscript{10}

**Earthquake Data Source**

The USGS Earthquake Hazards Program proved to be the best source of historical data for earthquakes in the United States. Their website, http://neic.usgs.gov/neis/Nepic/epic_rect.html, has data available in a variety of forms and time periods. The download process and the databases utilized for this portion of the template are somewhat different than those discussed previously and will be covered in some detail. It should be noted that the data consists of epicenters, or points on the earth’s surface, above the location of earthquakes, as closely as can be determined. The destructive effects of an earthquake may cover areas up to hundreds of square miles, depending upon its magnitude.

**Earthquake Methodology**

Data for earthquakes is downloaded and processed using tools that were similar to those used for tornadoes, severe winter storms, and thunderstorms. However, there are enough differences involved that detailed instructions are provided.

**Earthquake Data Acquisition and Processing.** Navigate to the website and review the process described for setting up the search parameters. The search parameters outlined below describe the process for downloading information from two databases that cover the same geographical area, a rectangle that encompasses all of Montana.

1. Output file type: Spreadsheet Format (comma delimited)

2. Data Bases: In order to get the most complete picture, two databases were chosen and the process was done twice in order to capture all of the data.

   **Data Base1:** USGS/NEIC (PDE) 1973-Present  
   **Data Base2:** Significant U.S. Earthquakes (1568 - 1989)

3. Rectangular Search Parameters: (this rectangle includes all of Montana)

\textsuperscript{10}Hyndman and Hyndman, *Natural Hazards and Disasters*, 64.
Click on Submit Search for the first database, and a list will appear that provides a listing of some 1,600 earthquakes recorded in the rectangle defined above. Copy them into a text editor program, such as Notepad, and then repeat the process for the second database. In database 2, select only those earthquakes listed before 1973 and copy them into the same file. This text file should be saved with an appropriate name, such as Rectangle Earthquakes. Copy the column headings into a separate text file and save them with the name Earthquake Metadata.

There are a number of ways to prepare the data for importation into ArcMap. The steps below outline one of the simpler processes.

1. **Open** the Rectangle Earthquakes file in Notepad and do a Save As, changing the file extension to .csv. Close the new file.

2. **Open** the new file in a blank Microsoft Excel Worksheet. The next step is to insert a new empty row at the top of the worksheet. Use the Metadata information to determine the appropriate column headings for all of the columns. Column headings should be all capital letters, no more than eight characters, and have no spaces.

3. The final task is to format the cells of each column appropriately. This can be accomplished by right clicking the letter above each column and selecting Format Cells. Use the Number Tab to select the appropriate category for each column. The logical choices are: Number for numbers such as year, latitude, and so on, and Text for codes such as the number of the month. When using the number code, ensure the appropriate number of decimal places is selected as well. The location data comes with a two decimal place level of precision. In Montana, this results in a latitude location precision of 1.11 km. When all this is completed, save the file again with an appropriate name (such as Rectangle_1872_PresentCombined.dbf), then save it again in .xls format just as insurance.

Note: at the time of this writing, the latitude and longitude values were in decimal degrees, which is the way they need to be for importation into ArcMap.
Earthquake Mapmaking. At this point the earthquakes can be placed on the map. Use the processes described previously to place the earthquakes on the map, create a new feature class of Montana earthquakes, and add it to the map. Open the attribute table of the new feature class and examine the column titled Magnitude. Most earthquakes listed have a very low magnitude or no data. The Richter scale table shows that earthquakes with a magnitude of less than 3.0 cause almost no damage and often go unnoticed. In an effort to clean up the data, it is necessary to insert one extra step at this point. Create a new feature class of those earthquakes that have a magnitude of 3.0 or higher.

Note: Do not join your earthquakes layer to Counties_All before doing this step.

1. Use the Select by Attribute function to select those earthquakes of magnitude 3.0 or higher. The figure below shows the settings and query to be used (Figure 5-22).

   ![Select By Attributes dialog box](image)

   Figure 5-22, Select Magnitude 3.0+

2. Click OK and the appropriate points will be selected. Close the Select by Attributes dialog box and use the Export Data tool to create a new feature class of the selected points. Give it an appropriate name (Mag3_MT_Earthquakes) and add it to the map.
Continue with the remainder of the steps at this point. Individual county maps depicting earthquakes are constructed in the same manner. The example here depicts earthquakes that occurred in Madison County. Additional information regarding transportation, hydrography, towns, and so on can be added as desired. Graduated symbols were used with the breaking points set for the appropriate spread of magnitudes. As before, the point symbol for earthquakes was acquired from the website of the Homeland Security Working Group (Map 5-19) (Map 5-20).

**Landslide Natural Hazard Maps**

The purpose of this series of maps is to cartographically portray the locations of and susceptibility to landslides occurring in Montana. The text discusses the characteristics and common causes of landslides and the acquisition and processing of data for the entire state. An appropriate county is selected for mapping and state inset maps are used when appropriate.

**Landslides**

The term landslide is defined as “the downward falling or sliding of a mass of soil, detritus, or rock on or from a steep slope.” \(^{11}\) Landslides occur in all fifty states and are most common in the mountainous areas of the country. Nationwide, they are one of the most costly types of disasters, resulting in excess of $3 billion damage and killing between twenty-five and fifty people annually.\(^{12}\)

In common use, the term landslide has come to include a wide variety of processes that are normally differentiated by the kinds of materials involved and the mode of movement. The reference contains excellent illustrations of each phenomenon, in addition to the table shown below. This table provides general information regarding

---


Earthquakes in Montana, 1872 to 2006

Number of Earthquakes Recorded Per County
- Yellow: 0
- Light Brown: 1 - 20
- Dark Brown: 21 - 50
- Orange: 51 - 148

Earthquake Magnitudes
- Green: 3.0 - 3.8
- Yellow: 3.9 - 4.8
- Orange: 4.9 - 7.7

Bruce A. Koerner
Department of Geography
The University of Montana
Earthquake Series
July 12, 2006

Map 5-19. Earthquakes in Montana
Earthquakes in Madison County
1872-2006

<table>
<thead>
<tr>
<th>Description</th>
<th>Richter Magnitudes</th>
<th>Earthquake Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>3.0-3.9</td>
<td>Often felt, but rarely causes damage.</td>
</tr>
<tr>
<td>Light</td>
<td>4.0-4.9</td>
<td>Noticeable shaking of indoor items, rattling noises.</td>
</tr>
<tr>
<td>Moderate</td>
<td>5.0-5.9</td>
<td>Can cause major damage to poorly constructed buildings over small regions.</td>
</tr>
<tr>
<td>Strong</td>
<td>6.0-6.9</td>
<td>Can be destructive in areas up to 100 miles across in populated regions.</td>
</tr>
</tbody>
</table>

Earthquake Magnitudes 3.0 +
- 3.0 - 3.8
- 3.9 - 4.8
- 4.9 - 6.2

Bruce A Koerner
Department of Geography
The University of Montana
Earthquake Series
July 12, 2006

Map 5-20, Earthquakes in Madison County
the type of movements and the materials normally associated with them (Table 5-6). It should be noted that all of these types of landslides have occurred in Montana at some point.

Table 5-6, Types of Landslides

<table>
<thead>
<tr>
<th>TYPE OF MOVEMENT</th>
<th>TYPE OF MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TYPE OF MATERIAL</td>
</tr>
<tr>
<td></td>
<td>BEDROCK</td>
</tr>
<tr>
<td>FALLS</td>
<td>Rock fall</td>
</tr>
<tr>
<td>TOPPLES</td>
<td>Rock topple</td>
</tr>
<tr>
<td>SLIDES&lt;br&gt;&lt;br&gt;ROTATIONAL&lt;br&gt;TRANSLATIONAL&lt;br&gt;LATERAL SPREADS&lt;br&gt;FLows&lt;br&gt;COPLEX&lt;br&gt;</td>
<td>Rock slide Debris slide Earth slide&lt;br&gt;Rock spread Debris spread Earth spread&lt;br&gt;Rock flow Debris flow Earth flow&lt;br&gt;(deep creep)&lt;br&gt;(soil creep)&lt;br&gt;Combination of two or more principal types of movement</td>
</tr>
</tbody>
</table>

Understanding why landslides occur is especially important to those involved in pre-disaster mitigation. For better understanding, causes of landslides are grouped into geological, morphological, and man-made categories. The list of causes in each category is extensive and was discussed in detail in the USGS Report, *Landslide Types and Processes*, referenced in the footnote below, and will not be listed again here. In most cases, some sort of triggering event is required in order to start a landslide. The most common triggers are seismic activity, volcanic activity, or water resulting in slope saturation. The detailed lists provide a starting point for a better understanding of landslides by officials. Other sources have simplified the characteristics and causes of landslides somewhat by consolidating them into categories of contributing factors (Table 5-7).

13 *Landslide Types and Processes*, 3.
14 *Landslide Types and Processes*, 4.
At the national level, the United States Geological Survey (USGS) has taken the lead in developing the strategy for landslide hazard mitigation. This effort includes the establishment of a Landslide Hazards Program, the primary objective of which is “to reduce the long-term losses from these (landslides) hazards by improving our understanding of the causes of ground failure and suggesting mitigation strategies.”\textsuperscript{16} In addition to their many other functions, they act as a clearinghouse for information and research on landslides, most of which is available free through their website http://landslides.usgs.gov/.

It is appropriate to discuss data and information available for mapmaking at this point. Much research has been conducted throughout the world related to answer the question of where and under what conditions landslides will occur. Because of the number of variables involved and their dynamic nature, this is an extremely difficult process. For example, a tree-covered mountainside might be stable today. But, heavy precipitation occurring after a major forest fire, extensive logging, or excavation could make it unstable.

One of the most comprehensive efforts to determine and graphically portray landslide potential throughout the United States was undertaken by the USGS. The

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Contributing Factors to Landslides} & \textbf{Stable} & \textbf{Unstable} \\
\hline
\textbf{Slope angle} & Gentle Slopes & Steep or vertical \\
\hline
\textbf{Local relief} & Low & High \\
\hline
\textbf{Climatic factors} & Temperature always above freezing & Freezing and thawing for much of the year \\
\textbf{Ice} & Film of water around soil particles & Oversaturation of soil with water \\
\textbf{Water in soil} & Frequent but light rainfall or snow & Long periods of drought with rare episodes of heavy precipitation \\
\hline
\textbf{Vegetation} & Heavily vegetated & Sparsely vegetated \\
\hline
\end{tabular}
\caption{Contributing Factors to Landslides}
\end{table}

results of this effort were published in 1982 as the *Landslide Overview Map of the Conterminous United States*. This map delineated areas where large numbers of landslides had occurred, as well as areas susceptible to landslides. It was designed to be used in large scale, or macro-scale, planning. The location and extent of individual landslides were not shown. Instead, larger areas were evaluated and classified as having high, medium, or low landslide incidence (number of landslides), or having high, medium, or low susceptibility to landsliding. The data used and discussed in the mapmaking section of this report was derived from this work. The results show that some Montana counties are much more vulnerable to this danger than others.

For those counties where landslides are a real danger, much more extensive work is required. As an example, the Seattle, Washington, area has been studied extensively in a collaborative effort for the purposes of mitigating potential disasters caused by this phenomenon. The results are contained in the USGS report entitled *Shallow-Landslide Hazard Map of Seattle, Washington*. Closer to home, the Montana Bureau of Mines and Geology (MBMG) has done extensive geologic mapping of the state. These maps are compiled at a larger scale (typically 1:100,000), and are more suitable for county level use. They are available for download from the MBMG website, http://www.mbmg.mtech.edu/, and are not reproduced here. Additionally, the MBMG has done more detailed work for some Montana communities, such as Billings, that is devoted specifically to landslides. As stated above, the process of determining the likelihood of a landslide occurring at a certain location or under certain conditions is a very complicated process. The mapmaking process described in the following section portrays a county’s overall potential for landslide activity. For those counties thought to be vulnerable, much more detailed professional study is normally required to establish the appropriate mitigation guidelines and procedures.

---

Landslide Methodology

The methodology used in the other map templates was followed here. Attention must be directed to the metadata, which provides information regarding the scale and appropriate uses of the information.

Landslide Data Acquisition and Processing.

1. The landslide data was acquired from the National Atlas website at http://nationalatlas.gov/atlasftp.html. From the homepage, scroll down and click on the Mapping Professionals link. On the next page, find the Raw Data link and click on it. Find the window titled Raw Data Download by Chapter and click on Geology. Scroll down to the field titled Landslide Incidence and Susceptibility. Download the data and the metadata in the shapefile format (lsoverp020.tar.gz) by clicking on the date. Unzip the file.

2. The shapefile contains landslide susceptibility information for the lower forty-eight states. The first step in processing is to extract the information for Montana and save it as a feature class in a geodatabase. Open a new session of ArcMap and add the Isoverp020 shapefile. Also add the MT_Boundary layer from your geodatabase. Use the Clip Tool to extract the Montana features from the dataset. Name the new feature (MT_Landslides) and close ArcMap.

Landslide Mapmaking. From this point, the remainder of the work was done in ArcMap. This is one of the simpler maps to produce because the data requires a minimum of manipulation.

1. Add the features MT_Boundary, MT_Counties, and MT_Landslides to ArcMap. The goal is to adequately display degrees of susceptibility and incidence while differentiating between the two. Because of this, two different sequential series of colors were selected. Additionally, the labels for each color were expanded to more adequately describe the condition portrayed. All of this work was done in the Symbology Tab of the MT_Landslide Layer Properties Dialog Box. Unique Values was selected in the Show Window and the INC_SUS Value Field identified. Adding all Values will invoke the six categories.

2. The MT_County_Seats and MT_NHS_Roads layers are added in order to provide the viewer with additional location information. Switch to the Layout View at this point in order to create a map. Add a legend showing only the landslide information, since that is the primary purpose of the map. The finished product should look something like the map shown (Map 5-21).
Map 5-21. Landslide Susceptibility and Incidence in Montana
Park County was selected because of the significant landslide activity in that part of Montana. The processes described previously (primarily Clip and Select by Attribute) were used to extract the Park County data from the various statewide layers. The symbol, label, and color schemes were imported from the Montana Landslide Map in order to maintain consistency. Since the goal was to portray landslide potential, only those communities with more than one hundred people were shown. Some experimentation was performed to determine the most appropriate data to use, with the results being listed below.

- Park_Cty
- Park_Cty_Pri_Sec_Roads
- Park_Cty_Hillshade
- Park_Cty_Landslide
- Park_Cty_Towns_100Plus
- Park_Cty_NHS_Roads

A secondary goal with the Park County map was to relate landslide potential to topography. To accomplish this, the Park_Cty_Hillshade layer was positioned at the bottom of the Table of Contents, with the Park_Cty_Landslide layer immediately above it. The object was to give the impression of draping the landslide layer over the hillshade. This was accomplished by experimenting with the Display Tab of the Park_Cty_Landslide Layer Properties Dialog Box. A setting of 50% achieved the best results, allowing one to see the general topographical features affected (Map 5-22).

**Wildland Fire Hazard Maps**

The purpose of this segment of the report is to provide some recommendations for cartographic products that focus on the mitigation needs of county and reservation officials in the area of wildland fire.

**Wildland Fire**

Wildland fires are one of the most expensive and destructive threats faced by Montanans today. This fact was discussed at the recent Montana Association of County Officials (MACO) conference in Bozeman, MT, on September 27, 2006. Bob Harrington, the Administrator of the Forestry Division of the Montana Department of
Landslide Susceptibility and Incidence in Park County, Montana

Map 5.22, Landslide Susceptibility and Incidence in Park County, Montana

Bruce A Koerner
Department of Geography
The University of Montana
Landslide Series
August 30, 2006
Natural Resources (DNRC) provided some facts regarding the not yet completed fire season.

1. The record-breaking 2006 season started in early July and continued without letup into the third week of September. The number of acres burned and associated costs exceeded those of 2000 and 2003, other record-breaking years.

2. Statewide, in all jurisdictions (federal, state, and local), there were 2,230 wildfires that consumed about 877,708 acres. Of these, 526 were categorized as large fires, each burning in excess of 100 acres. The cost to Montana state government for firefighting in 2006 exceeded $60,000,000.

3. All of the large fires and most of the small fires threatened some homes or infrastructure in the Wildland Urban Interface (WUI). More importantly, fires affecting the WUI are more dangerous and expensive, sometimes costing up to ten times as much to suppress as a pure wildland fire.

4. In addition to local and state firefighting assets, additional help was provided by other states, the U.S. government, and Canada. As the season progressed, acquiring outside assistance became very difficult because of large fires in other states.

Researchers have studied the extent and severity of the fire problem, as well as related issues such as fuels reduction, building codes, and funding options. The statistics were provided to the audience, composed primarily of county commissioners, as a prelude to discussions regarding how to deal with the problem. Preventive measures such as fuels reduction, building codes, and community education and outreach were all discussed.

The statistics were provided to the audience in the hope of stimulating a number of years. In its most basic sense, fire is a natural part of the landscape. However, this natural phenomenon has been made more severe in the last few decades due to years of the suppression, changes in climate, and changing population demographics, particularly in the western states. Most importantly, many people are choosing to build homes in or adjacent to forests and other wildland areas that are subject to wildfires.

In its most basic sense, fire is a natural part of the landscape. However, this natural phenomenon has been made more severe in the last few decades due to years of the suppression, changes in climate, and changing population demographics, particularly in the western states. Most importantly, many people are choosing to build homes in or adjacent to forests and other wildland areas that are subject to wildfires.

Researchers have studied the problem extensively for a number of years. In its most basic sense, fire is a natural part of the landscape. However, this natural phenomenon has been made more severe in the last few decades due to years of the suppression, changes in climate, and changing population demographics, particularly in the western states. Most importantly, many people are choosing to build homes in or adjacent to forests and other wildland areas that are subject to wildfires.

Researchers have studied the problem extensively for a number of years. In its most basic sense, fire is a natural part of the landscape. However, this natural phenomenon has been made more severe in the last few decades due to years of the suppression, changes in climate, and changing population demographics, particularly in the western states. Most importantly, many people are choosing to build homes in or adjacent to forests and other wildland areas that are subject to wildfires.
Risk Communities, guidelines for the development of Community Wildfire Protection Plans (CWPP), and prioritizes fuels reduction programs.\textsuperscript{18}

One of the most important developments resulting from the HFRA was the emphasis it placed on planning and prioritization at the local level. In its simplest sense, the HFRA provides communities with the opportunity to influence the manner in which fuel reduction projects occur on federal and nonfederal lands. This process is accomplished through the development of the CWPP. The minimum requirements for of the CWPP, as outlined in the CWPP Handbook, are:\textsuperscript{19}

1. **Collaboration**: Local, state, and federal government as well as other interested parties must participate in its development.

2. **Prioritized Fuel Reduction**: The CWPP must identify and prioritize areas for hazardous fuel reduction treatments and methods.

3. **Treatment of Structural Ignitability**: The CWPP must recommend measures that reduce the ignitability of structures in the area.

The Handbook also provides step-by-step instructions and recommendations for developing a CWPP. Step four of this process outlines the building of a community base map. The purpose of this map is to provide visual information from which stakeholders can assess and make recommendations regarding protection and risk reduction priorities. Recommendations for items to include in this map(s) are:

1. Inhabited areas at risk to wildland fire.

2. Areas of critical human infrastructure such as escape routes, municipal water supply facilities, power lines, and so on.

3. The community’s WUI Zone.

Step five of this process adds various types of risk assessments to the map(s). This includes identifying fuels on federal and nonfederal lands near the community, categorizing the relative frequency of fires in these areas, assessing vulnerability of homes, businesses, and essential infrastructure, and evaluating firefighting capabilities.\textsuperscript{20}

\textsuperscript{18} U. S. Congress, Healthy Forest Restoration Act, 108\textsuperscript{th} Cong. 1\textsuperscript{st} Sess., 2003. H.R. 1904.
\textsuperscript{20} Society of American Foresters 2004, 6.
Paula Rosenthal, Fire and Aviation Bureau, of the Montana DNRC, was able to provide information regarding the current status of CWPP’s. Of the fifty-six counties in Montana, fifty-three have elected to develop these plans. Approximately half of them are completed and are in various stages of implementation. Additionally, a statewide WUI map is under construction using the default distance of ½ mile from a community’s boundary. The HFRA allows communities to modify this default based on local needs and concerns. Once a CWPP is completed, the state WUI map is modified to reflect these. When constructing the various maps depicting fuels, risk assessment, fuel reduction priorities, and so on, many different methods and software types were used.\(^{21}\)

The Missoula County Community Wildfire Protection Plan has been completed and is available on the Internet at http://www.co.missoula.mt.us/des/CWPP.htm. It includes all of the maps discussed in the Handbook and a sample is shown below (Figure 5-23).\(^ {22}\) The work of mapping hazardous fuels and associated fuel reduction projects has already been completed and will not be duplicated here. In future PDM plan development or revision, the CWPP plans and their associated maps should be referenced and/or included as needed.

One of the most informative interviews for this section of the research was with Chief Scott Waldron of the Frenchtown Rural Fire District, Frenchtown, MT. Chief Waldron has been directly involved in the production and implementation of the Missoula County Community Wildfire Protection Plan. This effort included gathering significant amounts of data (triage the district) about the Frenchtown Fire District. But “gathering data accomplishes little if you don’t do anything with it.” At the county level, implementing fuels reduction programs, fire resistant building programs, and other direct action items are most important. Chief Waldron made these recommendations when asked about map products associated with wildland fire pre-disaster mitigation planning.

\(^{21}\) Paula Rosenthal, Fire and Aviation Bureau, MT DNRC, Interviewed by author October, 2006.
Figure 5-23, Fuels Reduction Priority Areas Map
Maps of the following items are important:\textsuperscript{23}

1. Transportation issues such as roads, escape routes, bridge capacities need to be identified.

2. You need to know where the structures are.

3. Water sources need to be identified.

The methods for developing map products associated with transportation and water sources for fighting wildland fire were demonstrated in the Location and Inventory Asset Map sections. The only changes necessary would be to produce them at a larger scale so more detailed characteristics could be shown. For most counties in Montana, this would involve building a series of maps in order to portray the entire county. Some field inspection work would also be necessary in order to verify the suitability of the water source, determine the best access routes, and establish any permission requirements.

Determining where the structures are located is another issue. Unlike urban areas, knowing where structures are located can be a problem in some of the rural areas of Montana. Many Montana Counties accomplished this process for residential structures several years ago as part of the E-911 program. Others are still in work. GPS technology was used to accurately locate and identify structures throughout the various counties. Additionally, the program includes a process for maintaining and updating this information.

The CAMA data introduced in the Inventory Asset portion of this project is another way to address this question, especially for non-residential structures. The examples shown here will once again use the data for Hill County, Montana, but could be applied elsewhere. Much of Hill County’s economy is based on agriculture which implies that many of the structures and other improvements are devoted to sheltering livestock, storing feed or machinery, and so on. Examples of identifying and mapping rural residential and other structures will be provided.

\textsuperscript{23} Chief Scott Waldron, Frenchtown Rural Fire District, Frenchtown, MT. Interviewed by author September, 2006.
Wildland Fire Methodology

This section of the research will focus on constructing map templates that make further use of the Cadastral and CAMA data in order to provide planning and mitigation information for counties and reservations.

Wildland Fire Data Acquisition and Processing. The procedures for acquiring the CAMA and Cadastral data for Hill County, Montana, have already been covered in Inventory Asset Section of this research. It should be noted that the CAMA data was developed and is maintained primarily for tax purposes. Because of this, those property parcels that are tax exempt for various reasons may not have structure data available. The examples shown here will primarily provide information regarding structures on privately owned parcels. Also, because of the larger scale map required for these examples, only that portion of the county near the community of Hingham will be mapped.

Wildland Fire Mapmaking. An examination of the PROPTYPE table in the CAMA data reveals a number of classifications for developed rural property that would potentially be of interest to the PDM mitigation process. These include Commercial rural (CR), farmstead rural (FR), industrial rural (IR), residential rural (RR), and so on. The first example will be to identify these parcels.

1. **Open** a new session of *ArcMap* and add the following features:
   - Hill_Cty_Towns and Hill_Cty_Boundary from the Hill_Cty_Inventory_Assets geodatabase;
   - GCDBSection and OwnerParcel from the Hill_Cty_Cadastral geodatabase;
   - and the ACREAGE, PROPTYPE, and the ACRETYPE tables from the Hill_Cty_CAMA geodatabase.

2. The extent of the data will be all of Hill County. **Use** the *Identify Tool* to identify Hingham and the *Zoom In* tool to zoom to the area around Hingham. The process will be to conduct a series of joins to identify certain types of rural parcels of interest. Because the join process has been discussed previously, only the sequence and the join fields will be outlined here.
3. **Join** the *ACREAGE table* (GEOCODE field) to the OwnerParcel feature class (ParcelID field). Then **Join** the *PROPTYPE table* (PROPTYPEID field) to the OwnerParcel + ACREAGE feature class (PROPTYPE field).

4. Make this Join permanent by **exporting** the *data* and **creating** a new *feature class* in the Hill_Cty_Inventory_Assets geodatabase. **Name it** appropriately (Hill_Cty.OwnerParcelAcreagePropTypeJoin) and **add it** to the map. The joins and tables can be removed at this point.

5. The goal of the next step will be to symbolize only those rural areas of interest. **Open** the *Layer Properties dialog box* of the new feature class and **go** to the *Symbology Tab*. In the *Value Field* **Select** PROPTYPEDESC and **Click on Add All Values**. This will invoke the default color scheme for all categories of property. The property types can be grouped or removed as desired. The *figure below* demonstrates one way to accomplish this (Figure 5-24).

![Layer Properties dialog box](image)

**Figure 5-24, Symbols for Property Types**

The map resulting from this process provides parcel locations where various types of structures are located. This is not a perfect solution for identifying structures for mitigation purposes, but provides a start. Also, other types of information contained in the CAMA data could be included to provide additional information. The map below demonstrates the initial results (Map 5-23).

Due to the nature of the CAMA data and some of the limitations of the ArcMap 9.1 software, mapping more detailed information, such as types and numbers of outbuildings, can become difficult. As an example, most farms and ranches have an
Stucture Locations Near Hingham, Montana

Property Categories
- Residential Property
- Commercial Property
- Farmstead
- Agricultural Land
- All Other Categories
- Roads
- Railroad
- Rivers and Streams

Bruce A Koerner
Department of Geography
The University of Montana
Wildland Fire Series
October 10, 2006

Map 5-23, Structure Locations
assortment of outbuildings. This assortment may consist of grain bins, barns, machine sheds, storage buildings, and so on. Additionally, the outbuildings may not be located on the same parcel of land as the home. The following procedure will demonstrate a method for mapping the number of outbuildings situated on a particular parcel of land.

For demonstration purposes, a similar area near Hingham, Montana, will be utilized.

1. Begin by doing a Save As of the Parcels_Hill_Cty map and call the new map OutbuildingParcels_Hill_Cty. Use the Add Data button to add the RESIMPOBY and OUTBUILDTYPE tables from the Hill_Cty_Cama geodatabase. Open both of these tables and examine them.

2. The purpose of the OUTBUILDTYPE table is to equate an outbuilding code with a text description of the structure. Similarly, the RESIMPOBY table is designed to link information about outbuildings to a particular parcel using the GEOCODE field. Furthermore, if a parcel has more than one type of structure, there will be a similar number of rows of data with the same GEOCODE. If a join were attempted at this point, the problem of a many-to-one relationship would be encountered.

3. The first step is to summarize the RESIMPROBY table based on the GEOCODE field. Left click on the GEOCODE column heading to select it, then right click and select Summarize. Expand the OBYQTY field and select sum. Export the table to an appropriate location and name it Bldg_Sum_Per_Geocode. Add it to the Table of Contents. The new table gives a total number of outbuildings per individual GEOCODE.

4. Join the new table to the OwnerParcel layer and open the Layer Properties Dialog Box when complete. Symbolize the parcels based upon the total quantity of outbuildings in the parcel.

This map of a segment of Hill County portrays the number of outbuildings located on parcels of rural land. The property boundaries were removed and the Roads feature added, which provides information regarding access to these parcels. If desired, specific types of outbuildings could be mapped as well. Once again, all of this would depend on the needs of the county as it pertains to the PDM plan mitigation process (Map 5-24).

The maps in this section presented some alternative ideas for maps designed to serve the purpose of wildland fire mitigation at the county or Indian reservation level. While not the only cartographic products that would serve this purpose, the focus was to stimulate
Outbuildings Near Hingham, Montana

Total Number of Outbuildings
- 1
- 2
- 3
- 4 - 5
- 6 - 8

Roads
Water Features
Railroad

Bruce A Koerner
Department of Geography
The University of Montana
Wildland Fire Series
October 10, 2006

Map 5-24. Total Outbuildings
thinking regarding the establishment of priorities of mitigation tasks and projects that can be accomplished at this level.

**Flood Natural Hazard Maps**

The purpose of this section is to describe the various characteristics of the flood events that might occur in Montana, the different types of data available, and the various map products that may be with it.

**Floods**

Floods in the United States account for about one-third of the annual dollar losses and up to 80% of the lives lost due to geologic hazards. The property loss statistics indicate these numbers are increasing as the average annual cost doubled between 1930 and 2000.²⁴

A flood is a natural event for rivers and streams and occurs when excess water from rainfall or snowmelt causes the river to overflow onto its banks onto the adjacent floodplains. Floodplains are lowlands adjacent to bodies of water that are subject to recurring floods. Hundreds of floods occur each year in the United States, killing an average of 150 people nationwide. Most of these deaths occur when people are swept away by flood waters. Floods are not necessarily seasonal and can occur at any time of the year in any part of the country. FEMA estimates that over nine million households are situated in various floodplains around the country.²⁵

**Flood Legislation**

In response to the increasing losses from flood hazards, the Congress of the United States passed the National Flood Insurance Act of 1968, which established the National Flood Insurance Program (NFIP). The purpose of this program was to provide for flood insurance within communities that were willing to adopt floodplain management programs to mitigate future flood losses. This legislation was expanded by


the Flood disaster Protection Act of 1973 which accomplished a number of things, one of which was to place increased emphasis on the need for floodplain mapping around the country. The NFIP is administered by FEMA.26

The risk data to identify floodplain areas are acquired through Flood Insurance Studies (FISs), which are hydrologic and hydraulic studies of flood risks developed by FEMA. Flood Insurance Rate Maps (FIRMs) are constructed from these studies depicting the spatial extent of the Special Flood Hazard Areas (SFHA). The SFHA is defined as the area subject to flood inundation having a one-percent chance or greater of occurring each year (also known as the one hundred year floodplain or base flood). This base flood is the national standard on which the insurance requirements of the NFIP are based.27

As GIS technology developed, FEMA implemented an automation program in 1992 to convert the paper based FIRM map products into digital format called Digital Flood Information Rate Maps (DFIRMs). These have evolved into digital products that are designed specifically for the creation of interactive multi-hazard digital maps. At the time this research was conducted, the only finished product DFIRM available from FEMA covered the Fort Peck Indian Reservation Area. Also, it is unlikely that compilation of DFIRM data for the entire state of Montana will ever be completed.28

As a substitute, FEMA has developed digital Q3 flood data, which is available for much of Montana. Although less comprehensive, it can be used for hazard mitigation, floodplain management, land-use planning, and other purposes. The Q3 Flood data is normally created by digitizing hardcopy FIRMs. Care must be exercised when using them due to the associated horizontal control issues.29

Floodplain Mapping

Currently, floodplain mapping for Montana is in a state of flux. Detailed digital map products are being constructed by various engineering firms for some of the more

---

populated counties. Others are engaged in performing this process with internal resources. Ultimately, those counties with both significant risk and significant population will have DFIRM data compiled for them. The current status of these efforts is available to the public at the Montana Flood Map Modernization Program website http://www.montanadfirm.com/. It should also be noted that DFIRM data is normally not suitable for mapping at the county scale. Larger scale maps are usually necessary for planning and mitigation purposes.30

The PDM plans reviewed for this research contained examples of most of these products. The time allowed for this project did not permit complete research in this area, but one additional factor became apparent during the PDM plan review. For the foreseeable future, some areas of Montana will not have Q3 or FIRM information available. Some guidelines for acquisition of maps and data that are available are contained in the publication FEMA 386-2, Understanding Your Risks.31

One of the plan developers overcame the data availability problem by using the following process. A generalized model of potential flood areas was developed by the creation of a map which incorporates hydrography, dams, and census blocks. The metadata and other sources for the hydrography feature were used to create individual feature classes for rivers, streams, and intermittent streams. Dams were added to isolate those hydrographic features upstream of any major flood control dam. Once isolated, the buffer tool was used to create an artificial flood plain using the following criteria:

- Rivers – 2500 feet each side
- Streams – 1750 feet each side
- Intermittent – 750 feet each side

The buffer areas were then intersected with the census blocks to isolate the population segments and areas most likely to be affected by flooding. The major fault of this

---

31 Understanding Your Risks, FEMA 386-2, July, 2004
method was that variations in terrain were not taken into account. It does provide an alternative to limitations based on data availability.\textsuperscript{32}

**Natural Hazards Summary**

This section of the research provided map templates suitable for most of the natural hazards that occur across Montana. The map making process outlined at the beginning of this research was utilized to gather and process the data, bring it into ArcMap, and construct the layout. In each case, localities that had experienced significant impact by the natural hazard were chosen to produce county or reservation maps. State maps were included in the report where appropriate. The portion on flood mapping was not developed fully because of time constraints and because the overall situation related to floodplain mapping is in a state of flux. Various agencies at all levels of government are working to compile DFIRM data and other map products that adequately portray risks associated with floods. More work will be required in this area in order to develop flood risk map templates suitable for use in PDM plan development.

Man-Made Disasters

The purpose of this segment of the research is to provide recommendations for cartographic products that focus on the area of man-made disasters. In many respects, this will be a continuation of the Location Map section that portrayed the natural and man-made characteristics of a county. This section will portray the manner in which we respond to a man-made disaster, either accidental, or intentional.

Man-Made Disasters

This portion of the thesis focuses primarily on two types of man-made disasters. The first is the broad category of incidents involving hazardous materials, primarily in the form of spills or discharges. An example of this type of disaster would be a tanker truck carrying gasoline overturning on the highway during a winter storm. The second category focuses on criminal activity, primarily in the form of terrorism or violence. Bombings are a common form of terrorist attack, both in the United States and abroad. We should also note that a single incident might have characteristics of both. The classic examples of this were the attacks on September 11, 2001 in New York and at the Pentagon. Criminal activity in the form of terrorists hijacking airplanes resulted in the discharge of large quantities of aviation fuel in a manner that resulted in fire and the loss of lives and property.

A qualitative assessment of the different types of disasters was included in the State of Montana Multi-hazard Pre-Disaster Mitigation (PDM) Plan that was completed in 2004. It should be no surprise that the participants ranked the combined impact of these disasters below any of the different types of natural disasters. In fact, terrorism was ranked below volcanic eruptions as a threat to Montana. The plan included a table listing specific incidents of this type that occurred in Montana during the period of 1979 to 2004.¹

A hazardous material incident, whether accidental or intentional, is a much more likely situation and can happen almost anywhere in Montana. First of all, hazardous materials are stored and/or used for a multitude of purposes throughout the state. Secondly, large quantities of hazardous materials are transported across Montana via the thousands of miles of highways and railways located here. This situation is made even more serious by the fact that many of the major transportation routes pass near the largest population centers in the state. Other important natural resources or critical infrastructure can be affected as well, creating a sort of domino affect. The state PDM plan indicates that 190 accidental releases exceeding 100 gallons of hazardous materials occurred in Montana between 1993 and 2004.²

For the purposes of PDM planning and mitigation (whether a hazardous material incident is accidental or intentional) may not be of critical importance. Numerous agencies are involved in the efforts to insure hazardous materials of all types are labeled, stored, protected, transported, and used in accordance with the appropriate guidelines and regulations. This is the critical first step in preventing incidents of this type or at least minimizing their affects. However, the PDM planning and mitigation process must operate on the assumption that hazardous material incidents will occur. Given that, areas of responsibility and procedures must be established that are clear for all to see. Training must be geared to address worst-case scenarios. Jurisdictional issues, memorandums of agreement, notification processes, sources of assistance, and the like are worked out in advance. Likewise, known sources of hazardous materials and/or likely mishap locations are identified whenever possible. The research conducted on this subject indicated that these issues have been addressed in detail throughout the state. First responders and others involved in emergency management at the local level know the answers to these questions. However, other government officials and the general public may not. The cartographic products constructed here are intended to provide basic information on this subject.

² State of Montana Pre-Disaster Mitigation (PDM) Plan. Pg. 3-59.
Methodology

This section will outline the processes used for constructing map templates for man-made disasters. Various additional options and ideas for their content will be presented.

Data Acquisition and Processing. The data used in this portion of the research was acquired from three primary sources. These include the CISDM project and NRIS, which have been discussed previously, and the Missoula County Mapping/GIS Department website: http://www.co.missoula.mt.us/Mapping_GIS/data_download.asp. This website is very well organized and provides access to many different types of data. No special instructions are required to use it.

The MT_Template_Man_Made_Hazard geodatabase was expanded to include the feature datasets shown in the following figure (Figure 5-25). Some Statewide Shapefiles from NRIS were imported directly into the MT_Hazard_Features feature dataset. In other cases, data for Missoula County was clipped from the statewide data and imported into the appropriate location. It is important to note that these three data sources are extensive and new information is being added continuously. The data used in constructing this set of maps should be considered a sample of what is available for Missoula County. This is not the case for all counties and Indian reservations in Montana.

![Figure 5-25, Man-Made Disaster Geodatabase](image)

Mapmaking-Missoula County Location Map and Population Density Map. In order for the reader to gain a sense of Missoula County, the first two maps constructed will be a Location Map and a Population Density Dot Map. The actual construction methods for these types of maps have been discussed in detail previously. A hillshade feature was
included in the Location Map to illustrate the varied topography of the county. Additionally, Missoula County contains large areas of national forest, lands administered by Montana Department of Fish, Wildlife, and Parks, and the Flathead Indian Reservation. These features were included in the Population Density map in order to explain why much of the county is devoid of population (Maps 5-25 and 5-26).

Mapmaking-Missoula County Rural Fire Districts. The purpose of this map is to display areas of responsibility for the various fire departments located throughout the county. Similar maps could be produced for law enforcement, ambulance service, or other categories of critical structures or infrastructures if desired.

1. The rural fire district boundaries were acquired from the Missoula County Mapping/GIS Department website, mentioned earlier. Once unzipped, this file was imported directly into the MT_Template_Man_Disaster geodatabase and then imported into the map. A distinct set of colors was chosen to represent the different districts.

2. The fire station feature class was part of the Critical Structures data obtained from the CISDM project. The fire stations located in Missoula County were clipped from the statewide data set and exported to the geodatabase mentioned above. The Homeland Security Working Group symbol for a fire station was utilized (Map 5-27).
Map 5-25, Location Map of Missoula County
Mapmaking-City of Missoula Police Patrol Zones. This map template depicts the patrol zones of the Missoula City Police Department. This dataset was also acquired from the Missoula County Mapping/GIS Department. Procedures similar to the previous map were used here. Likewise, these procedures could be used to portray fire station response areas for the city of Missoula if desired.

1. The Msla_Cty_Tiger_Roads feature class was positioned on top of the Msla_CITY_Police_Zones feature class for better orientation.

2. The Msla_CITY_Police_Zones feature class is broken down into four major zones with individual sub-zones. The four zones were given individual colors and the sub-zones were labeled. A 40% transparency was applied so that the general orientation of city streets could be identified.

3. The Msla_Cty_Police_Stations feature class was also extracted from the Critical Structures portion of the CISDM project. There are four law enforcement agencies that have offices in the city of Missoula. Only the Missoula City Police Department Headquarters is shown here (Map 5-28).
Map 5-28, Missoula City Police Patrol Zones
Mapmaking-Missoula County Hazardous Waste Sources. The final map of this series portrays a sample of the known events involving hazardous materials in Missoula County. The datasets used are just a few available from NRIS. The metadata for these layers needed to be examined carefully for before using in a map. Generally speaking, these are known sites of potential or actual hazardous waste spills that are being dealt with, or regulated, by the appropriate government agency. A sample of the other datasets available from NRIS is shown below.

- Coal Mine Permit Boundaries
- Montana Mining Districts
- Various Data Layers for Mining Activity Near Butte
- DEQ Petroleum Release Compensation Board Sites
- DEQ Remediation Response Sites
- Hazardous waste generated per city
- Groundwater Wells From GWIC

1. The datasets DEQ Underground Storage Facility Leak Sites, DEQ Non-Facility Petroleum Leak Sites, and DEQ Abandoned Mines Inventory were acquired from NRIS. These were unzipped, imported into the MT_Template_Man_Made_Hazard geodatabase, and imported into a blank ArcMap session. The Missoula County segments for each were selected and exported into the Msla_Cty_Hazard_Features feature dataset.

2. The base features of the Msla_Cty_Fire_Districts map were used as a starting point for this map. The new feature classes were added and symbolized appropriately. The result demonstrates that issues involving hazardous materials occur throughout the county and are especially prevalent in the most populated areas (Map 5-29).

Man-Made Hazards Summary

The map templates associated with man-made hazards concentrated on what is known about a county or reservation. Various types of response zones, or areas of responsibility, were illustrated. A method of portraying population densities, which typically represent the greatest potential loss of life, was also shown. Additionally, sites containing hazardous materials, known issues regarding problems with these sites, and abandoned mines were illustrated. The resulting map templates show that in many cases, man-made hazards occur in the more heavily populated areas, frequently along major...
Partial Listing of Hazardous Sites in Missoula County

Map 5-29, Partial Listing of Hazardous Sites in Missoula County

Legend:
- Reported Non-Facility Leaks
- Reported Underground Tank Leaks
- Abandoned Mines
- National Forest Lands
- Montana Fish, Wildlife, and Parks Lands
- Flathead Reservation

Bruce A Koerner
Department of Geography
The University of Montana
Manmade Disaster Series
November 1, 2006
transportation routes. This obviously makes the mitigation process that much more difficult.

**Cumulative Risk Maps**

In Montana, the types and degrees of risk to one locality are often significantly different from another. In the context of a PDM plan, a map portraying cumulative risk attempts to sum up the probable dangers to a county or reservation and display them visually. This subject was studied carefully, beginning with the examination of existing PDM plans. As shown in Table 3-1, of the ten PDM plans examined, five contained maps with this theme. Most often, the cumulative risk value, or factor, was associated with the census block feature for the area. Graduated colors were normally used to associate the degree of risk to the people and structures located within the boundaries of a particular census block.

The results of this process were not surprising. The census blocks in cities and towns were generally at greater risk than those in rural areas. This was a logical end since the cities and towns normally incorporate characteristics associated with risk. First of all, the people whose lives are put at risk are concentrated there. The majority of the structures and infrastructure within a county or reservation are also located there. Historically, cities and towns have often been located near rivers and streams, thus subjecting them to flood related hazards. Additionally, communities are frequently located near transportation routes used to move hazardous materials. Businesses within communities, such as gas stations and truck stops, routinely store and distribute hazardous materials. People are located in close proximity to larger structures at risk of destruction in case of an earthquake or tornado. These factors are not true of most of the more rural census block areas, many of which contain no people or structures at all.

After careful examination and research, it was determined that constructing a map template designed to portray cumulative risk for any county or reservation in Montana would be difficult to do. Among other factors considered, the limitations associated with data availability make this a daunting task. Additionally, the time limitations of this
research prohibited further investigation. Further research and examination of data will be necessary for the development of cartographic products that portray cumulative risk.

For those counties requiring a map of this type, Chapter Four of FEMA publication 386-2, *Understanding Your Risks*, outlines a step-by-step process for the creation of a Composite Map of estimated losses from various hazard events. Although a prototype composite map was not constructed during the project research, this Composite Loss Map fulfills the FEMA PDM plan guidelines and should meet the needs of Montana counties and reservations.

**Templates for County Pre-disaster Mitigation Plan Summary**

This section of the research focused on the development of map templates for county pre-disaster mitigation plans. The cartographic principles and methods portrayed in Section Four were incorporated into the processes utilized in their construction. The map making process, or steps, were outlined in the beginning of this section and incorporated into all of the maps produced. Detailed information regarding source material, characteristics of the potential disaster, acquiring and processing the data, and mapmaking were provided in each case. Where necessary, interviews were conducted with subject matter experts to assist in identifying those products that would most benefit county or reservation pre-disaster planning and mitigation. The map templates are divided into those general categories most frequently utilized in county and reservation plans. And most importantly, the templates serve as a basis for developing ideas and stimulating discussion regarding a number of issues. These include but are not limited to: mitigation priorities, additional desired cartographic products, the need for additional data development, and areas where new regulatory measures may be required.

Two areas will require further study in order to develop suitable cartographic products for PDM plans. These are maps associated with floods and those designed to portray cumulative risk. It should also be mentioned that attempts were made to

---

investigate other software used in mapping and analyzing man-made and natural hazards. The product mentioned most often was the Hazards U.S. Multi-Hazard (HAZUS-MH MR2) produced by FEMA. It is designed specifically to operate in conjunction with ESRI’s ArcGIS 9.1 program. Additionally, it contains standardized models for estimating potential losses from earthquakes, floods, and hurricane winds. Unfortunately, this software was under revision by FEMA at the time the research was conducted. Further work and experimentation with the HAZUS software is also recommended.
SUMMARY AND CONCLUSIONS

Summary

The Department of Geography of The University of Montana received a grant in 2006 from the Montana Critical Infrastructure GIS Committee (subsequently referred to as the committee) for the purpose of developing cartographic products for emergency management in Montana. This thesis represents the further development of a portion of that project and focused on the on the development of map templates for use in county and Indian reservation Pre-disaster Mitigation (PDM) Plans. The committee felt this work was necessary because of the nature of the cartographic products included in the PDM plans that had been produced since the enactment of the Disaster Mitigation Act of 2000. The purpose of the project and this thesis was to develop the methods to create standardized cartographic products that support PDM plans for county and tribal governments.

Three major groups of factors and events had converged simultaneously and resulted in the need for this research. First of all, Montanans are a diverse group of people and live in a diverse landscape. As such, their lives and property are at risk from a wide variety of natural and man-made hazards. Secondly, knowledge of these hazards and our ability to portray and analyze them has advanced significantly over recent decades. This is especially true since the advent of GIS and digital cartography. And finally, one of the primary means of reducing this risk is through the development and implementation of comprehensive and thoughtfully compiled PDM plans that contain well developed cartographic products. Additionally, basic goals and assumptions were developed in order to provide initial direction and guidelines for the research that subsequently took place. These are discussed in detail in Section One.

Section Two addressed the methodology utilized during the research conducted for the state of Montana and subsequently utilized for the development of this thesis. It was determined at the outset that legal standards for PDM plans would need to be examined and cartographic products suitable for use in plans developed for Montana.
would need to be identified. Likewise, cartographic principles applicable to PDM plans would need to be selected and outlined. And finally, map templates and the instructions for creating them would need to be developed.

Section Three begins with a detailed examination of the legal standards and associated “How to” guides for the development of PDM plans and the cartographic products they contain. Following this is a discussion of the investigation of existing plans and breakdown of the maps they contain. Additionally, the results of interviews, participation in DES exercises, and the project literature review are outlined.

The following section was devoted to a discussion of those cartographic principles and techniques that apply directly to the construction of maps suitable for use in PDM plans. The intent was to provide information, concepts, and principles of map making that will help to improve the quality of pre-disaster mitigation plans for Montana counties and Indian reservations. Additionally, a detailed discussion regarding the importance of selecting appropriate base map layers was included. Additional references were also provided.

The process that was utilized in the construction of all the map templates was established in the first portion of Section Five. In general, the steps were to acquire statewide data, acquire thematic data, process the data as necessary for importation into ArcMap, conduct any required analysis in ArcMap’s Data View, and then construct the map template in the Layout View. Additionally, priorities were set regarding the sources of data that would be used, geodatabase construction and conventions were outlined, and the spatial reference system that would be used throughout was selected.

The second portion of Section Five demonstrated the methods and techniques utilized in the construction of a variety of location maps. The mapmaking process outlined earlier was followed exactly and detailed instructions were included for each step. Also, it was here that many standards of style, format, font types, and other map elements were established, thus simplifying the overall mapmaking process. Most importantly, one of the key concepts of this thesis was reinforced. The map templates constructed here were meant to provide ideas and concepts, demonstrating some of the products that could be produced to aid the pre-disaster planning and mitigation processes.
Map templates associated with inventorying the natural and man-made assets within a county or Indian reservation were constructed in the third portion of Section Five. Once again, the templates fulfilled a secondary purpose of stimulating ideas regarding the content of cartographic products that best serve the needs of emergency managers in the area of pre-disaster mitigation planning. These needs will be as diverse as the landscape and population of Montana. The general subject areas included were property and structures, critical structures, high potential loss facilities, and population characteristics. Throughout the section, every attempt was made to illustrate the various problems encountered, ways of overcoming many of them, and areas where more work could be done. Additionally, various innovative methods of utilizing existing information were introduced.

Natural Hazards commonly experienced in Montana and the map templates depicting them made up the next portion of Section Five. In each case, localities that had experienced significant impact by the natural hazard were chosen to produce county or reservation maps. Additionally, state wide maps of some of the hazards were included where appropriate. The portion on flood mapping was not developed fully because of time constraints and because the overall situation related to floodplain mapping is in a state of flux. Various agencies at all levels of government are working to compile DFIRM data and other map products that adequately portray risks associated with floods. More work will be required in this area in order to develop flood risk map templates suitable for use in PDM plan development.

By necessity, map templates associated with man-made hazards, the next portion of Section Five, concentrated on what is known about a county or reservation. Since it is often difficult to predict where man-made hazards will turn into man-made problems, various types of response zones, or areas of responsibility, were illustrated. A method of portraying population densities, which typically represent the greatest potential loss of life, was demonstrated as well. Additionally, sites containing hazardous materials, known issues regarding problems with these sites, and abandoned mines were illustrated. The resulting map templates showed that in many cases, man-made hazards have often occurred in the more heavily populated areas, and frequently along major transportation routes.
The final portion of Section Five was devoted to a discussion of cumulative risk maps. This was the other area of the research that was not developed fully for the state project. As shown in Table 3-1, five of the ten PDM plans examined contained maps of this type. In many cases, graduated colors were normally used to associate the degree of risk to the people and structures located within the boundaries of a particular census block. Not surprisingly, the census blocks in cities and towns were generally at greater risk than those in rural areas. This would normally be where the population, their homes, and the local infrastructure would be concentrated. After careful examination and research, it was determined that constructing a map template designed to portray cumulative risk for any county or reservation in Montana would be difficult to do. Further research and examination of data will be necessary for the development of a map template that portrays cumulative risk.

**Conclusions**

The research for this thesis showed immediately that pre-disaster planning and mitigation in a state as large and diverse as Montana is a daunting challenge. Undoubtedly, this was a fact already well known to everyone involved in disaster and emergency services. The landscape, population demographics, and man-made features vary considerably from one county or Indian reservation to another. This is true of the potential natural hazards as well. As an example, some portions of the state are almost immune to tornadoes or earthquakes, while these natural hazards might be considered the greatest threat in others. Additionally, some areas might have little to fear from man-made hazards today. However, the development of new industry, shifting populations, or changes in transportation methods of toxic materials are just a few ways this situation could change significantly tomorrow. These are but a few of the reasons PDM plans are reviewed and updated every five years.

The reasons for undertaking this research at this time in Montana were presented in the introductory section of this thesis. Additionally, its value was verified by its recent publication on the Montana GIS Coordination website: http://giscoordination.mt.gov/criticalinfra/Projects/pdms.asp. Since DMA 2000 requires communities or local
governments across the nation to develop PDM plans, it is conceivable that the map templates and other information compiled in this thesis would be useful to DES personnel in other states around the country, many of which experience similar types of man-made natural disasters. In response to this question, copies of the report have been forwarded to the FEMA regional office for Montana. However, conversations with several Montana DES personnel and regional FEMA representatives revealed that little is known regarding the issue of states fostering a project similar to this one. Therefore, this is another area where additional research could be done.

It should also be noted that the cartographic procedures and map templates discussed in this thesis are both static and dynamic in nature. Generally speaking, the cartographic information developed in the section titled Cartography for Pre-disaster Mitigation Plan Maps will serve the needs of planners for the foreseeable future. New software, sources and types of data, or delivery methods will not change these concepts and standards appreciably. Maps will still need to serve the needs and physical characteristics of the human beings that use them. Proven map making standards such as balancing map elements, choosing appropriate symbols, and the selection of the optimal number and shade of colors will continue much as they are now. This is not true of the map content.

There are at least three primary ways that the map content will change. The first has to do with the information and data available. It has been stated throughout this thesis that the CISDM data, the information available from NRIS, and other primary sources are works in progress. New categories of information are added on a regular basis. Moreover, the different types of information are themselves dynamic in nature. As time passes, property changes hands (cadastral data), structures are added or removed (CAMA data), roads are built or improved (CISDM transportation data), and winter storms occur (NOAA or SHELDUS data). Because of these and other similar factors, attention will be needed to insure the best and most current information available is used in the PDM plan mapmaking process.

The second potential major change in map content has to do with the general category of science. Not surprisingly, the investigations conducted for this thesis revealed that researchers associated with government, private industry, academia, and
other institutions are constantly working to better understand the world we live in. Likewise, related work is being done to better analyze, describe, and portray new discoveries in this area. Some examples of this research include more accurate methods of estimating the damage caused by earthquakes, better predictive modeling techniques for estimating contamination areas for hazardous material releases, and so on. Some thought must be given by the appropriate government agencies to identifying and recommending for use the best scientific processes available for evaluating all types of risks.

The final, and possibly most important, change will happen because of the evolving needs of the counties or Indian reservations. Some counties in Montana are experiencing rapid population growth while others are in decline. In some areas, extractive industries are being supplemented or replaced by tourism, high tech industry, or other service oriented businesses. National defense requirements have caused some military installations to close and changed the mission of others. Transportation and industrial equipment and associated safety practices are continuously monitored and updated. For county and Indian reservation pre-disaster planning and mitigation purposes, this means the areas of concern will continue to change. Therefore, the content of the cartographic products needed to communicate these concerns must evolve as well.
BIBLIOGRAPHY


APPENDIX A

STATEMENT OF WORK

May 8, 2006

Methods and Procedures for Developing
Map Symbology and Cartographic Products for
Emergency Management in Montana

Montana Department of Administration/ITSD on
Behalf of the Montana Critical Infrastructure GIS
Committee – ODP Homeland Security Grant

And

The University of Montana
Geography Department – Social Sciences Research
Lab
# Table of Contents

- Project Title ................................................................. 8-3
- Project Manager - Contractor ........................................ 8-3
- Project Manager – Agency .............................................. 8-3
- Project/Task Objectives and Requirements ...................... 8-3
- Scope of Work, Deliverables and Acceptance Criteria - Phase 1 8-4
- Scope of Work, Deliverables and Acceptance Criteria - Phase 2 8-5
- Timeline and Period of Performance ............................... 8-7
- Compensation and Payment .......................................... 8-7
- Agency Staff, Roles and Responsibilities .......................... 8-7
- Contractor Performance Assessments ............................. 8-8
- Additional Terms and Conditions Specific to this SOW ....... 8-8
- Execution/Signature Block ............................................. 8-8
- Appendix I ................................................................. 8-9
Statement of Work

Project Title

Methods and Procedures for Developing Map Symbology and Cartographic Products for Emergency Management in Montana

This Statement of Work (SOW) is made and entered by and between MT Department of Administration/ITSD (Agency) and the University of Montana Geography Department (Contractor). The Agency and Contractor agree as follows:

Project Manager – Contractor

The Contractor’s Project Manager is:

Name: Paul Wilson  
Address:  
City: Missoula  
State and Zip: Montana 59812  
Phone: 406-243-4354  
Cell:  
Fax: 406-243-4840  
Email: paul.wilson@mso.umt.edu

Project Manager – Agency

The Agency’s Project Manager is:

Name: Stu Kirkpatrick  
Address: Weinstien Building, 101 N. Rodney  
City: Helena  
State and Zip: Helena, MT 59601  
Phone: 406-444-9013  
Cell:  
Fax: 406-444-1255  
Email: skirkpatrick@state.mt.us

Project/Task Objectives and Requirements

Timely, accurate, and easily communicated information is fundamental to the decision-making capability of any emergency response or preparedness mission. The real-time
capability to quickly visualize activity patterns, map locations, and understand the geographic context of emergency situations in a consistent manner should assist entities in providing an effective and efficient response to emergencies. The intended research will be divided into two phases. The first phase will be to develop a template or model for creating standardized cartographic products that can be used in the development of Montana County Disaster Mitigation Plans and to devise a system for building, storing, and delivering appropriate maps and other cartographic products in the event of an emergency. The second phase will be to continue to devise the methodologies involved in creating standardized map symbology that can be used to automate the delivery of discipline tailored map symbols for spatial data delivered by the Montana Critical Infrastructure and Structured Data Model (CISDM).

Scope of Work, Deliverables, and Acceptance Criteria

Phase 1 Scope of Work:

1. The team will study the county pre-disaster plan guide, develop a template for implementing county mitigation plans, and create a plan for assembling data that can be used by Montana counties for writing and illustrating their mitigation plans.
2. The team will participate in as many emergency management exercises, practice sessions, and meetings of principle disciplines as possible in order to learn more about and clearly identify how different disciplines view issues surrounding mitigation plans.
3. While under construction, the template will be shared with Montana Department of Emergency Services administrators and with a representative group of county mitigation officers for the purpose of allowing the research team to learn what types of cartographic products should be included and how they should be symbolized. Based upon this, a plan for assembling cartographic materials will be devised that can be used by all counties to help develop adequate plans.
4. A report will be produced and delivered to the Critical Infrastructures Committee regarding the findings of the team. In addition to the template and the plan described above, it will include an evaluation of the methods employed in the research and will make recommendations for further improvements.

Phase 1 Deliverables:

1. A template of cartographic products that can be used for implementing county mitigation plans. This will include:
   a. A complete listing of all information and source materials used in the creation of the template.
   b. Electronic and hardcopy version of the pre-disaster plan template that includes the complete structure of the plan, examples of text and tabular material, and a complete set of cartographic products.
2. Report on results of the investigation with recommendations concerning the direction of future work. This will include:

   a. The scope and objectives of the template.
   b. The methods used to develop the template
   c. Recommendations for the use and implementation of the template.
   d. Possible areas for monitoring and improving the quality of the pre-disaster plan.

3. A plan for distributing materials to the counties and for providing them with options for implementation, given their individual situations and technical capabilities.

Acceptance Criteria - Phase 1:

The following criteria will be used by the Agency to determine acceptance of the services and/or deliverables provided under this SOW.

1. Agency will read the initial report and consult the DES community to see if meets their needs and direction. Agency may recommend changes before acceptance.
2. Agency will examine the template and plan for illustrating county emergency response plans to see if the cartographic products described meet the requirements for the products required in the plans. Agency may recommend changes before acceptance.

Phase 2 Scope of Work:

1. The research team will gather symbol sets from national sources such as the Homeland Security Working Group (HSWG), National Incident Management System (NIMS), and others for use in establishing generic and specific discipline symbol sets for the emergency management disciplines within Montana.
2. Once the Montana thesaurus begins to mature, work will be done to learn how it classifies data and delivers it to the map so that the process of developing and classifying discipline specific map symbology can continue.
3. Information learned about the various disciplines in Phase 1 will be used to help structure symbology sets. It is anticipated that there will be a group of common symbols that will work for all disciplines.
4. Discipline specific symbol sets will need to be created, classified, and tested. Moreover, these symbol sets will need to be reviewed and approved by discipline experts throughout this process.
5. New symbology systems and symbols will need to be tested and evaluated in ongoing emergency management exercises and scenarios.
6. The team will also develop a plan for maintaining and updating map symbology.
7. A report will be produced and delivered to the Critical Infrastructures Committee regarding the findings of the team. This report will include the methodology involved in the development of symbology sets and their associated definitions, specifications, and aliases. These items will also be provided as part of a set of generic map symbols common to all, discipline specific symbol sets, and the method for maintaining and updating them.

**Phase 2 Deliverables:**

1. A working version of a standardized symbology system for emergency response compatible with the Montana Thesaurus and the Montana Critical Infrastructure/Structures Database delivered in electronic format. The standardized symbology system will include individual symbols sets for each user discipline as identified by research conducted in this project. Each symbol set will include:

   a. Symbols and names of all map features in the Critical Infrastructure/Structures Database that have been deemed universal to the various user disciplines.
   b. Symbols and names for map features that are unique to each discipline
   c. Alias names, definitions, and other information provided for all symbols as necessary.

2. A report to be delivered in electronic and hardcopy versions that describes and evaluates the methods for deriving the standardized symbology for emergency response to be used with the Montana Thesaurus to map spatial information within the Montana Critical Infrastructure/Structures database. This will include:

   a. A description of the abilities of the Montana Thesaurus and its related tables to deliver symbols to maps including their images, names, aliases, etc.
   b. Detailed guidelines for incorporating symbols sets and associated information into the Montana Thesaurus and its tables.
   c. Results of the interaction with representatives of the emergency management disciplines that allowed for the derivation of discipline specific symbols. This will include:

      i) A discussion of how the disciplines and their representatives were identified and contacted.
      ii) The methods utilized to identify their specific symbol requirements.
      iii) The methods used to validate ancillary information related to the symbols such as definitions, aliases, criticality ratings, etc.
      iv) The method of development of the symbols universal to all emergency management disciplines.

   d. Recommendations for dealing with improved technology, changes of CISDM and its associated thesaurus, and other factors that may demand change to the overall system at some future time.
e. The report will also include a plan for maintaining existing symbols, for incorporating emergency management disciplines not yet identified, and for modifying symbol sets already created.

**Acceptance Criteria - Phase 2:**

The following criteria will be used by the Agency to determine acceptance of the services and/or deliverables provided under this SOW.

1. Agency will read the initial report and consult the DES community to see if meets their needs and direction. Agency may recommend changes before acceptance.

2. Agency will examine the symbol style files and discipline specific classification of symbols to insure they link with CISDM and the Montana Thesaurus contained within CISDM. Agency may recommend changes before acceptance.

**Timeline and Period of Performance**

The period of performance for this project will start on May 1st and the work tasks are estimated to continue through Nov 30, 2006. The State has the right to extend or terminate this SOW at its sole discretion.

**Compensation and Payment**

Agency shall pay Contractor an amount not to exceed $44,773 dollars for the performance of all activities necessary for or incidental to the performance of work as set forth in the SOW. A detailed breakdown of costs is shown in Appendix I. Contractor may submit an initial invoice after delivery and acceptance of all deliverables from phase 1. Contractor may submit a final invoice after delivery and acceptance of all deliverables from phase 2.

**Contractor Staff, Roles and Responsibilities**

Paul Wilson, Professor, University of Montana Geography Department will serve as project manager. Paul will have oversight duties over all aspects of the project and will maintain the project schedule, timeline, and project planning revisions.

**Agency Staff, Roles and Responsibilities**
Stewart Kirkpatrick, GIS Bureau Chief, ITSD, will be responsible for project oversight and administering this contract. Eric Eidswick will assist with project oversight and quality assurance.

**Contractor Performance Assessments**

Not Applicable

**Additional Terms and Conditions Specific to this SOW**

None

**Execution/Signature Block**

In Witness Whereof, the parties hereto, having read this SOW in its entirety, do agree thereto in each and every particular.

<table>
<thead>
<tr>
<th>Approved</th>
<th>Approved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dick Clark, CIO</td>
<td>Paul Wilson</td>
</tr>
<tr>
<td>MT Dept. of Administration/ITSD</td>
<td>University of Montana Geography Dept.</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Signature</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Print or Type Name</td>
<td>Print or Type Name</td>
</tr>
<tr>
<td>Title</td>
<td>Title</td>
</tr>
<tr>
<td>Date</td>
<td>Date</td>
</tr>
</tbody>
</table>
## Statement of Work Budget Breakdown

<table>
<thead>
<tr>
<th></th>
<th>Phase I</th>
<th>Phase II</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salaries</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Wilson Salary</td>
<td>$1,200.00</td>
<td>$2,400.00</td>
<td>$3,600.00</td>
</tr>
<tr>
<td>Salary (2 Graduate Students)</td>
<td>$10,031.33</td>
<td>$20,062.67</td>
<td>$30,094.00</td>
</tr>
<tr>
<td><strong>Salary Totals</strong></td>
<td>$11,231.33</td>
<td>$22,462.67</td>
<td>$33,694.00</td>
</tr>
<tr>
<td><strong>Travel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Travel Totals</strong></td>
<td>$2,010.67</td>
<td>$4,021.33</td>
<td>$6,032.00</td>
</tr>
<tr>
<td><strong>Equipment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laptop Computer w/Monitor</td>
<td>$1,854.00</td>
<td>$1,854.00</td>
<td>$1,854.00</td>
</tr>
<tr>
<td>Portable Voice Recorder</td>
<td>$100.00</td>
<td>$100.00</td>
<td>$100.00</td>
</tr>
<tr>
<td>300 GB External Hard Drive</td>
<td>$300.00</td>
<td>$300.00</td>
<td>$300.00</td>
</tr>
<tr>
<td>80 GB Flash Drive</td>
<td>$150.00</td>
<td>$150.00</td>
<td>$150.00</td>
</tr>
<tr>
<td>Portable Printer</td>
<td>$80.00</td>
<td>$80.00</td>
<td>$80.00</td>
</tr>
<tr>
<td><strong>Equipment Totals</strong></td>
<td>$2,484.00</td>
<td>$2,484.00</td>
<td>$2,484.00</td>
</tr>
<tr>
<td><strong>Other Expenses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reproduction Costs</td>
<td>$500.00</td>
<td>$300.00</td>
<td>$800.00</td>
</tr>
<tr>
<td>Admin (1%) + Laboratory Use (2%)</td>
<td>$447.00</td>
<td>$896.00</td>
<td>$1,343.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$100.00</td>
<td>$200.00</td>
<td>$300.00</td>
</tr>
<tr>
<td>Communications</td>
<td>$40.00</td>
<td>$80.00</td>
<td>$120.00</td>
</tr>
<tr>
<td><strong>Other Expenses Totals</strong></td>
<td>$1,087.00</td>
<td>$1,476.00</td>
<td>$2,563.00</td>
</tr>
<tr>
<td><strong>Overall Totals</strong></td>
<td>$16,813.00</td>
<td>$27,960.00</td>
<td>$44,773.00</td>
</tr>
</tbody>
</table>

1: It is our intention to deduct any unforeseen non-salary expenses from the travel budget.

2: Equipment will be purchased in phase 1, but used throughout the project.