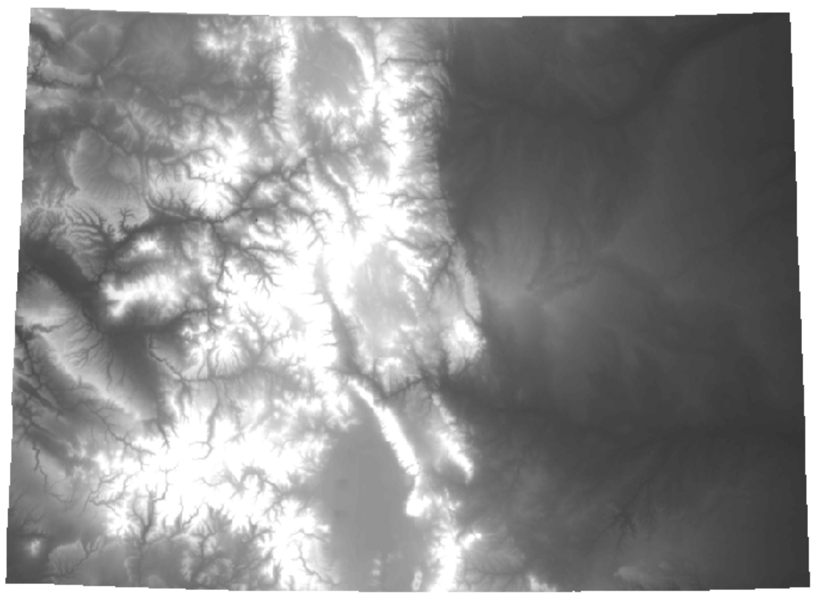
NATURAL HAZARDS RISK ASSESSMENT FOR THE STATE OF COLORADO



Prepared by:
GEOG 4230/5230 –
Hazard Mitigation & Vulnerability Assessment Class
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In support of:
Colorado State Hazard Mitigation Plan, 2004
State of Colorado, Division of Emergency Management

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1 INTRODUCTION

1.1 Purpose and Objectives

In October 2000, the United States Congress passed the Disaster Mitigation Act of 2000, referred to as DMA 2000. DMA 2000 was developed by the Federal Emergency Management Agency (FEMA) and amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1989. This act required that all state hazard mitigation plans be revised to "identify the natural hazards, risks and vulnerabilities of areas in the state" (DMA 2000).

Because the State of Colorado had a limited amount of time and resources available for the preparation of the Natural Hazard Mitigation Plan (CDEM, 2004), the original spatial evaluation of the natural hazards risk assessment (presented in Appendix F of CDEM, 2004) was somewhat limited. Marilyn Gally, the Colorado State Hazard Mitigation Officer, and Dr. Deborah Thomas at the University of Colorado at Denver and Health Sciences Center devised a project to improve the spatial evaluation of the existing natural hazards risk assessment. Students in the *GEOG4230/5230: Hazard Mitigation and Vulnerability Assessment* class completed this work during the fall, 2004, semester. This report summarizes and documents the work completed in support of the natural hazards risk assessment. It is envisioned that this report will be used to supplement and strengthen the next update of the state hazard mitigation plan.

The main objectives of this report are to:

- Identify and address potential data gaps in the state assets database provided by the Colorado Office of Risk Management.
- Correct the addresses provided in the state assets database so that building locations could be represented spatially in a map layer.
- Prepare maps which identify state assets that may be threatened by natural hazards and estimate potential losses.
- Identify potentially vulnerable populations that may be threatened by natural hazards.

1.2 Document Organization

In addition to this Introduction section, this report is organized into the following sections:

Section 2 summarizes the key terms that will be used in this assessment, discusses the concepts of vulnerability, social vulnerability and special needs populations, and summarizes several case studies from the literature on social vulnerability. This section also provides a summary of the risk assessment approach that will be utilized in the hazards assessment.

Section 3 provides information on how the spatial data layers for state assets, vulnerable populations, and natural hazards were created. This section details the process of identifying data gaps in the state assets database and geocoding building locations. It also summarizes the potential data issues and limitations encountered as part of this analysis.

Sections 4 through 12 each focus on a single natural hazard and contain information on the data sources, compilation and conversion methods, as well as limitations of the available spatial data for each hazard. Each section also summarizes the potential risks to state assets and vulnerable Special Needs populations as identified from spatial map overlays and summary tables.

Section 14 provides a summary of future research opportunities and recommendations to strengthen and supplement future risk assessments for natural hazards.

2 GENERAL CONCEPTS AND ASSESSMENT APPROACH

2.1 Key Terms and Concepts

For the purposes of this report, **risk** is defined as "the probability of harmful consequences, or expected loss (e.g., death, injury, property damage), resulting from interactions between a given natural hazard and vulnerable conditions" (UN, 2002). The purpose of a **risk assessment** is to "determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability" (UN, 2002). Based on this definition, a risk assessment must consider not only the hazard event itself but also the underlying vulnerability of the potentially impacted population. A risk assessment must also consider the resilience, or coping capabilities, of this population.

This concept of risk is presented in the following equation:

Risk = Hazard x Vulnerability / Resilience

Hazard - A given threat that has the potential to adversely impact humans and/or the environment.
Vulnerability - The susceptibility of a given population to a specified hazard event.
Resilience - The ability of a given population to withstand and recover from a specified hazard event.
(UN, 2002)

Based on this equation, it is possible for the same hazard event to yield very different predicted risks due to differences in underlying population vulnerability and resilience. For example, the predicted risks for two different towns from a single tornado event may be very different depending upon the factors contributing to the overall vulnerability and resilience of each community. Such factors can include, but are not limited to, the types of homes within each area (e.g., % of all residences that are modular homes), whether or not residences had completed tornado mitigation measures prior to the event, the socio-economic status, age, gender, and/or education of the community residents.

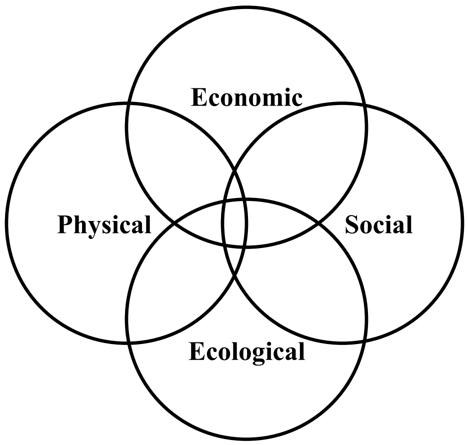
Risk assessments can be used to identify locations and populations that may be more likely to be adversely impacted by a hazard event. This information is vitally important when preparing hazard mitigation plans. Hazard mitigation planning is a dynamic process built on practical assessments of past and present information to anticipate future hazards and provide meaningful strategies to address possible impacts and identified needs. The primary objectives of any hazard mitigation plan are to reduce vulnerability and increase resilience, thereby reducing potential risks. While there are varying implementation strategies that can be adopted to achieve these goals, risk reduction strategies can usually be categorized as prevention, mitigation, or preparedness.

Prevention includes activities intended to altogether avoid the adverse impacts from a hazard event. For example, land use restrictions that do not allow for structures to be built within a floodplain area prevent potential risks to structures from flooding events. **Mitigation** efforts will limit or lessen the potential impacts from a hazard event. For example, existing structures in floodplain areas can be elevated to reduce the potential impacts from a flood. **Preparedness** encompasses activities that are conducted prior to a hazard event to ensure an adequate, timely, and effective response. Early warning systems and mandatory evacuations are examples of preparedness measures.

2.2 Vulnerability

2.2.1 Defining Vulnerability

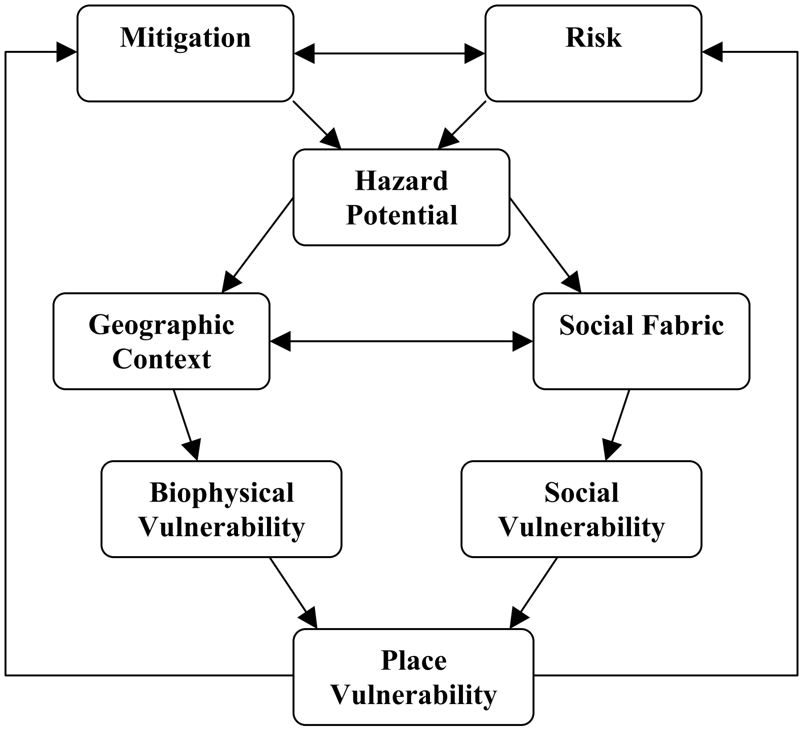
Originally, the concept of vulnerability was thought of solely in terms of structural integrity with regard to building construction and design. However, over the past 20 to 30 years, the notion of vulnerability has changed to include not only the built environment but also human populations. Vulnerability is shaped by several inter-related factors including physical, economic, ecological, and social conditions (UN, 2002).



Factors Influencing Vulnerability
(UN, 2002)

The term **vulnerability** can have different meanings and interpretations depending upon the context in which it is used. It can be characterized broadly, such as in Mitchell (1989), which defined vulnerability as “the potential for loss.” Vulnerability can also be described more specifically in regard to specific social, geographical, financial, structural, or environmental factors. For example, in a report entitled “Living with Risk: A global review of disaster reduction initiatives,” vulnerability is defined as “a set of conditions and processes resulting from physical, social, economical, and environmental factors, which increases the susceptibility of a community to the impact of hazards” (UN, 2002). While definitions for vulnerability may vary widely, a key concept in all is the susceptibility to potential hazards.

The figure below presents a hazards-of-place model of vulnerability developed by Cutter (1996) that illustrates the interactions between risk, mitigation, and vulnerability. As seen, the vulnerability of a place to a specified hazard, also referred to as “place vulnerability,” is a function of both biophysical and social factors. Biophysical vulnerability is based on the type of hazard, the frequency with which the hazard occurs, and the geographical context of the hazard event (Cutter et al., 2000). Social vulnerability is influenced by factors such as age, race and ethnicity, gender, education, disabilities, and financial resources (Cutter et al., 2000).



Hazards-of-Place Model of Vulnerability
(Cutter et al., 2000)

In the Flood Hazard Mitigation for Colorado report by Kistner, et. al, vulnerability is defined as "a relationship between occurrences of extreme events, the proximity of people to these occurrences, and the degree to which these people are prepared to cope with these extremes of nature." Two terms in this definition are important to highlight – proximity and occurrence. The proximity of a place or population to a hazard is important to understand when estimating potential risks and evaluating the effectiveness of mitigation strategies. The frequency with which a hazard occurs at a location is also important with regard to preparedness measures.

The definition for vulnerability provided by Tarek and Weeks (2003) focuses on another important factor – resilience. Vulnerability is described as "the degree to which socioeconomic systems and physical assets in urban areas are either susceptible or resilient to the impact of natural hazards." The authors focus on the resilience and vulnerability of the built environment as it relates to socioeconomic class.

As part of an analysis of the affects of Hurricane Mitch, the Consultative Group for the Reconstruction and Transformation of Central America (CGRTCA) described vulnerability as "any condition of susceptibility to external shocks that could threaten people's lives and livelihoods, natural resources, properties and infrastructure, economic productivity, and a region's prosperity" (CGRTCA, 1999). This description captures each of the facets that contribute to vulnerability. The analysis states that vulnerability is exacerbated in impoverished areas due to weak infrastructure, a failure to implement prevention and preparedness measures, and an inability to recover from a hazard event.

Cutter (2003) concludes that "vulnerability manifests geographically in the form of hazardous places (e.g., floodplains, remnant waste sites); thus, spatial solutions are required, especially when comparing the relative levels of vulnerability between places or between different groups of people who live and work in those places." In short, because vulnerability at a place is characterized by so many potentially inter-related factors, the best way to assess vulnerability is spatially.

2.2.2 Social Vulnerability

If the term vulnerability is to be defined as "the susceptibility of a given population to a specified hazard event," then the term social vulnerability focuses on the word "given." This word necessitates that there are differing populations, and they are distinguished by various social factors. These factors play a part in susceptibility, and they include gender, age, race, ethnicity, income, education, and special needs.

Not all social groups can or will be able to prepare for, react, and respond to hazards in the same way or with the same effectiveness. If the State desires to mitigate hazards in such a way that is fair to all, it must recognize that all social groups and situations cannot be treated the same. Social justice requires that special attention be given to certain disadvantaged groups, whether they are elderly, young, minorities, or poor.

A literature review reveals that relatively little attention has been given to the interaction of social vulnerability and natural hazards. Additionally, most Hazard Mitigation Plans fail to address the social vulnerability aspect, instead focusing solely on the hazard events and how to mitigate the effects of the events. Any attention given to the effect of hazards upon populations is done in a general way, with no consideration given to social factors within the populations.

2.2.3 Case Studies on Social Vulnerability

There are only a handful of case studies in available literature focusing on social vulnerability. Attachment 1 provides a summary of two cases studies on social vulnerability that have been conducted in the United States. Attachment 1 also provides a list of journal articles and books that address the concept of social vulnerability.

2.2.4 Vulnerability of Populations in Colorado

Colorado is vulnerable to an array of natural hazards (e.g., avalanches, floods, wildfire, and hail). For example, historical data indicates that the occurrence and frequency of hazard events in northeastern Colorado and Denver County may be more susceptible to severe weather events such as hail, high winds, and tornados. However, avalanches often impact mountain communities and highways, while flash flooding events often impact residential homes located in floodplain areas. A spatial analysis of vulnerability helps to identify locations and populations that may be at higher risk due to natural hazard events. A state-wide vulnerability assessment will help to identify areas in which mitigation efforts would be most effective in reducing potential risks, thereby reducing susceptibility and increasing resilience.

According to the US Census Bureau, about 9.3% of Colorado's 4 million-plus population lives below the poverty line (US Census Bureau, 2004). As stated above, socioeconomic status and poverty can increase a population's vulnerability to a hazard event. For example, poorer individuals are more likely to reside in mobile homes and substandard housing which are much more susceptible to damage in a tornado event. A spatial evaluation of vulnerability can be used as a tool that helps identify these susceptible populations and locations.

It is important to understand that an assessment of vulnerability attempts to show a relationship between human populations and their surrounding physical environment. Clearly defining and determining vulnerability is an important step in preparing effective hazard mitigation plans. By identifying vulnerable areas that are ill-prepared for a potential hazard event, risk managers can focus mitigation efforts on those areas that are most likely to benefit from mitigation measures.

2.2.5 Special Needs Populations

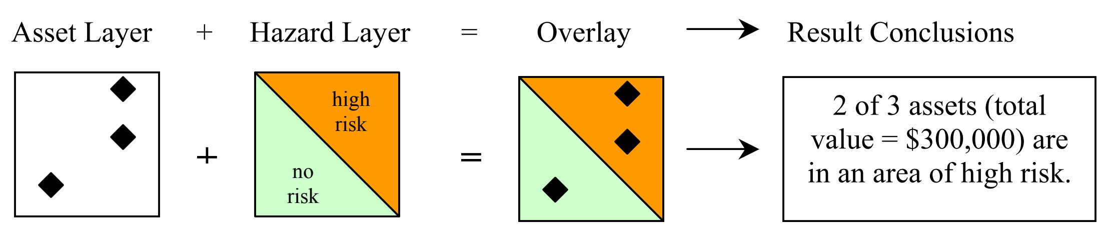
With the occurrence of a hazard event, the population groups that are most at risk are "Special Needs" populations. A Special Needs person is one who would require special assistance in the event of a hazard, more so than the average person. These populations include individuals (primarily non-workers) located in hospitals, nursing homes, group homes, schools, jails and prisons, and other such facilities. Special needs groups require assistance not just during a hazard event, but also before and after the event (i.e. during mitigation/preparation and response/recovery efforts). Disasters are socially created; therefore, mitigation efforts should focus on those populations that are most vulnerable. A spatial hazards evaluation of potential risks to special needs populations helps to identify visually where there is an intersection between the locations of hazard occurrences and Special Needs populations. This is essential in determining where to direct future efforts and resources.

2.3 Risk Assessment Approach

As stated previously, the primary objective of this report is to provide an assessment of potential risks in Colorado from natural hazard events. It is envisioned that this evaluation will aid the State of Colorado in designing natural hazard mitigation strategies and developing hazard response plans.

In accord with the Disaster Mitigation Act of 2000, state mitigation plans are directed to identify which state assets are potentially threatened by hazards and determine the magnitude, frequency, and probability of natural hazard event occurrences with respect to these assets. For the purposes of this report, state assets include buildings, building contents, vehicles, equipment, landscaping, and outdoor recreational facilities (CDEM, 2004).

In this assessment, potential risks to state assets were evaluated spatially using ESRI's ArcGIS® 9.0 software. State assets will be converted from a simple database of location addresses into a map "layer" of assets for the entire state of Colorado through a process called "geocoding". This assets layer can then be combined with, or "overlayed" with, other map layers which reflect the relative risk categories for each natural hazard. This overlay will then be used to identify the number of assets that may be threatened by a specified hazard event. The state assets data layer will also be used to estimate the total value ($) that may be at risk from a specified hazard event. A simplified example of this concept is illustrated in the figure below.



In addition to identifying potential risks to state assets from natural hazards, this assessment will also attempt to identify key vulnerable, or special needs, populations that may also be at risk. A similar overlay approach will be utilized for this evaluation.

Section 3 provides information on how each of these spatial data layers were created and compiled.

3 DATA ACQUISITION, MODIFICATION, AND COMPILATION

As described previously, this evaluation will utilize spatial overlays to assess potential risks to state assets and vulnerable special needs populations from natural hazards in Colorado. In order to perform this analysis, spatial data layers are needed which provide the locations of all state assets and any special needs populations. In addition, spatial hazard layers are required which provide estimates of the frequency, magnitude and relative risk associated with each hazard type for the entire state of Colorado.

All of the data utilized as part of this assessment are provided electronically in the attached report CD. Attachment 2 provides detailed information and documentation of the data sources, the methods used to create each spatial layer, along with the metadata for each layer from ArcGIS®. The following sections provide a brief summary of the information provided in Attachment 2.

3.1 State Assets

3.1.1 Data Sources

The state assets database was compiled by the Colorado Office of Risk Management (CORM) and summarizes assets within each of the 19 Colorado state government departments (Agriculture, Correction, Education, Health Care, Policy and Financing, Higher Education, Human Services, Labor and Employment, Law, Local Affairs, Military and Veterans Affairs, Natural Resources, Personnel and Administration, Public Health and Environment, Public Safety, Regulation Agencies, Revenue, State, Transportation, and Treasury), the Legislature, and the Office of the Governor (CDEM, 2004). State assets include, but are not limited to, office buildings, building contents, vehicles, equipment, monitoring sites, campgrounds, landscaping, restroom facilities, barns and sheds, classrooms and dormitories, prison facilities, hatcheries, workshops, training centers, and outdoor recreational facilities (CDEM, 2004).

The database was provided electronically as an Excel® spreadsheet by the State Hazard Mitigation Officer. This database provides information on the addresses of state assets, the value of the buildings and their contents, which buildings have sprinklers and alarm systems, the types of materials used in the building construction, and identifies which assets are located in a floodplain. There are a total of 6,028 records in the state assets database, which comprise more than 2,351 unique addresses/records. Of these, 50 could not be located and entered onto a map because of missing address and zip code data.

3.1.2 Addressing Identified Data Gaps

While the CORM spreadsheet provided an extensive database of state assets, there were two substantial data gaps that were identified – the University of Colorado at Boulder campus and the University of Colorado Health Sciences Center (UCHSC) Fitzsimons campus.

University of Colorado, Boulder Campus. Because the University of Colorado at Boulder (CU-Boulder) manages their own assets and do not participate in the state risk program, no campus buildings or housing for CU-Boulder was included in the CORM state assets database. Upon request, Cindy Davis, the CU-Boulder Campus Emergency Officer, was able to provide an Excel® spreadsheet of the CU-Boulder campus buildings as well as a CD containing pictures and building values for every building on every CU campus. Unfortunately, the data summarized in the CU-Boulder spreadsheet did not capture all of the same information as summarized in the CORM database (e.g. presence of fire and burglar alarms, sprinkler systems, type of roofing material). Although these fields in the CORM database could not be populated, the most important fields – building address and value – were present. A total of 209 records (167 unique addresses) for the CU-Boulder campus were added to the state assets database.

University of Colorado Health Sciences Center, Fitzsimons Campus. Data for the University of Colorado Health Sciences Center (UCHSC), Fitzsimons campus were included in one of the data files provided by the CU-Boulder Campus Emergency Officer. While only limited data were available for buildings on the Fitzsimons campus, the address and building value were available. A total of 15 records were added for the UCHSC Fitzsimons campus to the state assets database.

Other Potential Data Gaps. To ensure that no other significant data gaps were present in the state assets database, the blue government pages (state section) of the phone book were manually checked against the original CORM file. This task was made more difficult due to apparent address errors in the original CORM database and because building addresses in the original file were not identified using a standard naming convention. While 30 addresses were initially identified in the manual review for inclusion into the state assets database, 18 of the 30 were found to be either county or federal assets. The remaining 12 addresses were added to the state assets database.

3.1.3 Geocoding Process Methodology

"Geocoding" is a method in which address information provided in a tabular format is converted into spatial coordinates. This process is similar to using pushpins to identify address locations on a street map. GIS applications, such as ESRI's ArcMap® utilize an algorithm to automate this geocoding process. In order for geocoding to be successful (i.e., match the table address to a map location), the addresses must be provided in a specific format, and must have valid entries for each input field. If a geocoding algorithm is unable to match an address, this location must be manually matched using an interactive matching process. The details of the geocoding process (and documentation of changes in addresses made in the interactive process) are recorded in the state assets directory of the data CD in three documents: 1) 'FloodandNonflood State Assets Geocoding Changes Documentation.doc'; 2) 'Methodology.doc'; and 3) 'Start to Finish.doc'.

CORM State Assets. The original state assets database was geocoded in two steps: 1) those in the floodplain and 2) those not in the floodplain. Those not in the floodplain consisted of over 6000 address that actually represented 1830 unique addresses. The values were summed for all of them and a single point created for each of the unique addresses. All state assets in the floodplain were geocoded.

CU-Boulder Campus. Because the CU Boulder addresses generally listed a building on campus, the most recent campus map was utilized and the points interactively placed in the GIS layer. Using this method all of the locations were located, representing 216 places.

UCHSC Fitzsimons Campus. The Fitzsimons campus only had 15 building addresses that required geocoding. The matching success for these addresses was 100%.

3.1.4 Data Issues/Limitations and Additional Data Gaps

Not all of the addresses in the database (50) could be geocoded because of incorrect or inadequate information. In addition, many of the records were missing the building and content values, which are vitally important for the purposes of determining exposure. There was also limited information for other high-value assets such as vehicles and heavy equipment. There could potentially still be some data gaps in the state assets database, but without comprehensive inventories from each department/agency it would be impossible to identify these assets. Also related to this, some of the assets in the database were not actually owned by the state. Generally, the overall quality of matches was fairly good.

Geocoding Quality	
Number matched with score of 80-100	1,592
Number matched with score less than 80	246
Number tied with score 80-100	78
Number tied with score less than 80	16
Number matched to the zip code centroid	231
Number matched manually	138
Number missing	50
TOTAL	**2,351**

3.2 Special Needs Populations

When assessing potential risks, it is necessary to evaluate not only the exposure of specific locations to a hazard, but also the vulnerable populations that may be impacted during the hazard event. Initially, the scope of work for this project included an evaluation of both populations that were located in state buildings (e.g., personnel) as well as Special Needs populations. Unfortunately, an inventory of state owned/leased buildings as provided by the State Buildings Department was of limited use in evaluating personnel populations. For this project, the population vulnerability assessment focused only on 'special needs' populations, regardless of whether they were located in state buildings. Data were gathered on special needs populations within four specific areas: hospitals, schools, detention facilities (jails/prisons), and group homes.

3.2.1 Hospitals

Hospitals are crucial infrastructure in any disastrous event to attend to casualties. They can also be located in risky areas. Hospitals have a high number of people who are immobile and are seen by the general populace as places of refuge and care. If a hospital is susceptible to hazards or danger, then the need for population management and notification is crucial, as well as the evacuation of current patients. Total bed counts were analyzed to give emergency managers an idea of either capacity or potential numbers needed to be evacuated.

Data Sources.
The layer and data retrieved for analyses were acquired from the Colorado Department of Public Health.

Process Methodology.
The data connected to the layer were initially in a text format, which was changed using Microsoft Excel, so that the TOTBEDS column in the layer could be used for analysis.

Data Issues/Limitations and Identified Data Gaps.
The dependence of rural communities on critical care facilities cannot be underestimated. The number of care givers (doctors, nurses, etc.) is also not an established population within the available data.

3.2.2 Schools

Schools were identified as having significant populations that would require special attention should a hazard event occur. A school population is, in general, not a mobile one. Many students are car-pooled or take the bus to school, which could pose significant problems should the school need to be evacuated quickly and efficiently.

Colorado school enrollment (K-12), grew by 29% in the last decade, and is continuing to grow rapidly. In just ten years, the number of students could increase by over 100,000 - from 790,000 in 2000 to 900,000 in 2010. It could easily surpass one million by 2025. Another 10,000 public school students per year would require the construction of at least 20 new schools every year. In Douglas County alone, a planning committee has estimated the county will need ten new schools in the next five years to keep up with its population. (Jobe, 2004)

With this amount of growth, it is important that schools are identified as holding large vulnerable populations, and appropriate planning measures should be taken to decrease their vulnerability. In addition, schools can house smaller populations of special need groups. These groups include:

> *English-language learners* - All students whose first language is not English are counted as English language learners. Limited English proficiency could cause difficulty in that student or their families receiving a warning efficiently, while this group could not be counted individually, it is important to include them in the assessment of this data as Colorado has a large Hispanic population.
>
> *Low-income students* - Many districts identify these students by those who qualify for free or reduced-price lunches. This data is also not available to the public, however it is important to identify that these students are large percentages of the overall school population. This may be especially true in smaller, more economically challenged towns across Colorado.
>
> *Special education students* - All students with individualized education programs should be included as well. These students may require special transportation as they may be confined to a wheelchair or not individually mobile at all. Again, this data is not publicly available, or it would have been included in the data.

Originally, the goal was to identify not only school data, but also data on all daycare facilities located within the state. Due to time constraints and the fact that information on daycares could not be given out because of security measures, it was concluded that incorporating daycare information into the hazards risk assessment was not feasible.

Data Sources. Relevant data for Colorado schools were first identified on the Colorado Department of Education website (CDE, 2004). Upon request, the Colorado State Department of Education provided an Excel spreadsheet that included data on public and non-public schools, as well as K-12, vocational/technical schools, and colleges, for the 2003 school year. This spreadsheet provided the schools name, address, phone number, contact person, and school size. There were 861 public schools and 407 non-public schools identified for the State of Colorado. While this dataset was compiled as a start to improving the understanding of this group's vulnerability, the schools from the HAZUS-MH Colorado data were utilized for the for the purpose of analysis because it was deemed to be more compete.

Process Methodology. The Excel spreadsheets provided by the Colorado State Department of Education were formatted and uploaded into ArcMap. Initially, 71.1% of the school addresses could be matched using a geocoding algorithm. Any addresses that could not be geocoded were matched using Mapquest.com and Switchboard.com. One of the limitations of the data as originally provided by the state, was that the available addresses had been compiled for the purposes of mailing. Because of this, some addresses did not represent a physical building location (e.g., P.O. Box). Those addresses that were not physical locations had to be cross-referenced on the Internet (GreatSchools.net, 2004) and a physical address was manually added. After making these address corrections, 77.1% of the school addresses were able to be geocoded successfully. For public schools, 198 of 861 addresses were unable to be matched. For non-public schools, 76 of 407 addresses were unable to be matched.

Data Issues/Limitations and Identified Data Gaps. As stated above, no information could be located for daycare facilities or preschools. In addition, information was not provided on class sizes (i.e., number of students) due to security issues. While there appear to be a few counties that are missing schools data such as Jackson County and Lincoln County; schools where larger populations are expected to exist appear to be complete.

3.2.3 Detention Facilities

The inmate population in a jail or prison is of special concern should a hazard event directly impact a detention facility. Inmates are a Special Needs population because, not only are they unable to make decisions for themselves in regards to protective measures or evacuation, but it is crucial that they be kept in custody throughout a hazard occurrence.

Data Sources. The data for detention facilities was gathered from pertinent Internet websites and includes county jails, state prisons, and federal prisons. County data was provided by the County Sheriffs for Colorado (CSOC, 2004), state data was provided by the Colorado Department of Corrections (CDOC, 2004), and federal data was provided by the US Department of Corrections, Federal Bureau of Prisons (FBOP, 2004). For each detention facility, the following data were collected - facility name, address, city, zip code, phone number, and inmate capacity. Complete data were lacking for approximately half of the facilities. Therefore, phone calls were placed to detention facilities in order to obtain data that were not readily available on the Internet sites, as well as to verify address information and inmate capacity. A total of 96 detention facilities were identified for the State of Colorado.

Process Methodology. All data for detention facilities were input into Excel spreadsheets, and relevant comments were entered as needed. Shapefiles of Colorado counties and roads/streets were downloaded from the Colorado Department of Transportation website (CDOT, 2004) and added as layers in ArcMap. Each Excel spreadsheet was imported into ArcMap and the facility addresses were geocoded. Approximately half of the addresses were able to be matched automatically using geocoding. The remaining addresses were matched using MapQuest.com and FEMA's Flood Mapping website (FEMA, 2004). All of the 96 detention facilities were successfully geocoded.

Data Issues/Limitations and Identified Data Gaps. The number of people incarcerated each year is increasing at an alarming rate, and new facilities are regularly being built. Therefore, the potential number of inmates at risk and affected facilities are unknown quantities for the future. Additionally, the inmate capacity at each facility is not a count of what the inmate population will be at the time of a hazard event – the inmate count is often less than capacity, but sometimes exceeds capacity (i.e. overcrowding conditions).

3.2.4 Group Homes

Group homes, such as assisted living facilities and drug rehabilitation centers, were identified as a Special Needs population because individuals in these locations may need medication, medical devices, and/or restraints and may not be easily transportable.

Data Sources. Data on group home locations were obtained from the Health Facilities Locator on the Colorado Department of Health website (CDOH, 2004)

Process Methodology. These were copied and pasted electronically to create a file that could be geocoded.

Data Issues/Limitations and Identified Data Gaps. While data identifying the locations of group home facilities were available, information on capacity and staff was not provided.

3.3 Natural Hazards Data

For the purposes of this assessment, risks from the following natural hazards were evaluated – avalanche, drought, earthquake, wildfire, flood, landslide, severe weather (hail, tornados, high winds) – in relation to state assets and vulnerable populations. The data management process involved the identification and compilation of hazard data and the refinement of existing data sources. A detailed summary of the natural hazard data sources, process methodology, potential data issues, and identified data gaps is provided as part of each hazard-specific risk assessment section (Section 4 through Section 12).

4 RISK ASSESSMENT - AVALANCHE

4.1 General Information

Avalanches occur when the gravitational stress pulling snow downhill exceeds the bond strength between grains of snow in the snow cover. According to the Colorado Avalanche Information Center (CAIC), several conditions are needed in order for an avalanche to occur; 1) a steep slope, 2) a weak layer in the snow cover, and 3) a trigger. About 98% of all avalanches occur on slopes between 25 and 50 degrees. Avalanches release, or "run", most often on slopes above timberline that face away from prevailing winds which allow for the collection of blowing snow. However, avalanches can run on small slopes well below timberline, such as gullies, road cuts, and small openings in the trees. While dense trees can anchor the snow to steep slopes and prevent avalanches from starting, avalanches can release and travel through a moderately dense forest. *Source: CAIC (2004)*

Colorado ranks highest in the country for deaths due to avalanches between 1950 and 2003 (CDEM, 2004). In Colorado, avalanches occur most commonly between November and April. As of May 1, 2004, there were 2,106 avalanches reported in Colorado in the 2003-2004 avalanche season. In 2003-2004, avalanches were responsible for seven injuries and three deaths. Most deaths are attributable to avalanches triggered by climbing or snowmobiling activities (CDEM, 2004).

State assets that are potentially at risk from landslides include highways, roads, vehicles and outdoor facilities. Potential at-risk populations include mountain communities, motorists along highways, and tourists and recreational visitors on or near steep slopes.

4.2 Hazard Data Documentation

4.2.1 Data Sources

Unfortunately, no existing spatial data were located for avalanches in Colorado. However, avalanche events, as listed in the Colorado Geological Survey Annual Reports published by the Colorado Avalanche Information Center (CAIC, 2004), were used to compile data from the 1990-1996 and 1998-2002 avalanche seasons. To compensate for the missing seasons of 1996-1997 and 1997-1998, information was taken from the Internet (Avalanche.org, 2004).

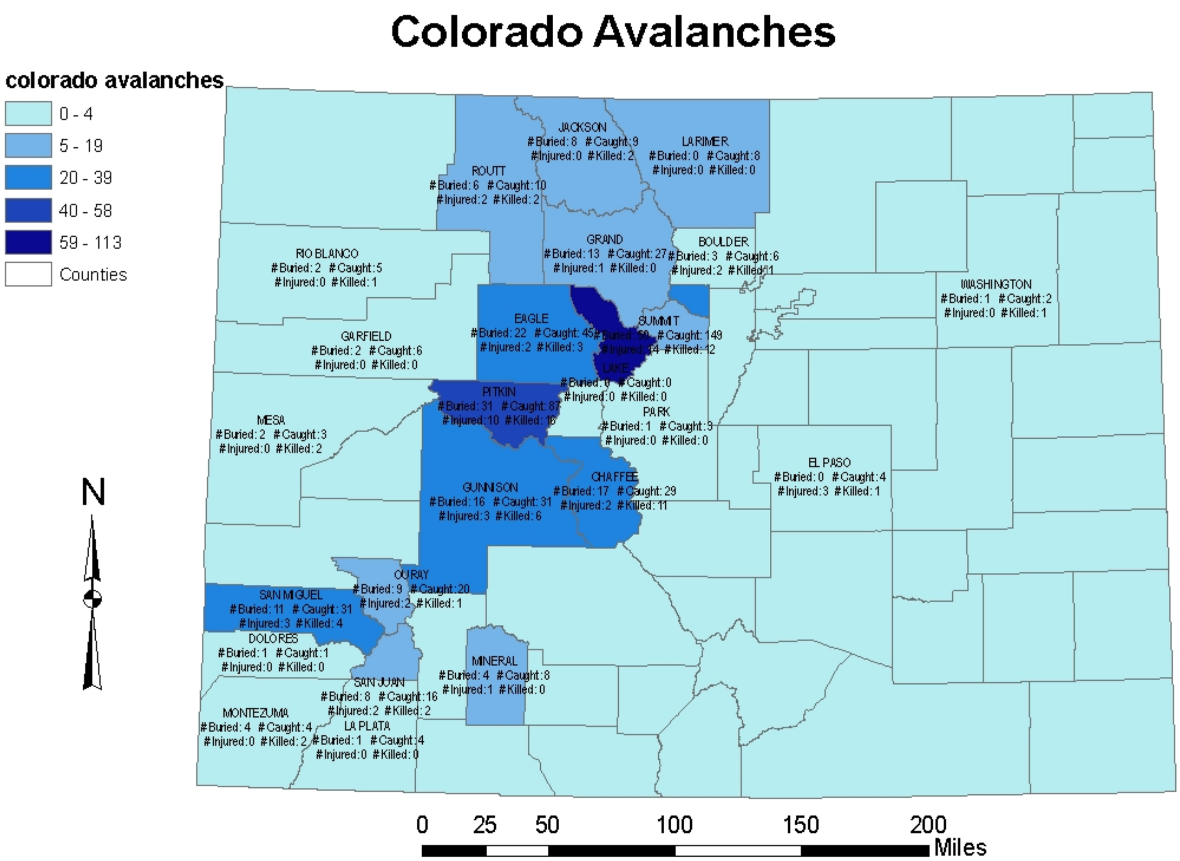
4.2.2 Process Methodology

Information on avalanche date, location, county, number of people caught, number of people buried, number of people injured, number of people killed, monetary and/or building or vehicle damages were compiled the data into an Excel spreadsheet from the annual reports. This Excel file was imported into ArcMap. The avalanche file was "joined" with the Colorado county boundary layer as provided by the using the common attributes of county to create a spatial avalanche layer. This avalanche spatial layer depicts the number of avalanche events per county in Colorado.

4.2.3 Data Issues/Limitations and Identified Data Gaps

Although, the Colorado Geological Survey had data going back 50 years, spatial data were not readily available for the purposes of this assessment. Because the avalanche spatial layer was created based on summary statistics by county, there are no point data representing individual avalanche events. As noted above, summary statistics were also not available for the 1996-1997 and 1997-1998 seasons. Data from the American Avalanche Association that were used to address the 1996 to 1998 gaps did not include all avalanche events in Colorado, only the events in which someone was caught, injured, or killed or monetary damage was recorded. Thus, statistics for these years may be too low.

4.3 Avalanche Hazard



5 RISK ASSESSMENT - DROUGHT

5.1 General Information

Droughts in Colorado can be a catalyst for an array of other natural hazards. With the semi-arid climate of Colorado, it is quite common to experience periods of drought. However, long-term periods of drought can have significant effects on agriculture, tourism, and wildfire incidence. Historically, Colorado has had several dry periods spanning the last 80 years including severe drought events in the 1930's, the late 1970's, and most recently in 2002 and 2003. Source: McKee et al. (1999)

It is difficult to assess the state assets and populations that are potentially at risk due to drought because many of the impacts from drought can be delayed and this is a slow on-set hazard. In other words, while some drought impacts are relatively acute and apparent (e.g., brown grass) the overall impacts may be more chronic in nature and may not become apparent until much later. In reality, state assets are probably not differentially affected by drought, nor are special needs populations impacted. Thus, the data were compiled so that this hazard can be monitored forward in time, but they were not analyzed in relation to state assets and vulnerable populations.

5.2 Hazard Data Documentation

5.2.1 Data Sources

Data table images of drought hazard data for the state of Colorado were obtained from the Colorado Climate Center in Adobe Acrobat *.pdf* format (CCC, 2004). The data provided ratings by month for August 2000 to April 2004 of the "Colorado Modified Palmer Index" (a drought measurement index). In addition, a map image (*.jpg*) was acquired from the same source that displayed the twenty-five geographical regions referenced by the Colorado Palmer Modified Index data. Attachment 2 provides lists of additional spatial and non-spatial data sources that provide additional information on drought in Colorado.

5.2.2 Process Methodology

The drought hazard data tables were converted from an Adobe Acrobat *(.pdf)* file to an Excel spreadsheet. Summary statistics on drought within each county were calculated in Excel. The Colorado drought regions map was converted from a *.jpg* format to a *.tif* format using Adobe Photoshop software. This *.tif* file was georeferenced in ArcGIS® using the Colorado state boundary shapefile provided by the Colorado State Department of Local Affairs (DOLA, 2004) to create a final rectified georeferenced map image. From this georeferenced image, vector polygons of the Colorado drought regions were digitized and attributed to produce a shapefile. This shapefile was joined together spatially in ArcMap by the common attribute of region number. The final result was a state-wide shapefile providing data for spatial analysis of measurable drought hazard by region.

5.2.3 Data Issues/Limitations and Identified Data Gaps

After a very extensive search, no spatial, GIS-enabled, or long-term drought data were identified. Instead, tabular data resources of short-term data were used, along with digital static map images, to create low-grade GIS data. Imperfections of this data include a very general map image with no projection or scale, which lead to a high root mean square error (RMSE) in geo-rectification creating compounding error. Also, data topology is substandard, "silver polygons" and overlapping polygons exist.

6 RISK ASSESSMENT - EARTHQUAKE

6.1 General Information

More than 1,000 faults have been mapped in Colorado. However, geological studies indicate that only 90 of these faults are potentially active, meaning they have moved in the last 1.6 million years. Since 1867, Colorado has had more than 400 earthquakes of magnitude 2.5 to 3 on the Richter scale. The largest known earthquake in Colorado occurred on November 7, 1882, and had an estimated magnitude of 7.5. A summary of notable historic earthquake occurring in Colorado is provided in the Colorado Natural Hazard Mitigation Plan (CDEM, 2004).

Earthquakes are a unique natural hazard in that human activities have been known to trigger earthquakes. For example, deep injection of liquid waste at the Rocky Mountain Arsenal likely induced the most economically damaging earthquake that occurred on August 9, 1967 and caused more than a million dollars in damage. Coal bed methane mining is another man-made activity that is suspected to stimulate earthquakes. Based on the historical record, an earthquake of magnitude 6 or greater is expected to occur in Colorado within the next several centuries. Source: (CDEM, 2004)

State assets that are potentially at risk from earthquakes include buildings, bridges, tunnels, roadways, communication towers, and vehicles. Potential at-risk populations include individuals located near existing fault areas, deep well injection sites, and coal bed methane mining areas. Detailed information on populations that may be at risk from earthquakes is provided in the Earthquake Evaluation Report (an attachment to CDEM, 2004).

6.2 Hazard Data Documentation

6.2.1 Data Sources

In 1996, the USGS created a National Hazard Map for earthquakes that included probabilistic ground motions for eight return periods ranging from 100-year to 2500-year. In 2002, the USGS renewed their National Hazard Map and increased the risk in Colorado, most significantly in the Front Range (by approximately 10%).

6.2.2 Process Methodology

HAZUS-MH, an earthquake loss estimation tool developed by FEMA, uses the USGS Hazard Map to simulate probabilistic ground motions and estimate losses. To delineate moderate, low, and very-low hazard zones for Colorado, a 2500-year probabilistic event with a driving magnitude of 7.0 was run using HAZUS-MH for the State of Colorado. The resulting peak ground acceleration (by census tract) was used to delineate the zones using an equal-interval distribution.

6.2.3 Data Issues/Limitations and Identified Data Gaps

As stated above, there are over 90 quaternary faults that have been discovered in Colorado in recent years and many of them have not been closely examined. Many researchers in Colorado suggest that this USGS Hazard Map has underestimated the risk in Colorado. Studies have shown that earthquakes of magnitude 7.0 or higher have occurred in recent geologic history.

6.3 Data Summary

Metrics of Exposure	Relative Risk Categories for Earthquake		
	Moderate	Low	Very Low
State Asset Evaluation			
# of State Assets	177/2301	1860/2301	264/2301
% of All State Assets	8%	81%	11%
State Assets ($Millions)	$175	$7,513	$1,423
Special Needs Evaluation			
# of Hospitals	15/162	121/162	26/162
% of All Hospitals	9%	75%	16%
Est. # of Vulnerable Individuals in Hospitals*	311	10,020	1,611
# of Schools	67/1695	1479/1695	149/1695
% of All Schools	4%	87.3%	9%
Est. # of Vulnerable Individuals in Schools**	18,214	644,323	37,762
# of Detention Facilities	11/90	54/90	25/90
% of All Facilities	12%	60%	28%
Est. # of Vulnerable Individuals in Facilities***	2,537	22,513	9,978
# of Misc. Facilities	3/71	66/71	2/71
% of All Facilities	4%	93%	3%

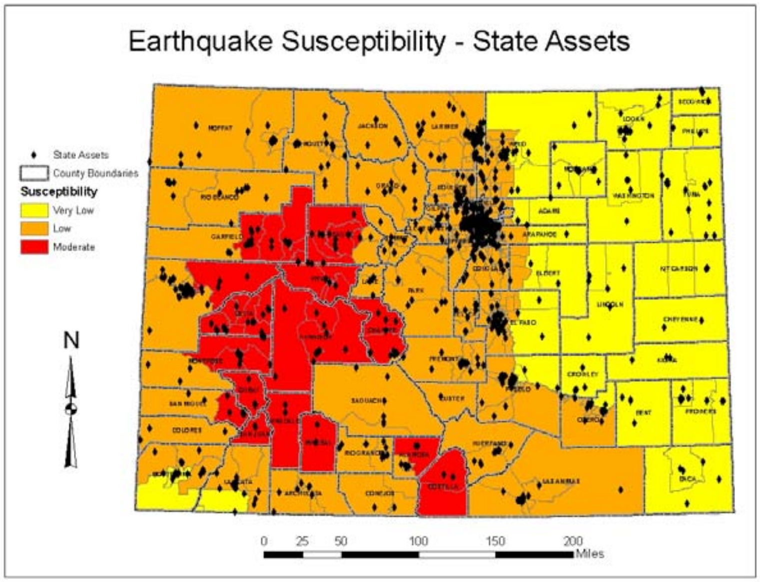
*Based on total # of beds

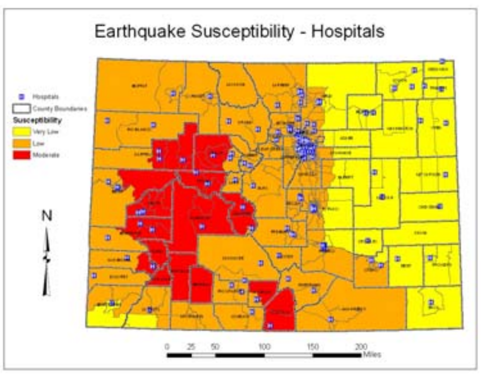
**Based on student enrollment from 2002

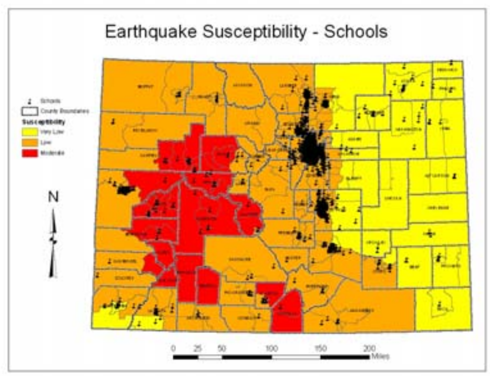
***Based on inmate capacity

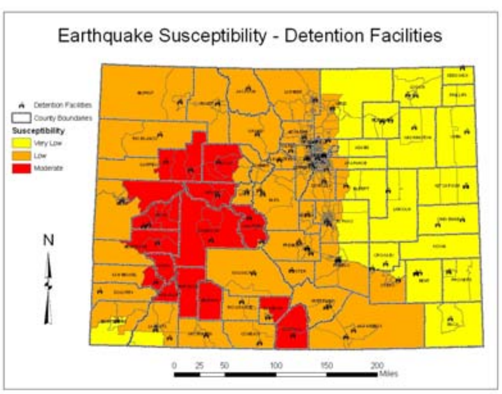
****Children Group Homes & Mental Health Facilities

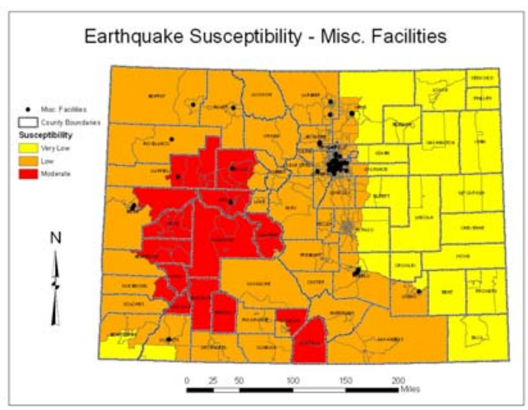
6.4 Earthquake Maps











7 RISK ASSESSMENT - WILDFIRE

7.1 General Information

Colorado's forests are recovering from years of fire exclusion. The danger of uncontrolled wildfires has increased tremendously over the last several decades as the growing population moves further into the mountains and forests. After a severe drought season in 2002, a multitude of fires, including the largest wildfire in recorded state history, raged across Colorado. Continuing drought conditions, combined with an influx of people moving into wildland areas, will continue to place the issue of wildfire to the forefront. Insect (beetle kill) and disease also continue to spread and grow in intensity, increasing the risk of a wildfire (Colorado State Forest Service, 2004).

7.2 Hazard Data Documentation

According to the Colorado State Mitigation Plan Appendix F, state asset losses due to wildfires are unknown. The populations at risk were those who occupied areas which were in the wildland urban interface areas, such as mountain residents, and seasonal and permanent workers in the rural mountainous regions.

7.2.1 Data Sources

The Colorado Wildland Urban Interface (WUI) hazard assessment layer was created using raster digital data provided by the Colorado State Forest Service of Colorado State University for the purposes of preparing wildfire hazard assessments in Colorado. The layer and accompanied data was obtained via Colorado State University. The WUI spatial layer contained data from 2002 on slope, aspect, fuel hazard, disturbance regime and return interval which were used to establish the relative fire risk or hazard.

7.2.2 Process Methodology

The WUI spatial layer was used without any modifications.

7.2.3 Data Issues/Limitations and Identified Data Gaps

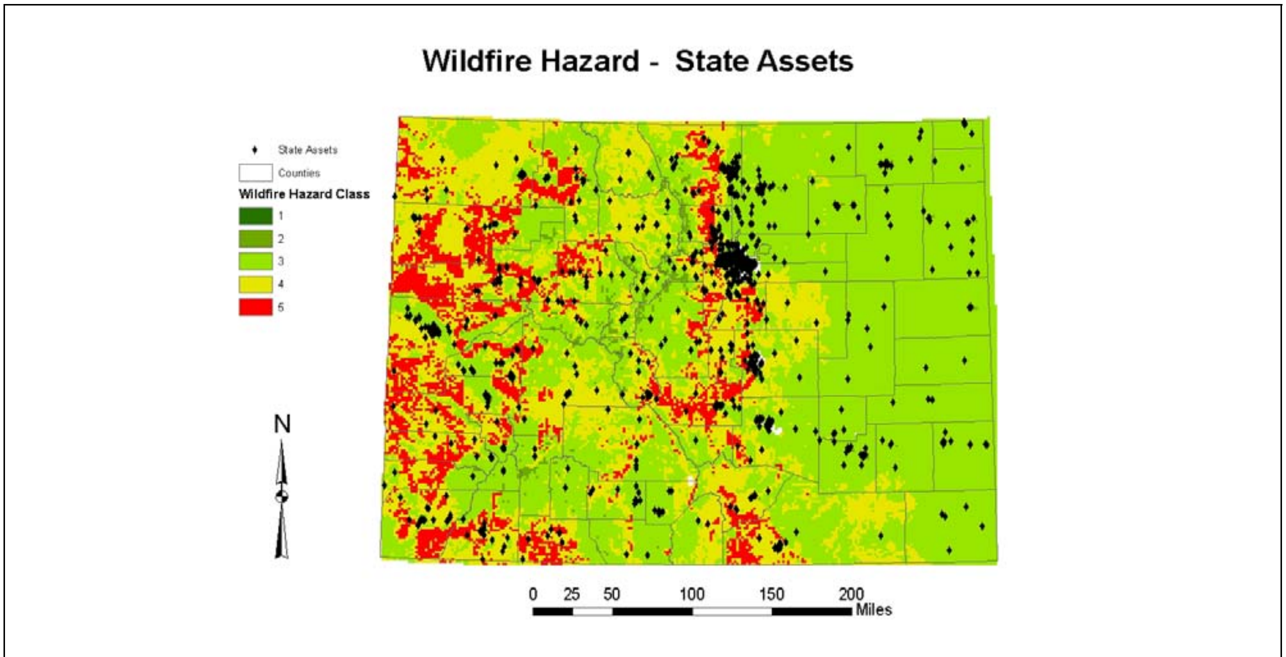
Information provided in the WUI spatial layer is from 2002 and may not reflect current risks from wildfire in the WUI.

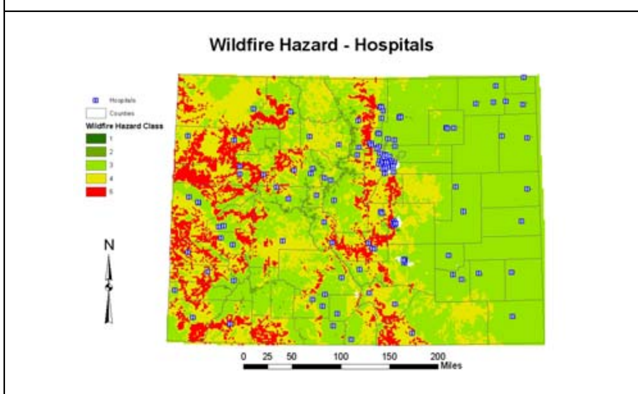
7.3 Data Summary

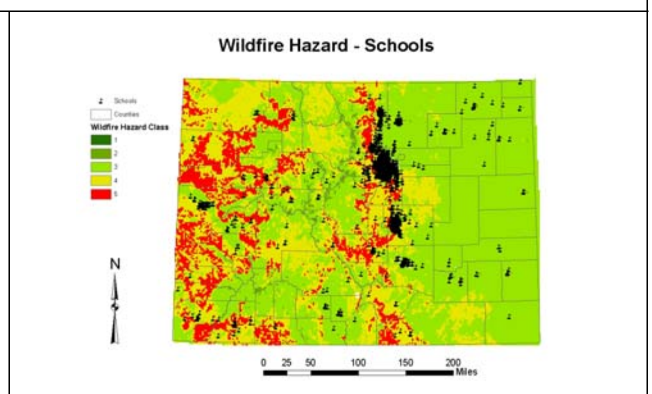
Metrics of Exposure	High	Med-High	Medium	Med-Low	Low
State Asset Evaluation					
# of State Assets	36/2,301	337/2301	1695/2301	41/2301	192/2301
% of All State Assets	2%	15%	74%	2%	8%
State Assets ($)	$229,287	$6,955,812	$97,238,133	$600,012	$11,941,669
Special Needs Evaluation					
# of Hospitals	8/162	13/162	105/162	0/162	36/162
% of All Hospitals	5%	8%	65%	0%	22%
Est. # of Vulnerable Individuals in Hospitals*	44	134	9815	0	1,949
# of Schools	20/1695	207/1695	1252/1695	1/1695	215/1695
% of All Schools	1.2%	12%	74%	0%	13%
Est. # of Vulnerable Individuals in Schools**	3,522	100,363	530,713	357	65,344
# of Detention Facilities	1/90	10/90	55/90	2/90	22/90
% of All Facilities	1%	11%	61%	2%	24%
Est. # of Vulnerable Individuals in Facilities***	192	6,922	23090	315	4,509
# of Misc. Facilities****	0/71	5/71	62/71	0/71	4/71
% of All Facilities	0%	7%	87%	0%	6%

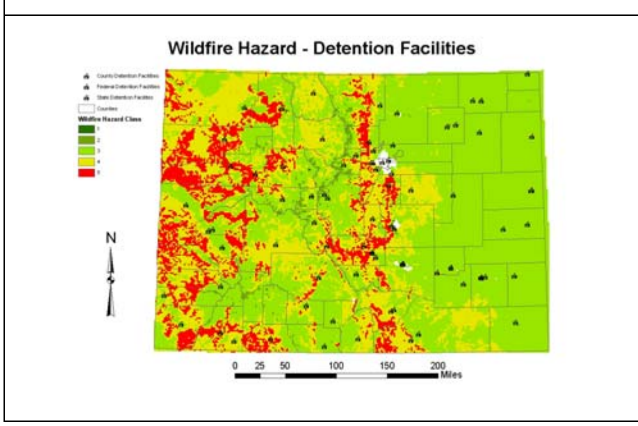
*Based on total # of beds
**Based on student enrollment from 2002
***Based on inmate capacity
****Children Group Homes & Mental Health Facilities

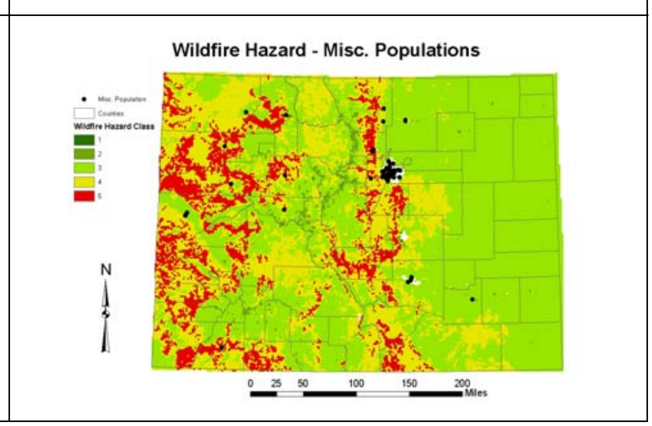
7.4 Wildfire Maps











8 RISK ASSESSMENT - FLOOD

8.1 General Information

Most streams and rivers in Colorado have the potential to flood. Human encroachment into floodplain areas has increased the likelihood of harm and structural damage due to flooding events. Today, flood prone areas have been identified in 268 cities and towns and in all 64 counties in Colorado. Using information supplied from local government, it is estimated that approximately 250,000 people are now living in Colorado floodplain areas. The Colorado Water Conservation Board (CWCB) estimates approximately 65,000 homes and 15,000 commercial and industrial structures are located in Colorado's floodplains. From the early 1900's to 2003, cumulative state flood losses from the most damaging floods are estimated at over $5 billion (2003 dollars). Source: CWCB (2004)

State assets that are potentially at risk from floods include buildings, equipment, highways, roads, and bridges located in and near floodplains. Potential at-risk populations include those living in 100- and 500-year floodplains, motorists along highways and bridges, and those participating in recreational activities along the water.

8.2 Hazard Data Documentation

8.2.1 Data Sources

The Q3 Flood Data product is a digital representation of certain features in the FEMA Flood Insurance Rate Map that can be used in spatial evaluations. The Q3 flood data for Colorado were downloaded from the FEMA Flood Map Store (FEMA, 2004). Unfortunately, flood data were only available for nine counties: Adams, Arapahoe, Boulder, Denver, El Paso, Jefferson, Larimer, Morgan and Pueblo. The flood hazard indicators were categorized using FEMA's flood zone designations. Zones A and AE represented areas that were in a 100-year flood plane or have a 1% annual chance of flooding. Zone X500 represented areas that were in a 500-year flood plane or have a 0.2% annual chance of flooding.

8.2.2 Process Methodology

The Q3 flood data for each of the 9 Colorado counties were merged into a single comprehensive Q3 data layer. This comprehensive Q3 layer provides shapefiles of both the 100- and 500-year flood hazard zones.

8.2.3 Data Issues/Limitations and Identified Data Gaps

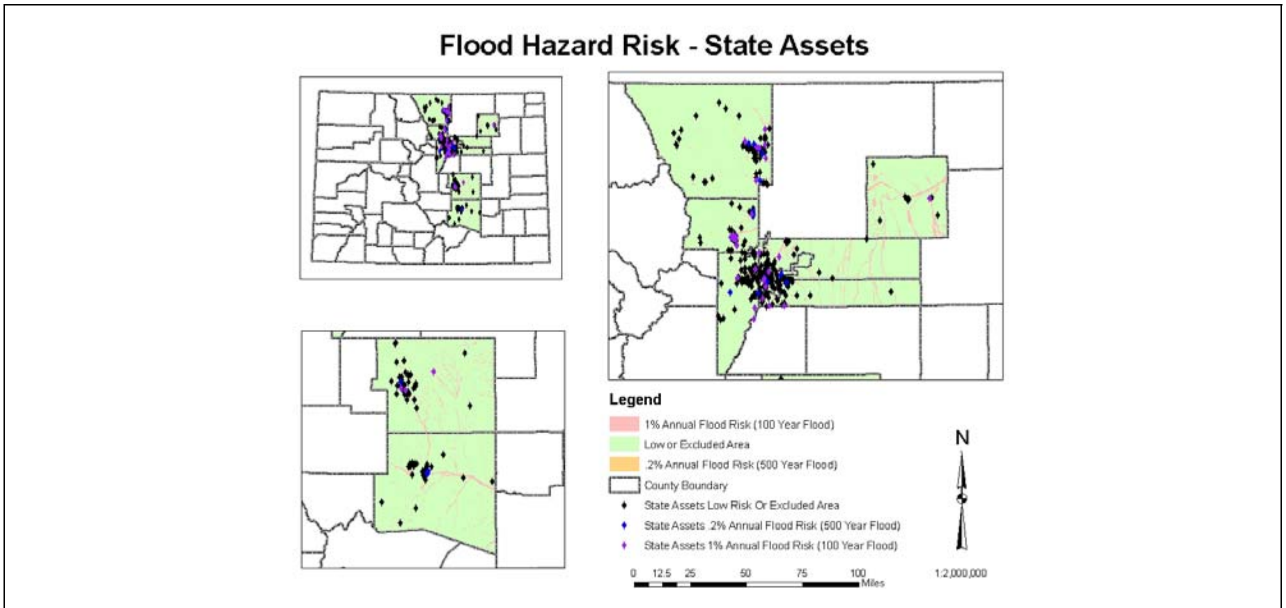
The Q3's that were utilized for data collection were produced in the 1980's and are likely out of date for several counties. For example, the Denver County data does not reflect the annexation of DIA, and no data exist for Broomfield County. In addition, only 9 of 64 counties in Colorado were represented in the existing Q3 layer. However, these nine counties represent those with the largest populations that are most likely to be impacted by floods.

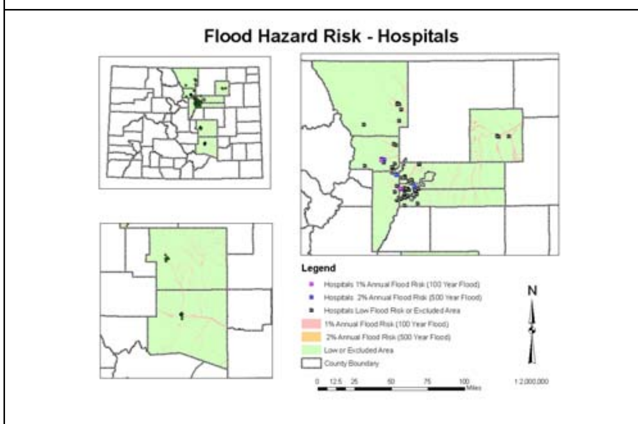
8.3 Data Summary

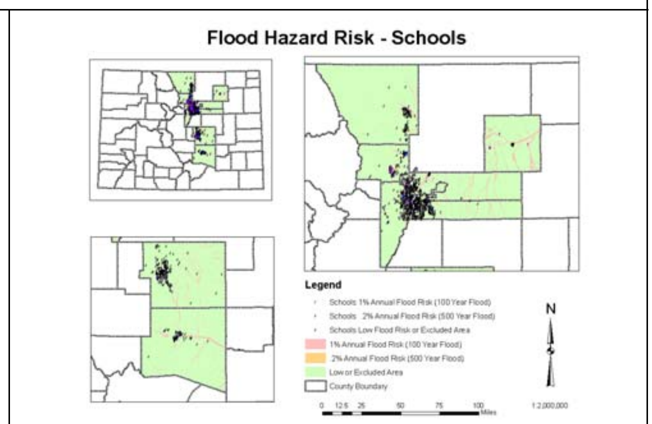
Metrics of Exposure	Relative Risk Categories for Floodings in Adams, Arapahoe, Boulder, Denver, El Paso, Jefferson, Larimer, Morgan, & Pueblo County		
	1% Annual Risk (100year flood)	.2% Annual Risk (500 year flood)	Areas Less Than .2% OR Area Not Studied
State Asset Evaluation			
# of State Assets	130/1278	40/1278	1108/1278
% of All State Assets	10%	3%	87%
State Assets ($Millions)	$177	$140	$5,689
Special Needs Evaluation			
# of Hospitals	3/74	4/74	67/74
% of All Hospitals	4%	5%	91%
Est. # of Vulnerable Individuals in Hospitals*	281	87	9,517
# of Schools	38/1259	31/1259	1190/1259
% of All Schools	3%	2%	95%
Est. # of Vulnerable Individuals in Schools**	16,676	9,626	532,479
# of Detention Facilities	0/20	4/20	16/20
% of All Facilities	0%	20%	80%
Est. # of Vulnerable Individuals in Facilities***	0	2088	10,055
# of Misc. Facilities****	1/51	2/51	48/51
% of All Facilities	2%	4%	94%

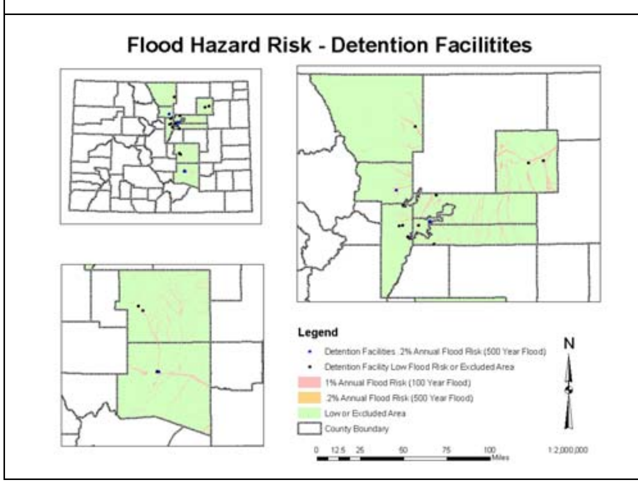
*Based on total # of beds
**Based on student enrollment from 2002
***Based on inmate
capacity
****Children Group Homes & Mental Health Facilities

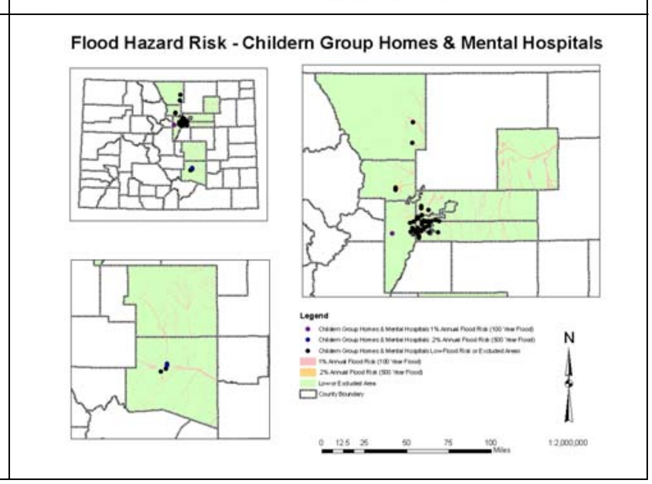
8.4 Flood Maps











9 RISK ASSESSMENT - LANDSLIDES

9.1 General Information

The Colorado Geological Survey defines landslides as the "downward and outward movement of slopes composed of natural rock, soil, and/or artificial soils." Landslides are also referred to as rockslides, debris slides, slump, lateral spreading, debris avalanche, earth flow, and soil creep. Landslides occur frequently in Colorado, with damage estimates for structures exceeding 3 million dollars annually (CDEM, 2004).

A summary of notable historic landslides occurring in Colorado and a detailed assessment of the current landslide conditions are presented in the Colorado Landslide Hazard Mitigation Plan (Jochim et al., 1988). This mitigation plan was subsequently updated as part of the 2002 Review and Priority List for Critical Landslides in Colorado (CGS, 2002). As part of this report, landslide areas are classified into three tiers based on estimates of the severity of the hazard and extent or magnitude of potential impacts.

Tier 1 – Serious cases needing immediate or ongoing attention because of the severity of potential impacts.

Tier 2 – Very significant but less severe, or where adequate information and/or mitigation is in place, or where current development pressures are less extreme.

Tier 3 – Similar to Tier 2, but with less severe consequences or primarily local impact.

In Colorado, there are 46 locations that have been identified as priority landslide areas. State assets that are potentially at risk from landslides include highways, roads, vehicles and outdoor facilities. Potential at-risk populations include communities in wildfire burn areas, motorists along highways, tourists and recreational visitors on or near steep slopes, and communities built on top of underground mining areas.

9.2 Hazard Data Documentation

9.2.1 Data Sources

Spatial landslide hazard data for the continental United States were obtained from US Geological Survey, National Landslide Information Center. Data were provided as a downloadable polygon feature shapefile (NationalAtlas.gov, 2004). In this shapefile, each polygon provides a qualitative estimate of landslide risk based on historical landslide incidence and predicted susceptibility. A description of the landslide risk categories is as follows:

Low: Low landslide incidence (<1.5 % of the area is involved in landsliding)
Mod: Moderate landslide incidence (1.5-15% of the area is involved in landsliding)
High: High landslide incidence (>15% of the area is involved in landsliding)
Sus-Mod: Moderate susceptibility to landslides and low incidence
Sus-High: High susceptibility to landslides and low incidence
Combo-Hi: High susceptibility to landslides and moderate incidence
No-Data: No data exist for these areas

9.2.2 Process Methodology

The original shapefile obtained from the National Landslide Information Center provided coverage for the entire continental United States. In order to limit the coverage to Colorado, the shapefile polygon feature was clipped using a Colorado state boundary layer downloaded from the State of Colorado Department of Local Affairs (DOLA, 2004).

9.2.3 Data Issues/Limitations and Identified Data Gaps

The available landslide layer has a map scale of 1:4,000,000. Because this is a relatively high scale, a state-level assessment will have considerable uncertainty due to limited resolution and accuracy may be an issue. Also, this large scale does not allow for local identification of assets at risk, only a general assessment of the landslide risk for an area.

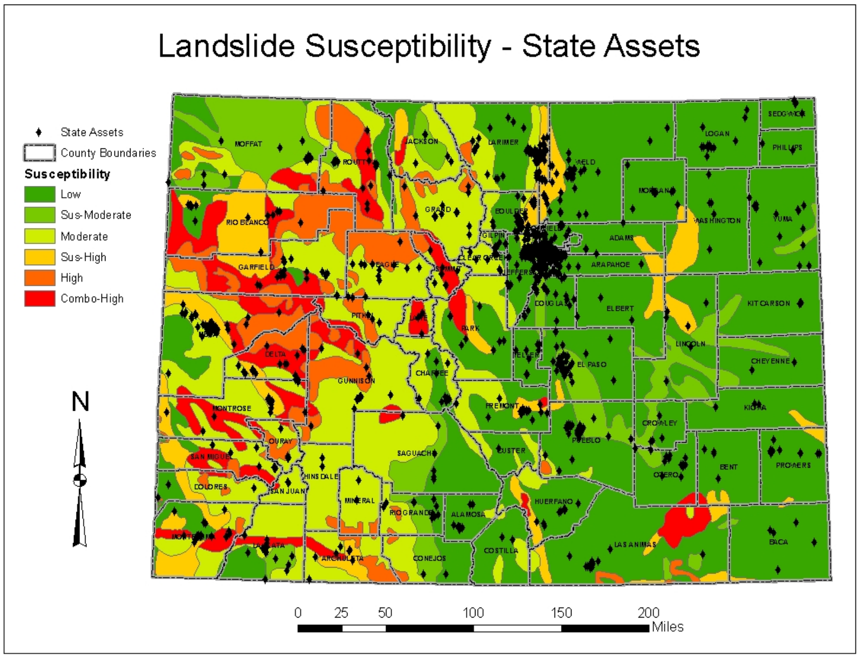
9.3 Data Summary

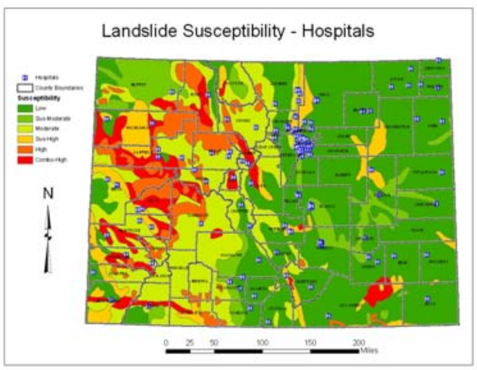
Metrics of Exposure	Relative Risk Categories for Landslides					
	Combo-High	High	Sus-High	Moderate	Sus-Moderate	Low
State Asset Evaluation						
# of State Assets	88/2301	36/2301	183/2301	720/2301	362/2301	912/2301
% of All State Assets	4%	2%	8%	31%	16%	40%
State Assets ($millions)	$43	$20	$971	$2,883	$1,718	$3,477
Special Needs Evaluation						
# of Hospitals	5/162	4/162	16/162	20/162	17/162	100/162
% of All Hospitals	3%	2%	10%	12%	10%	62%
Est. # of Vulnerable Individuals in Hospitals*	86	68	1,061	452	2,925	7,350
# of Schools	40/1695	7/1695	142/1695	215/1695	497/1695	794/1695
% of All Schools	2%	0.4%	8%	13%	29%	47%
Est. # of Vulnerable Individuals in Schools**	12,112	2,367	57,280	75,565	216,757	336,218
# of Detention Facilities	3/90	1/90	7/90	15/90	9/90	55/90
% of All Facilities	3%	1%	8%	17%	10%	61%
Est. # of Vulnerable Individuals in Facilities***	97	62	2,255	3584	4,072	21,785
# of Misc. Facilities	3/71	2/71	2/71	5/71	17/71	42/71
% of All Facilities	4%	3%	3%	7%	24%	59%

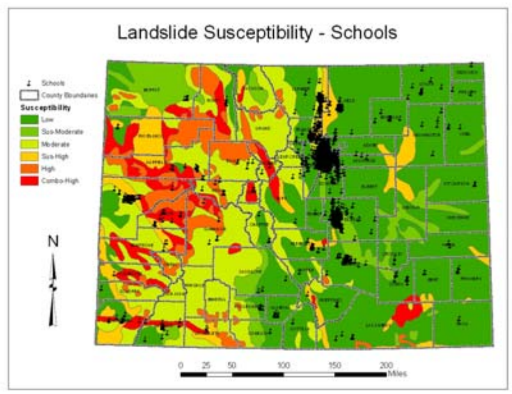
*Based on total # of beds

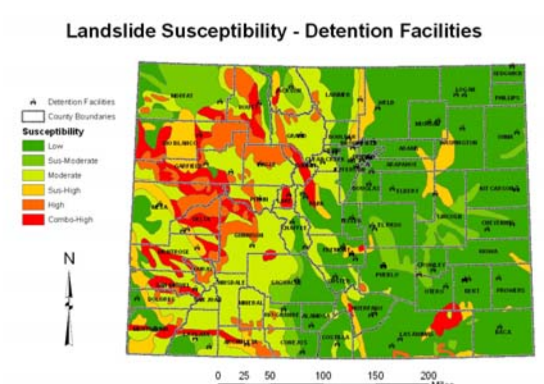
**Based on student enrollment from 2002

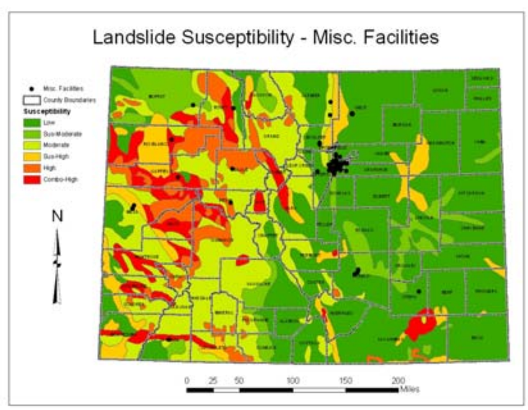
9.4 Landslide Maps











10 RISK ASSESSMENT - HAIL

10.1 General Information

Hail is formed when water droplets in thunderstorm clouds freeze to create a hailstone. Hailstones can range in size from peas to baseballs, and can cause significant damage to buildings, vehicles, and crops. Storms are most frequent in northeastern Colorado. Between 1993 and 2000, Colorado experienced more than 2000 events of hailstorms, with over $300 million in damages. During this time, the most vulnerable county in Colorado was Weld County, with 176 events and $33 million in damages. There have been no deaths attributed to hailstorms, but minor injuries have been reported. Source: National Climatic Data Center (NCDC, 2004)

State assets that are potentially at risk from hail include buildings, outdoor equipment, vehicles, and landscaping. Potential at-risk populations include motorists, outdoor workers, outdoor recreationists, individuals residing in hail prone areas.

10.2 Hazard Data Documentation

10.2.1 Data Sources

A shapefile that summarized hail events from 1955 through 1995 across the United States was obtained electronically from CDEM. Hail events from May 1995 through July 2000 were obtained from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) (University of South Carolina, 2004). Data provided in SHELDUS include county, event date, injuries, fatalities, crop damage, and property damage.

10.2.2 Process Methodology

In order to limit the coverage of the 1955-1995 shapefile of hail events to Colorado, it was clipped using a Colorado state boundary layer downloaded from the State of Colorado Department of Local Affairs (DOLA, 2004). The table obtained from SHELDUS included an array of severe weather events including tornado, wind, hail, and lightning. In order to identify hail events in Colorado from 1995 to 2000, the SHELDUS table was separated by hazard type. This process resulted in a total of 42 hail events in Colorado from 1995 to 2000.

10.2.3 Data Issues/Limitations and Identified Data Gaps

Unfortunately, the hail data provided in SHELDUS only included events through 2000. While, the National Climatic Data Center had hail event data through 2004, events were identified by city and there were no geographic identifiers (e.g., latitude/longitude, county) that allowed for spatial representation. Without latitude/longitude coordinates, the hail data from the National Climatic Data Center could not be displayed in the hail shapefile and were excluded from the risk assessment. Because the hail spatial layer created from SHELDUS was created based on summary information by county, there were no point data representing individual hailstorm events.

10.3 Summary Data

Metrics of Exposure	Relative Risk Categories for Hail		
	High	Moderate	Low
State Asset Evaluation			
# of State Assets	205/2301	1320/2301	776/2301
% of All State Assets	9%	57%	34%
State Assets ($)	$848,083,054	$6,264,875,498	$1,998,560,606
Special Needs Evaluation			
# of Hospitals	13/162	79/162	70/162
% of All Hospitals	8%	49%	43%
Est. # of Vulnerable Individuals in Hospitals*	1297	9,095	1,550
# of Schools	272/1695	1143/1695	280/1695
% of All Schools	16.0%	67%	17%
Est. # of Vulnerable Individuals in Schools**	120,566	505,251	74,482
# of Detention Facilities	3/90	33/90	54/90
% of All Facilities	3%	37%	60%
Est. # of Vulnerable Individuals in Facilities***	1,461	17,359	16,208
# of Misc. Facilities****	8/71	51/71	12/71
% of All Facilities	11%	72%	17%

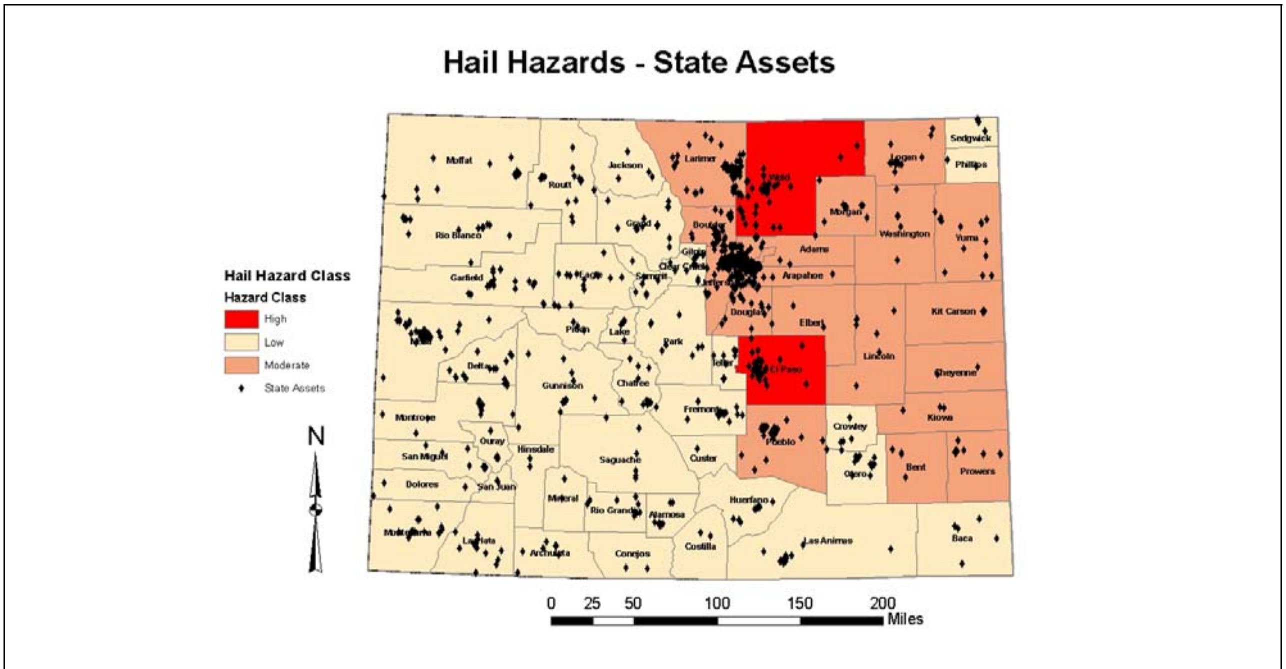
*Based on total # of beds

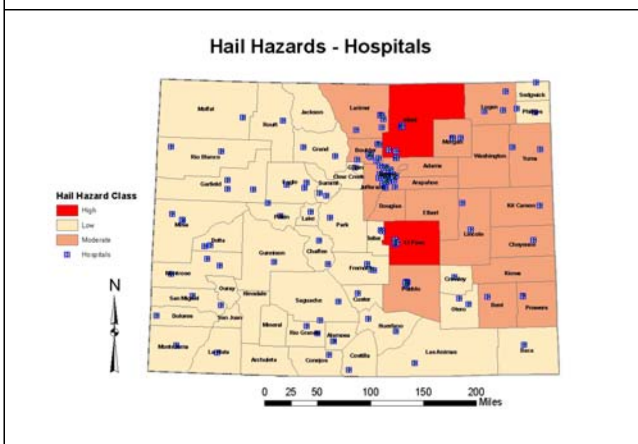
**Based on student enrollment from 2002

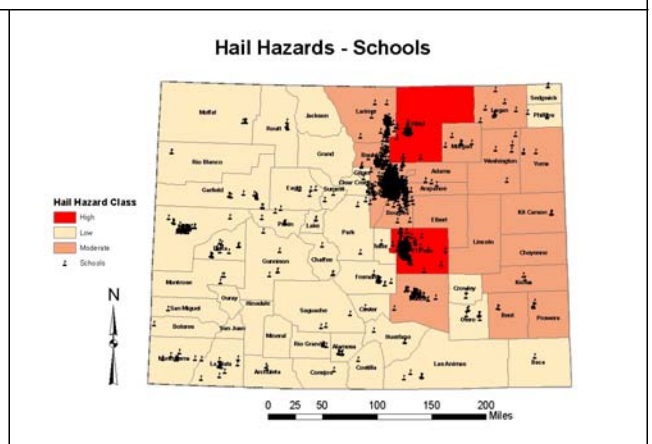
***Based on inmate capacity

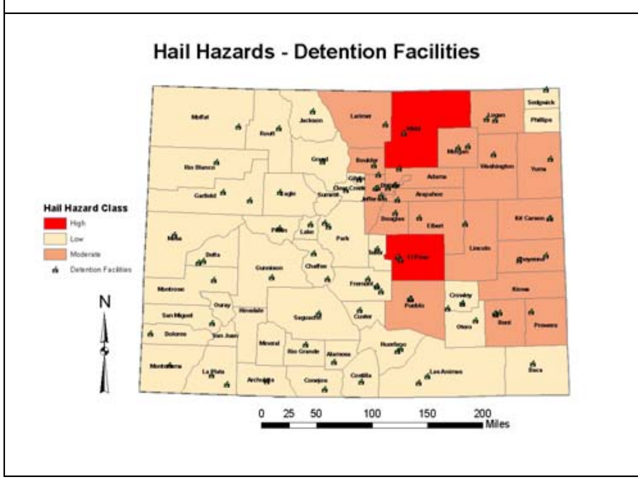
****Children Group Homes & Mental Health Facilities

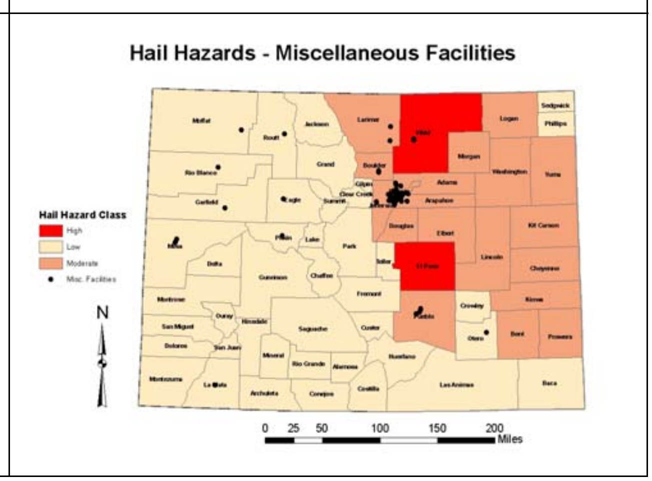
10.4 Hail Maps











11 RISK ASSESSMENT - TORNADOS

11.1 General Information

Colorado has one of the highest occurrences of tornado events in the United States. However, it ranks fairy low in damages, injuries, and deaths. Of the 1,161 events recorded between 1955 and 1995, records show only 2 deaths, 157 injuries, and $67 million in damages. Tornados occur most frequently in Colorado between the months of May and July. Tornados are categorized using the "Fujita scale", which estimates the wind speeds after a tornado by studying the damage caused by the tornado to structures. Typically, Colorado tornados rank as an F0 (light damage) on the Fujita scale, with only a few events reaching an F2 (considerable damage) classification. Based on historical data, the two most vulnerable counties are Weld County and Adams County. Sources: Disaster Center (2004), The Tornado Project (2004)

State assets that are potentially at risk from tornados include buildings, power lines, vehicles, and landscaping. Potential at-risk populations include motorists, outdoor workers, outdoor recreationists, individuals residing in tornado prone areas.

11.2 Hazard Data Documentation

11.2.1 Data Sources

A shapefile that summarized tornado events from 1955 through 1995 across the United States was obtained electronically from CDEM. Tornado data for Colorado from March 1995 through May 2004 were provided by the National Climatic Data Center (NCDC, 2004). Tornado data were compiled in an Excel spreadsheet, which included information on the Fujita scale ranking, location, injuries, property damage, and crop damage.

11.2.2 Process Methodology

In order to limit the coverage of the 1955-1995 shapefile of tornado events to Colorado, it was clipped using a Colorado state boundary layer downloaded from the State of Colorado Department of Local Affairs (DOLA, 2004). The data obtained from the NCDC for events from 1995 to 2004 were compiled into an Excel spreadsheet. Latitude and longitude coordinates associated with each event were obtained from an Internet hyperlink for each event within NCDC's database. The coordinates for the 1995-2004 dataset were then converted to the same format used in the 1955-1995 dataset.

11.2.3 Data Issues/Limitations and Identified Data Gaps

Point locations for the tornado event data were converted from latitude/longitude into a uniform coordinate system so that the spatial data could be used in a risk analysis. Latitude/longitude, reported as degrees, minutes, and seconds, were converted to decimal degrees in Excel using a conversion equation provided by Pearson Software Consulting (Pearson, 2004). Unfortunately, not all of the available tornado data contained latitude/longitude coordinates. Of the 435 tornado events for Colorado included in the database, approximately 30 could not be spatially represented and were excluded from the risk assessment. In addition, many tornado events do not record damage estimates. Exclusion of these damage estimates may potentially underestimate impacts in the hazards assessment.

11.3 Data Summary

Metrics of Exposure	Relative Risk Categories for Tornadoes		
	High	**Moderate**	**Low**
State Asset Evaluation			
# of State Assets	234/2301	289/2301	1778/2301
% of All State Assets	10%	13%	77%
State Assets ($)	$855,027,882	$874,767,626	$7,381,723,650
Special Needs Evaluation			
# of Hospitals	15/162	29/162	118/162
% of All Hospitals	9%	18%	73%
Est. # of Vulnerable Individuals in Hospitals*	904	2,285	8,813
# of Schools	204/1695	501/1695	901/1695
% of All Schools	12.0%	30%	53%
Est. # of Vulnerable Individuals in Schools**	95,936	232,313	372,050
# of Detention Facilities	2/90	18/90	70/90
% of All Facilities	2%	20%	78%
Est. # of Vulnerable Individuals in Facilities***	2,020	7,565	25,443
# of Misc. Facilities****	14/71	4/71	53/71
% of All Facilities	20%	6%	75%

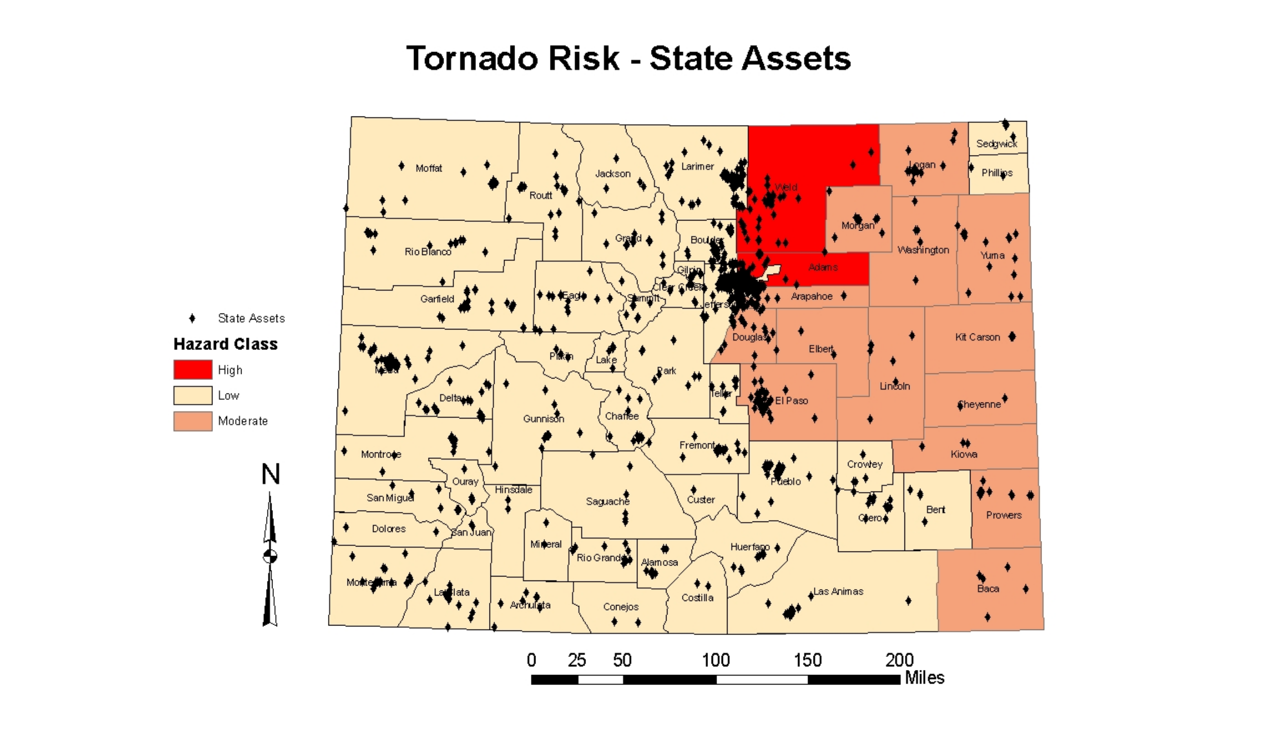
*Based on total # of beds

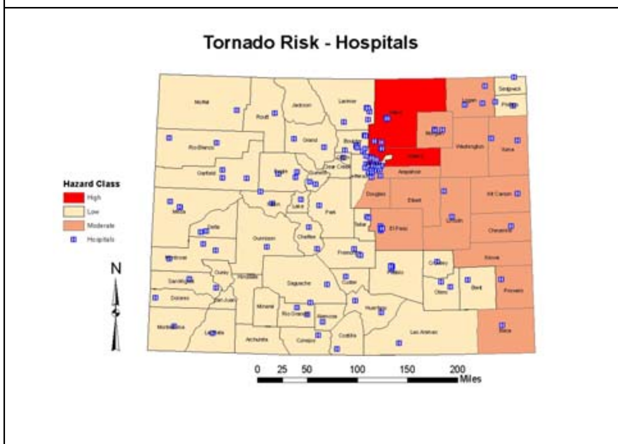
**Based on student enrollment from 2002

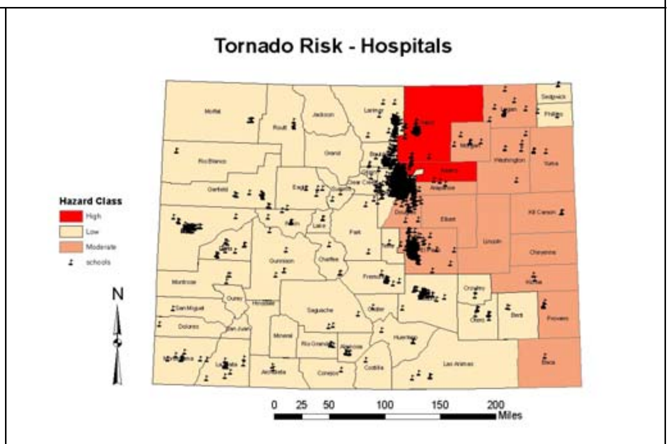
***Based on inmate capacity

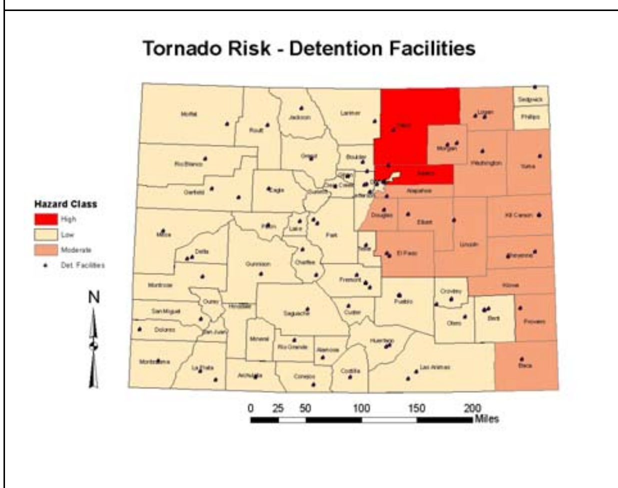
****Children Group Homes & Mental Health Facilities

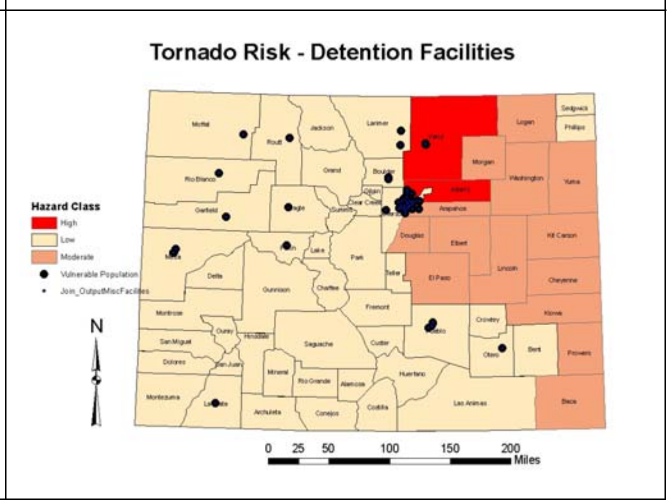
11.4 Tornado Maps











12 RISK ASSESSMENT - HIGH WINDS

12.1 General Information

In Colorado, there are two main sources of hazard due to high winds – downslope winds and severe weather. Chinooks come from descending air descending down the eastern slopes of the Rockies, and have been known to cause localized damage. However, most wind damage in Colorado is attributable to severe weather events. With wind speeds reaching over 100mph, these wind gusts from severe weather have broken power lines, turned over tractor trailers, and caused injuries and death due to flying debris. From 1993 to 2000, the state experienced 1,041 high wind events, resulting in 12 deaths, 170 injuries, and more than $40 million in damages. Denver County is more vulnerable to high winds due to its extensive infrastructure and dense population. Source: National Climatic Data Center (NCDC, 2004)

State assets that are potentially at risk from high winds include buildings, power lines, communication towers and antennas, and landscaping. Potential at-risk populations include motorists, outdoor workers, outdoor recreationists, and individuals residing in areas prone to severe wind events.

12.2 Hazard Data Documentation

12.2.1 Data Sources

A shapefile that summarized severe wind events from 1955 through 1995 across the United States was obtained electronically from CDEM. Severe wind events from February 1995 to December 2000 were obtained from the Spatial Hazard Events and Losses Database for the United States (SHELDUS) (University of South Carolina, 2004). Data provided in SHELDUS include county, event date, injuries, fatalities, crop damage, and property damage.

12.2.2 Process Methodology

In order to limit the coverage of the 1955-1995 shapefile of severe wind events to Colorado, it was clipped using a Colorado state boundary layer downloaded from the State of Colorado Department of Local Affairs (DOLA, 2004). The table obtained from SHELDUS included an array of severe weather events including tornado, wind, hail, and lightning. In order to identify high wind events in Colorado from 1995 to 2000, the SHELDUS table was separated by hazard type. This process resulted in a total of 352 wind events in Colorado from 1995 to 2000.

12.2.3 Data Issues/Limitations and Identified Data Gaps

Unfortunately, wind data provided in SHELDUS only included events through 2000. While the National Climatic Data Center had high wind event data through 2004, events were identified by city and there were no geographic identifiers (e.g., latitude/longitude, county) that allowed for spatial representation. Without latitude/longitude coordinates, the wind data from the National Climatic Data Center could not be displayed in the wind shapefile and were excluded from the risk assessment. Because the wind spatial layer created from SHELDUS was created based on summary information by county, there were no point data representing individual wind events.

12.3 Data Summary

Metrics of Exposure	Relative Risk Categories for Hail		
	High	Moderate	Low
State Asset Evaluation			
# of State Assets	205/2301	1320/2301	776/2301
% of All State Assets	9%	57%	34%
State Assets ($)	$848,083,054	$6,264,875,498	$1,998,560,606
Special Needs Evaluation			
# of Hospitals	12/162	74/162	76/162
% of All Hospitals	7%	46%	47%
Est. # of Vulnerable Individuals in Hospitals*	721	9,477	1,744
# of Schools	146/1695	1030/1695	519/1695
% of All Schools	8.6%	61%	31%
Est. # of Vulnerable Individuals in Schools**	64,233	448,191	187,875
# of Detention Facilities	2/90	20/90	68/90
% of All Facilities	2%	22%	76%
Est. # of Vulnerable Individuals in Facilities***	970	11,972	22,086
# of Misc. Facilities****	10/71	48/71	13/71
% of All Facilities	14%	68%	18%

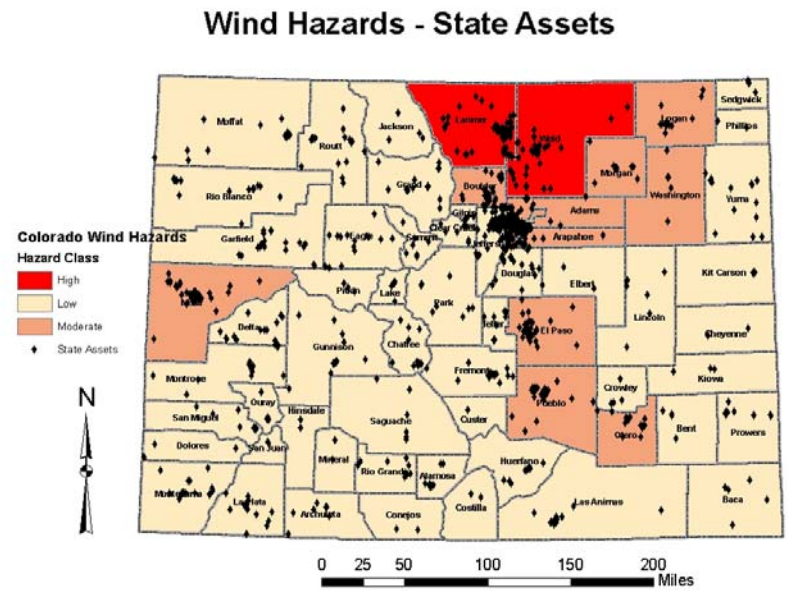
*Based on total # of beds

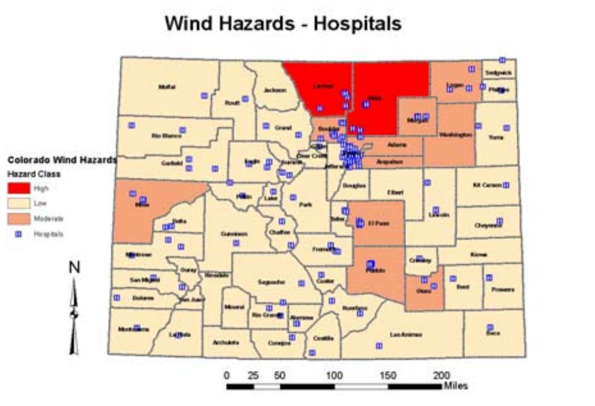
**Based on student enrollment from 2002

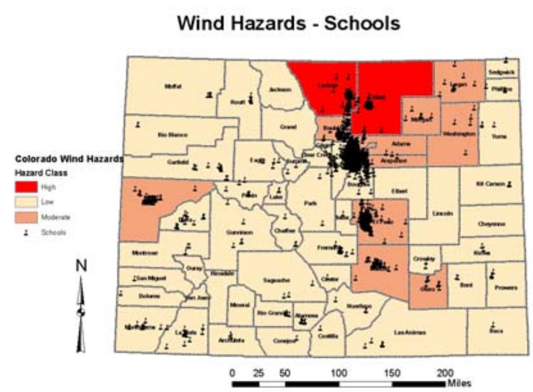
***Based on inmate capacity

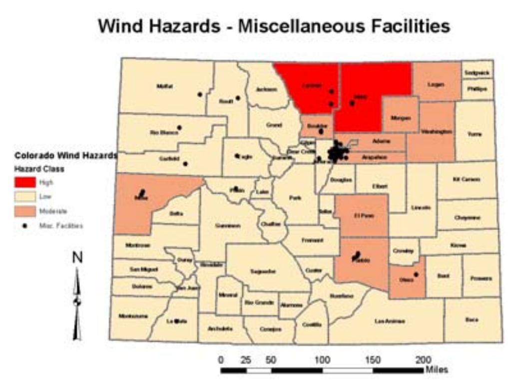
****Children Group Homes & Mental Health Facilities

12.4 Wind Maps









13 RECOMMENDATIONS FOR FUTURE RESEARCH

There are many possibilities for future research on the topic of state hazard assessment, but one of the main goals of future work should be to establish a state data clearinghouse. There were numerous errors and gaps in the database records that limited the amount and accuracy of the analysis. A centralized state database needs to be established to correct and complete the information. The Natural Hazard Mitigation Plan (CDEM, 2004) had estimates of each county and department's assets value that could be misleading because many of the entries in the database did not have building and content values. These values, as well as other types of information, would have to be estimated and continually and slowly added to the database. After updating, the assets layer should be re-compared to the hazards layer every few years to assess the change in vulnerability.

This database also needs information regarding the numbers of people typically present in each facility during work hours so that an analysis of the human risk can also be done. Also, including assets such as vehicles and heavy equipment would be important as these have high replacement values. While collecting all of this information would be time-consuming and difficult, much of it probably already exists. Basically, an accurate inventory would have to be compiled by each department/agency and provided to a central processing team in charge of maintaining the database.

There are many possible work applications for compiling data in this manner. For instance, an engineer inspecting buildings could report on the condition of the building and its risk to hazards such as flooding. Once recorded in the database, the GIS program could create a list of the buildings in need of mitigation or repair. Also important would be the recording of all mitigation projects and their effects. If this information were available, it would be possible to determine which mitigation strategies were the most cost-effective.

The claims section of CDEM (2004) is important because it shows that the two biggest causes of loss between 1994 and 2000 were fire and water, with wind and lightning also causing a fair amount of damage. Accordingly, mitigation efforts should be focused on reducing losses from these hazards. The main goal of future mitigation work should be to pick the most cost-effective mitigation strategies and implement them at the locations most at risk.

The State could use this analysis to assist individual counties in implementing hazard mitigation programs. A priority list of vulnerable counties could be created and county-specific workshops could be conducted to identify mitigation strategies for each particular hazard. For some counties there may be multiple hazards to consider. As an example, Weld County may be impacted by both hail and tornados. Unfortunately, this report does not provide a summary of overall risks from multiple natural hazards. However, this report could be used to designate and prioritize which county would need the most funding for mitigation projects given the magnitude of the events to which they are vulnerable. Regardless of their priority, each county should use the analysis provided to assess their vulnerability and make appropriate mitigation choices.

14 REFERENCES

Avalanche.org. 2004. Avalanche accidents, summary. URL: http://www.avalanche.org/accidnt1.htm. Last accessed: December 11, 2004.

Colorado Avalanche Information Center (CAIC). 2004. URL: http://geosurvey.state.co.us/avalanche/. Last accessed: December 11, 2004.

Colorado Climate Center (CCC). 2004. Drought Resources. URL: http://ccc.atmos.colostate.edu/palmerindex.php. Last modified: September 8, 2004. Last accessed: December 11, 2004.

Colorado Department of Corrections (CDOC). 2004. URL: www.doc.state.co.us. Last updated: November 18, 2004. Last accessed: December 11, 2004.

Colorado Department of Education. 2004. Colorado Education Statistics. URL: http://www.cde.state.co.us/index_stats.htm. Last updated: December 6, 2004. Last accessed: December 11, 2004.
Colorado Department of Health (CDOH). 2004. Health Facilities - Licensing and Certification. URL: http://www.cdphe.state.co.us/hf/hfd.asp. Last updates: November 4, 2004. Last accessed: December 11, 2004.

Colorado Department of Local Affairs (DOLA). 2004. Cartography / GIS Section. Colorado Division of Emergency Management. URL: http://www.dola.state.co.us/oem/cartography/GISData.htm. Last accessed: December 11, 2004.

Colorado Department of Transportation (CDOT). 2004. URL: www.dot.state.co.us. Last accessed: December 11, 2004.

Colorado Division of Emergency Management (CDEM). 2004. State of Colorado Natural Hazard Mitigation Plan. Prepared by the Colorado Office of Emergency Management in 2001. Updated by the Colorado Division of Emergency Management in 2004. (Available at: http://www.dola.state.co.us/oem/Mitigation/MIT1.HTM)

Colorado Flood and Weather Information. 2004. Colorado Flood and Weather Information. URL: http://cwcb.state.co.us/flood_watch/. Last updated: September 15, 2004. Last accessed: December 11, 2004.

Colorado Geological Survey. 2002. Review and Priority List for Critical Landslides in Colorado. Colorado Geological Survey, Department of Natural Resources, Denver, CO. 2002

Colorado State Forest Service. last viewed at 12/12/2004 (Available at: http://www.colostate.edu/Depts/CSFS/),

Colorado Water Conservation Board. 2004. Flood Hazard Mitigation Plan for Colorado, June 2004. Colorado Water Conservation Board. (Available at: http://www.dola.state.co.us/oem/Mitigation/plan/07%20%20Flood%20Plan%202004.pdf)

Consultative Group for the Reconstruction and Transformation of Central America (CGRTCA). 1999. "Reducing Vulnerability to Natural Hazards: Lessons Learned from Hurricane Mitch, A Strategy Paper on Environmental Management." Workshop May 25-28, 1999. URL: http://www.iadb.org/regions/re2/consultative_group/groups/ecology_workshop_1.htm Last accessed: December 4, 2004.

County Sheriffs of Colorado (CSOC). 2004. URL: www.csoc.org. Last accessed: December 11, 2004.

Cutter, SL. 1996. Vulnerability to Environmental Hazards. Progress in Human Geography 20:529-539.

Cutter SL, JT Mitchell, MS Scott. 2000. Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. Annals of the Association of American Geographers 90(4):713-737.

Cutter, SL. 2003. The Vulnerability of Science and the Science of Vulnerability. Annuals of the Association of American Geographers 93(1):1-12.

Disaster Center. 2004. Colorado Tornados. URL: www.disastercenter.com/colorado/tornado.htm. Last accessed: December 11, 2004.

Disaster Mitigation Act (DMA). 2000. The Disaster Mitigation Act of 2000. 44 CFR, Parts 201 and 206, Interim Rule.

Federal Bureau of Prisons (FBOP). 2004 US Department of Corrections, Federal Bureau of Prisons, National Institute of Corrections. URL: www.bop.gov. Last accessed: December 11, 2004.

Federal Emergency Management Agency (FEMA). 2004. FEMA Flood Map Store. FEMA, Map Service Center. URL: http://store.msc.fema.gov. Last accessed: December 11, 2004.

Federal Emergency Management Agency (FEMA). 2004. Flood Hazard Mapping -- Frequently Asked Questions (Q3 Flood Data). Last accessed: December 11, 2004. URL: http://www.fema.gov/fhm/fq_q3.shtm#q346. Last updated: October 25, 2004.

Greatschools.net. 2004. Colorado. URL: http://www.greatschools.net/modperl/go/CO. Last accessed: December 11, 2004.

Jochim, CL, WP Rogers, JO Truby, RL Wold, G Weber, and SP Brown. 1988. Colorado Landslide Hazard Mitigation Plan. Colorado Geological Survey, Department of Natural Resources, Denver, CO. 1988.

Kistner and Associates. 1999. Flood Hazard Mitigation Plan for Colorado. Prepared by Kistner and Associates, Highlands Ranch, CO. Prepared for the Colorado Water Conservation Board, Department of Natural Resources. December 1999. Available at: http://cwcb.state.co.us/flood_watch/409%20plan.pdf

McKee, Thomas B., Nolan J. Doesken, John Kleist. 1999. Historical Dry and Wet Periods In Colorado. Colorado State University, Dept of Atmosphere Science. Climatology Report No. 99-1, Part B: Appendices.

Mitchell, JK. 1989. Where Might the International Decade for Natural Disaster Reduction Concentrate Its Activities?. DNDR 2, Natural Hazards Research and Applications Information Center, Rutgers University. September 1989.

National Atlas. 2004. Map Layers Warehouse. NationalAtlas.gov. URL: http://nationalatlas.gov/atlasftp.html. Last modification: November 23, 2004. Last accessed: December 11, 2004.

National Climatic Data Center (NCDC). 2004. Storm Event Database. URL: http://www.ncdc.noaa.gov/oa/climate/linktoed.html. Last modification: November 9, 2004. Last accessed: December 11, 2004.

Pearson Software Consulting, LLC (Pearson). 2004. Latitude and Longitude in Excel. URL: www.cpearson.com/excel/latlong.htm. Last accessed: December 11, 2004.

Rashed, Tarek, and John Weeks. 2003. Assessing Vulnerability to Earthquake Hazards Through Spatial Multicriteria Analysis of Urban Areas. International Journal of Geographical Information Science 17(6):547-576.

The Tornado Project. 2004. Tornadoes by State. URL: www.tornadoproject.com/alltorns/cotorn.htm. Last accessed: December 11, 2004.

United Nations (UN). 2002. Living with Risk: A global review of disaster reduction initiatives. Preliminary version 2002. Geneva, July 2002.

University of South Carolina. 2004. SHELDUS Version 2.1 - Spatial Hazard Events and Losses Database for the United States. University of South Carolina, Hazards Research Lab. URL: http://go2.cla.sc.edu/hazard/db_registration. Last accessed: December 11, 2004.

US Census Bureau. 2004. Colorado QuickFacts. URL: http://quickfacts.census.gov/qfd/states/08000.html. Last updated: July 9, 2004. Last accessed: December 6, 2004.

ATTACHMENT 1

CASE STUDIES ON SOCIAL VULNERABILITY

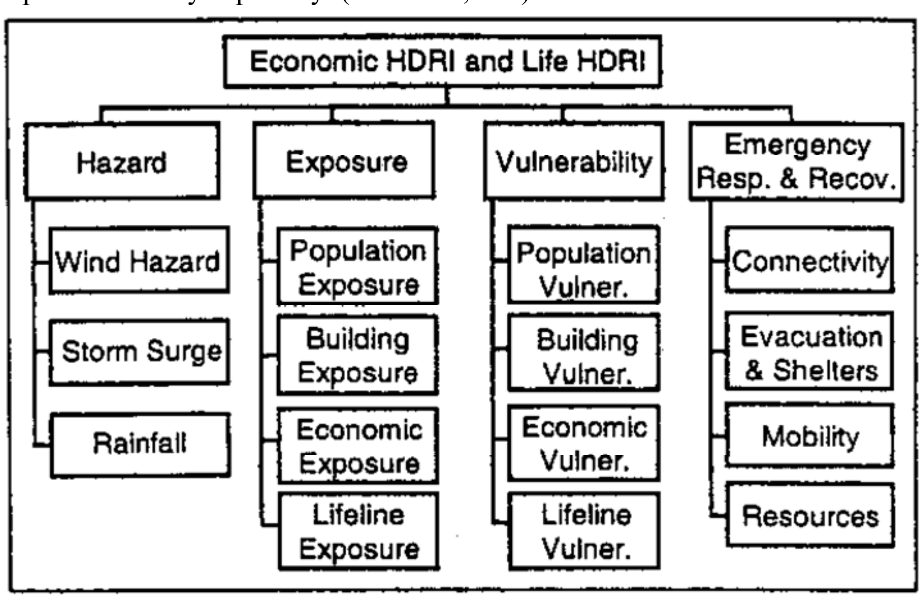
Comparing the Hurricane Disaster Risk of U.S. Coastal Counties
Rachel A. Davidson, Assoc. Member, ASCE, and Kelly B. Lambert, Student Member, ASCE
Natural Hazards Review, Vol. 2, No. 3, August 2001, pp. 132-142

In creating mitigation plans, the overall goal is to turn research into practice and educate as well as protect populations that are identified as being vulnerable to one or many hazards. Unfortunately, there is often a breakdown of communication and the mitigation plan isn't utilized fully to prepare or educate the identified population. The goal of this case study is to bring together the aspect of social vulnerability, as well as hazard mitigation planning, and identify how these are utilized in real-life applications to minimize damage to at-risk populations.

In the journal article 'Comparing the Hurricane Disaster Risk of U.S. Coastal Counties' Davidson and Lambert described the Hurricane Disaster Risk Index (HDRI) that was developed to compare the relative risk a hurricane disaster would have on economic and life loss in different coastal counties in the United States. It was also created to support local, state, and national government agencies as they make decisions regarding:

1. Resource allocation decisions
2. High-level planning decisions
3. Raise public awareness of hurricane risk including causes and ways to manage it.

This is an example of how Geographic Information Systems (GIS) can be operationalized to address specific cases of vulnerability. The social vulnerabilities that were dealt with in this case were the vulnerabilities of coastal counties. The authors state that there are four main factors that contribute to a county's hurricane disaster risk. These were: the hazard, exposure, vulnerability, and emergency response/recovery capability. (Davidson, 134)



There were social vulnerabilities identified by recognizing that not all loss can be attributed to dollars and lives. There are also impacts upon the economy and life of the community that are taken into account. These were identified as *economic disaster risk*, which was the total hurricane-related economic loss expected within a county annually, and *life disaster risk*, which was the number of hurricane-related deaths and injuries expected within a county annually. Dollars and units were not used to gauge these definitions, but rather a scale of 1-10 was used to determine how the quality of life was affected and would continue to be affected by a hurricane event.

GIS was used to identify all these attributes and process them into a mathematical equation that calculated risk. Under hazards, GIS was used to identify where high winds, storm surge, and rain have occurred over the past fifty years, however large or small the extent of damage they caused was. Exposure was calculated by identifying the number of people and value of structures that have been or would be affected by a hurricane. Individuals or groups that would be more or less likely to be to be injured, killed, displaced, calculated person vulnerability or have their daily lives disrupted in some form by a hurricane. These were found to depend on age, physical limitations and hurricane awareness. Emergency response was evaluated by number of shelters available, emergency evacuation clearance times, and the percentage of the population expected to evacuate.

In all, fifteen counties were selected along the eastern coast to demonstrate how this tool could be effective in evaluating vulnerable counties. If used, this tool could compare counties based on life or economic loss, to compare within a county area that would be more vulnerable, and to assess the overall risk that a county may have. The risk was broken down into smaller factors that a community could work on to make themselves less vulnerable. For example, a county may have a smaller chance of a hurricane striking, but slow emergency response raises their risk level. This is an item that can and should be changed to lower vulnerability, and as this tool brings it to attention, communities are more likely to fix their problems rather than wait for disaster to strike. Taking care of building vulnerability, population locations, as well as emergency response time can all lower the risk, and if budgets are tight, this tool allows communities to focus on the area that needs the most attention to optimize their monetary spending.

Local, state, and government officials can utilize the HDRI tool to assess how they can lower the risk within their counties and communities. This is an example of how technology can go beyond paper and reach populations to teach them how to identify and respond to their vulnerability. This is done through education and simplified processes that are easy to understand and help prioritize resources.

Social Vulnerability to Environmental Hazards

Cutter, Susan L.; Boruff, Bryan J.; and Shirley, W. Lynn. (2003, June) “Social Vulnerability to Environmental Hazards”. *Social Science Quarterly, 84*, 2: 242-261

In this study by Cutter, et al. county-level socioeconomic and demographic data from 1990 was utilized to create a Social Vulnerability Index (SoVI) for the U.S. This was a very important study because much of the contemporary work on social and quality-of-life indicators is relegated to popular rating places guides such as *The Places Rated Almanac*, *America’s Top-Rated Cities*, or comparative environmental quality. Currently there is no consistent set of metrics that can be used to assess a population’s vulnerability to environmental hazards.

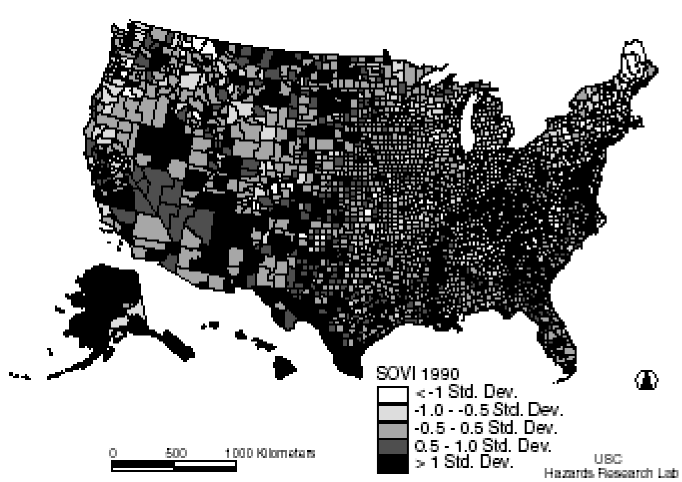
Luckily, there is a consensus throughout the social science community as to what some of the major factors of social vulnerability are, such as: lack of access to resources, limited access to political power and representation, social capital, beliefs and customs, building type and age, frail and physically limited individuals, and type and density of infrastructure and lifelines. The disagreements are upon the variables that represent these major factors.

Eleven composite factors were found to differentiate U.S. counties according to their relative level of social vulnerability in 1990. They are detailed below:

- Personal Wealth was measured by per capita income, percentage of households earning more than $75,000 per year, median house values, and median rents.
- Age is important because the two demographic groups most affected by disasters are the elderly and children. The number of elderly was measured by the percentage of the population over 65 and percentage receiving Social Security benefits.
- The density of the built environment describes the degree of development of the built environment and reflects which counties should expect structural losses from a hazard event.
- Single-sector economic dependence reflects that when the major industry suffers a significant setback from a hazard event, the entire population that is employed by that industry suffers. Occupation, another major factor, has very similar issues to this factor. White-collar workers are more able to go to meetings and do office work after an event than factory workers whose place of employment has just been demolished.
- The nature of the housing stock (such as mobile homes) and the nature of ownership (i.e. renters) and the location (urban vs. suburban) combine to produce the social vulnerability depicted in the housing stock and tenancy factor.
- Race and ethnicity are two different factors, but they both reflect on access to resources, cultural differences, and the social, economic and political marginalization of specific populations. Another major factor that comes into play with ethnicity is fluency of English and the ability to communicate with authorities.

FIGURE 2

Comparative Vulnerability of U.S. Counties Based on the Social Vulnerability Index (SoVI)



Cutter, et al. found that the five most socially vulnerable counties in the U.S. are: Manhattan Borough in New York City (it is the most vulnerable), San Francisco County in California, Bronx County also in New York City, Kalawao County in Hawaii, and Benton County in Washington. The five least socially vulnerable counties in the United States are: Yellowstone National Park County in Montana, Poquoson County in Virginia, Los Alamos County in New Mexico, Tolland County in Connecticut, and Moore County in Tennessee. All of the five least vulnerable counties with the exception of Yellowstone National Park County are populations of largely suburban, wealthy, white, and highly educated residents.

By using this Social Vulnerability Index and improving on the data, the State of Colorado would be on the right track to identifying the social vulnerability of its residents.

Other Articles and Books on Social Vulnerability

Translating climate change impacts at the community level. Frank Duerden. Arctic, June 2004 v57 i2 p204(9)

Social capital, collective action, and adaptation to climate change. W. Neil Adger. Economic Geography, Oct 2003 v79 i4 p387(18)

Methodological reflections on the use of remote sensing and geographic information science in human ecological research. *Matthew D. Turner.* Human Ecology: An Interdisciplinary Journal, June 2003 v31 i2 p255(25)

Hurricane 07B in the Godavari Delta, Andhra Pradesh, India: vulnerability, mitigation and the spatial impact. Greg O'Hare. The Geographical Journal, March 2001 v167 i1 p23

Seasonal Forecasting of African Rainfall: Prediction, Responses and Household Food Security. Richard Washington; Thomas E. Downing. The Geographical Journal, Nov 1999 v165 i3 p255

The geography of disaster vulnerability in megacities - A theoretical framework. J.I. Uitto. Applied Geography, Jan 1998 v18 i1 p7(10)

Uncovering the Hidden Costs of Coastal Hazards. Sheila D. David; Sarah Baish; Betty Hearn Morrow. Environment, Oct 1999 v41 i8 p10

Shifting sands. (Sahel region of sub-Saharan Africa) Simon Batterbury. Geographical, May 1998 v70 n5 p40(6)

Vulnerability and industrial hazards in industrializing countries: an integrative approach. M.F. de Souza Porto; C.M. de Freitas. Futures, Sept 2003 v35 i7 p717(20)

Where two sides meet: the assessment and analysis of place vulnerability for costal counties of the United States. Christopher T. Emrich; Byron Boruff; S.L. Cutter. Bulletin of the South Carolina Academy of Science, Annual 2003 p75(2)

The Angry Earth: Disaster in Anthropological Perspective. (Book Review) David Butz. Environments, August 2002 v30 i1 p99(3)

Disaster demographics: mapping high-risk populations can save lives during a catastrophe. Darrell A. Norris. American Demographics, August 1987 v9 n8 p38(4)

Disaster Evacuations: Tourist-business Managers Rarely Act as Customers Expect. Thomas E. Drabek. Cornell Hotel & Restaurant Administration Quarterly, August 2000 v41 i4 p48

Revealing the Vulnerability of People and Places: A Case Study of Georgetown County, South Carolina. S.L. Cutter; J.T. Mitchell; M.S. Scott. Annals of the Association of American Geographers, Dec 2000 v90 i4 p713(25)

Poverty and Disaster in the United States: A Review of Recent Sociological Findings. Natural Hazards 32:89-110, 2004. Fothergill, Alice and Peek, Lori A.

Coping and pulling through : action processes in vulnerable situations / edited by Vivianne Châtel, Marc-Henry Soulet ; translation by Margaret Lainsbury ; revised by John Richardson. Aldershot, Hants ; Burlington, Vt. : Ashgate, c2004

Building safer cities [electronic resource] : the future of disaster risk / edited by Alcira Kreimer, Margaret Arnold, Anne Carlin. Washington, D.C. : World Bank, c2003.

Richland County, South Carolina, hazard vulnerability assessment / USC Hazards Research Lab. [Columbia, S.C.] : The Lab, 2002.

Unnatural disasters / Janet N. Abramovitz ; Linda Starke, editor. Washington, D.C. : Worldwatch Institute, c2001.

Crucibles of hazard: mega-cities and disasters in transition / edited by James K. Mitchell. Tokyo ; New York : United Nations University Press, c1999.

ATTACHMENT 2

METADATA AND DETAILED PROCESS METHODOLOGY FOR SPATIAL DATA

(provided electronically on the attached CD)