EXPLORING COMMUNITY RESILIENCY TO FLOOD DAMAGE THROUGH THE ASSESSMENT OF FLOOD MITIGATION STRATEGIES: A CASE STUDY OF RAPID CITY, SOUTH DAKOTA

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Authorization to Submit Thesis

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Abstract

Hazard mitigation planning and mitigation strategy implementation can reduce community vulnerability to flood hazards when done properly. Mitigation strategies can aid in community resilience to flooding damages. Existing research has explored these strategies in the comprehensive plan and hazard mitigation plan; however other community plans address this hazard as well. This research investigated flood strategies found in various community plans to determine the spatial distribution of flood mitigation strategies. Stakeholder perspectives on current strategies were evaluated through interviews. Climate change projections were evaluated since they may create the impetus for enhanced mitigation strategies in the future. These three elements aided in the determination of areas that may be a high priority of future mitigation strategies.

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Introduction

During the twentieth century, flooding was the most devastating and frequent natural disaster in the United States in terms of loss of life and damage (Watson et al, 2011). One in every three federal disaster declarations in the United States is for flooding (Watson et al, 2011). The exposure of human assets to flood prone areas is what makes these catastrophes extremely costly. Exposure can be defined as the degree to which a system experiences environmental stress (Adger, 2006). Historically, building along rivers had economic benefits (Burby, 1998), including transportation capabilities and fertile land in river valleys. Communities often focus on flood protection and prevention in a community and do not incorporate the benefits of flooding for fertile land in their comprehensive plans (Watson, et al. 2011). Because of ports, fisheries, and outdoor recreation, billions of dollars in investment are allocated for coastal and river development despite their high hazard risks, exposing more community assets to flood hazards (Burby, 1998).

One way to reduce exposure to flood hazards is to have hazard mitigation plans that aim to limit development in hazard prone areas (Burby, 1998). Hazard mitigation can be defined as actions taken to reduce the risks to people and property from hazards (Schwab, 2010). To minimize the risk of natural hazards, society could shift towards "sustainable hazard mitigation" which links proper management of natural resources to local, economic, and social resiliency. Planners can play key roles in shaping the way a community interacts with natural hazards by understanding the community's specific hazards and finding the most efficient land uses to reduce hazard risk (Burby, 1998). Planners must view hazard

mitigation as an integral part of their plans (Mileti, 1999). Since hazard mitigation plans hold no regulatory authority and are only presented as recommendations, mitigation actions must be included in comprehensive plans and zoning regulations if reduction of community vulnerability is a goal (Schwab, 2010).

Vulnerability can be greatly reduced, and community resiliency to flooding increased, through sustainable land use and hazard mitigation planning (Schwab, 2010; Burby, 1998). Vulnerability is, quite simply, the potential for loss (Cutter et al, 2003). Many federal agencies in the United States are moving from disaster vulnerability to disaster resiliency since it has a more proactive nature (Cutter et al, 2008). Resiliency can be defined as the capacity of a social system to respond, recover, and adapt to disasters (Cutter et al, 2008; Adger, 2006). A natural hazard can be defined as a threat to people and property and natural disasters can be defined as singular events that result in widespread losses to people, property, and the environment (Cutter, 2001). Natural hazards and disasters are difficult to deal with and cannot be prevented; however, their impacts can be minimized through proper pre-event mitigation actions (Godschalk, 1999; Burby, 1999). Hazards interact with psychological, social, institutional, and cultural processes within a society that can amplify or reduce the way they view their hazard risk (Kasperson, 1988). This societal risk can be defined as the multiplication of the probability of an event and the magnitude of specific consequences (Kasperson, 1988).

Hazard mitigation planning's primary purposes relate to reducing the impacts of disaster events and the facilitation of recovery (FEMA, 2008). Pre-disaster mitigation efforts and land use planning can greatly reduce the funding needed to help a community recover, and it has been estimated that for every $1 spent on hazard mitigation, $4 is saved

in the event that disaster recovery benefits become necessary (MMC, 2005; Burby, 1999; Schwab, 2010). Federal agencies provide various grants to encourage hazard mitigation projects and have policies in place requiring communities to have hazard mitigation plans. In spite of the federal grant programs, much of the expense of hazard mitigation falls on local communities. The one dollar spent to save four dollars in response and recovery belongs to local governments and often many communities choose not to spend that one dollar instead relying on federal funding that comes with disaster declarations (Frazier et al. 2013).

In the face of local challenges, the Federal Emergency Management Agency (FEMA) has enacted various mitigation strategies for states regarding flooding (FEMA, 2012). Flooding mitigation efforts exemplify the multi-dimensional nature of hazard mitigation planning by incorporating natural science, social science, and engineering into mitigation strategies (Correia et al, 1998). Land use planning for instance can be used to minimize the impacts of natural hazard events (Burby, 1999; Wood et al, 2007; Frazier et al., 2010). By using land use planning in conjunction with other forms of hazard mitigation, losses due to natural disasters can be greatly reduced (Burby, 1999; Schwab, 2010). FEMA encourages the integration of hazard mitigation with other plans, however most hazard mitigation plans (HMP) are stand-alone documents because they appear to have very few connections to the other elements of the plan (Schwab, 2010; Mileti, 1999).

Often in society, we struggle to cope with planning for contemporary hazard events, and yet for many communities climate change will exacerbate these hazards. Plans and protocols may be in place to mitigate current hazard events, but they may be inappropriate to

the actual risks currently faced by communities with climate change potentially aggravating contemporary hazards risks (Arthurton, 1998). Climate change may also bring new hazards to areas where they currently do not exist (Adger, 1999). As such, societal losses due to natural hazards can be increased through the impacts of climate change. Most present day flood regulations do not effectively address current hazards and do not reflect future climate change impacts (Watson, 2011). As the climate shifts, the frequency and magnitude of flood events may change. Frequency, with regards to natural hazards, can be defined as how often an event is likely to occur (Alcantara-Ayala, 2002). Magnitude can be defined as the characteristics or extent of the event (Alcantara-Ayala, 2002). It is imperative that plans incorporate future and contemporary hazard risks in order to allow for continued development in hazardous areas.

Natural hazards are a societal issue and will be exacerbated as communities continue to increase their population density and more exposed assets along hazardous areas. If reduction of hazard losses is a goal in the community, research needs to be conducted to find more effective mitigation methods. This research attempts to do this by identifying existing mitigation strategies in Rapid City, South Dakota and determining their adequacy based on a review of contemporary and planned mitigation strategies across various plans, the risk perception of relevant stakeholders and its impact on local hazard mitigation, and the potential impacts of future climate change on local mitigation strategies.

Goals and Research Questions

The main goal of this research is to identify ways to increase community resiliency through improvements to current flood mitigation strategies. The sub goals are as follows:

- Conduct an assessment of flood mitigation strategies within local plans
- Interview salient stakeholders to help understand the perception of preparedness in current mitigation strategies
- Explore the extent to which climate change will impact flooding in the community
- Determine additional strategies to improve community resiliency

These goals will be achieved by addressing the following research questions:

1. Are current flood strategies consistent with contemporary and potential community hazard risks?
2. What are the stakeholder perceptions of flood mitigation strategies in the community?
3. What will the climate change impacts be on flooding in this community?
4. What are opportunities and constraints for enhancing current mitigation strategies?

A Case Study: Rapid City, South Dakota

The figure below shows the location of the study area. Rapid City is located in Pennington County which is found in the southwest corner of the state of South Dakota. Figure 1 below shows this map.

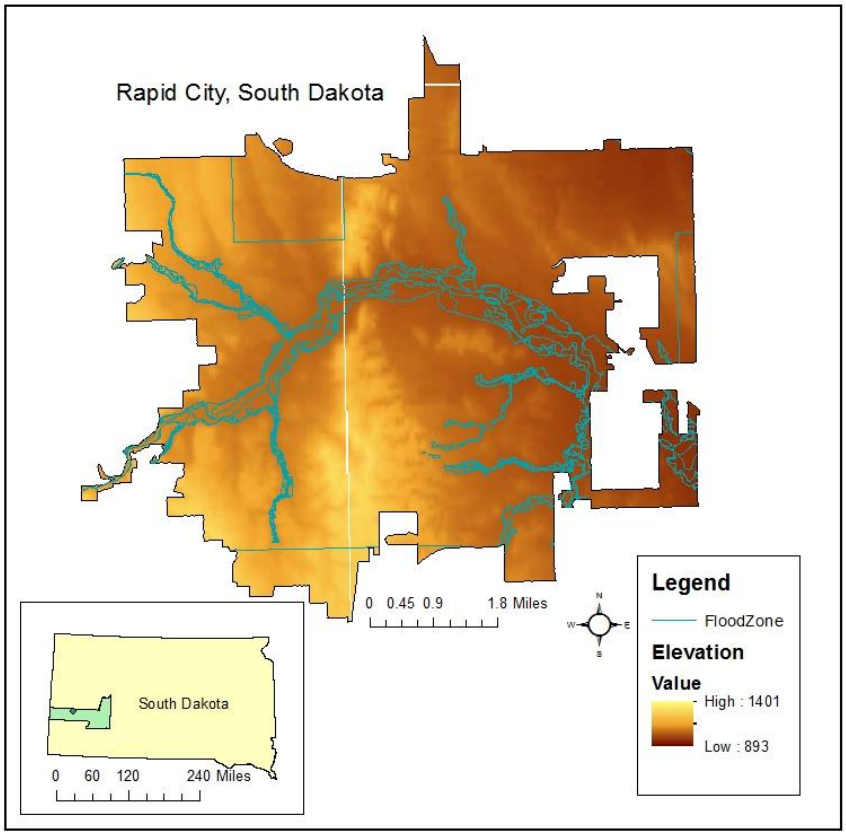

Figure 1: Case study area map

The population in Metropolitan Statistical Area (MSA) of my study region is 126,382. An MSA is a geographic entity that has at least one urbanized area of 50,000 or more in population and a surrounding area with a high integration of social and economic ties. This MSA includes both Pennington and Meade County. For the purpose of this research, Meade County will not be explored. In 2010, the population of Rapid City was 67,956 with estimates of a two to three thousand increase in the last few years. Pennington County had a population of 100,948 in 2010 with estimates of increases of four to five thousand in the last few years (Annual Estimates of the Resident Population, 2013). The

largest employer in the area is Ellsworth Air Force Base with 4,503 employees both military and civilian (Rapid City Economic Development, 2012). The community has a history of flooding as evidenced by numerous historical floods (occurring in 1890, 1892, 1901, 1907, 1926, 1949, 1952, 1960, 1962, 1972, 1975, 1981, 1993, 1997, 2001, 2004, 2008, 2009, 2011, 2013) (UNR Webmaster, 2013).

Rapid City has historically been inundated with floods and has found ways to recover after large flood events. They are the largest population center located within a valley in the Black Hills which creates the conditions necessary for flash floods. Rapid Creek runs through the city and is located under a major interstate and under many major bridges which can be exposed to structural destruction when flooding occurs.

The 1972 Flood in Rapid City

The Rapid Creek flood took place on June 9, 1972 at around midnight. This was a 500-year flood and had a peak discharge of 50,000 cubic feet per second which was ten times greater than the previous flood record. The flood claimed the lives of about 238 people and injured about 3,057 people, as estimated by the Red Cross. The damage of this event, which included 1,335 homes and 5,000 cars, totaled $160 million. Rapid City is in the 500-year flood plain, which indicates that the city has a 0.2% chance of experiencing a flood of this magnitude every year (Carter, 2002).

Since the flash flood entered Rapid City at midnight, residents were unaware of the imminent disaster. One factor that led to such devastating damage was the lack of communication between the National Weather Service (NWS) and the citizens of Rapid City. The office did not have any system in place to transmit a warning to the media,

emergency officials, or any other necessary personnel. They had a one-way telephone hotline to the media, which operated through a verbal notification of information (Carter, 2002).

Since 1972, many mitigation strategies have been enacted to reduce the impacts of a future flood since there has been significant population growth within the area and so many lives were lost in that year's flood. However, since there has not been a flood of equal or greater magnitude since 1972, it is difficult to determine if these strategies are effective since they remain untested against that type of disaster.

The impetus for selecting this study site is not only its history with flooding, but also because Rapid City has traditionally responded to flood events with hazard mitigation planning. The mitigation strategies in place in 1972 were ineffective, and this research will examine the spatial relationship of strategies to the floodplain, stakeholder perceptions of current mitigation strategies, and how climate change could affect the success of these strategies in the future.

Literature Review

Floods are the single greatest natural catastrophe and are one of the most well chronicled hazards in human history (Watson, et al, 2011). Inland floods are the result of storm water runoff that exceeds the capacity of stream and river systems often exacerbated by frozen ground, ice jams, wind, icing, landslides, mudflow, debris flow, and the failure of dams and levees (Watson et al., 2011). Natural disasters occur when the forces of nature impact people and property (Godschalk, 2003). These disasters can occur anywhere, but flooding generally occurs proximal to waterways and areas of runoff. Because of

transportation capabilities, people have lived along rivers since antiquity (Watson, et al, 2011). Since people are drawn to areas along rivers, property values are often quite high. High property values are attractive to developers and, consequently, residential properties tend to be built in hazard prone areas such as along rivers because of the scenic views (Burby, 1998). However, unregulated development and high volumes of people and property in the hazard area can decrease the capacity of riparian zones to naturally mitigate hazard impacts through water retention or filtration (Watson et al, 2011).

Traditionally, mitigation efforts to control flooding created a false sense of security and the notion that flooding can be tamed. This allowed for development along waterways. Because of this occupancy of the floodplain, flooding is the main disaster in the United States (Burby, 1998). In order to protect infrastructure from damage, a significant portion of mitigation funds are often spent on structural mitigation practices, such as dams or levees. These structures often fail during a disaster and require a great deal of additional clean up in an area that was previously considered protected (Brookings Institution Metropolitan Program, 2005). Once a disaster occurs, recovery efforts often involve rebuilding in the same hazard prone area (Burby, 1998). White and Burby discuss that an adjustment of the human occupancies to the floodplain. They suggest utilizing the natural resources associated with the flood plain in order to create the most efficient land use while reducing the impacts of a flood (White, 1945; Burby, 1998).

To adequately explore ways to adjust the human occupancy to the floodplain in a community, a proper hazard assessment should be conducted. Hazard assessments have three parts that include hazard identification, vulnerability assessment, and risk analysis.

These three levels together aid in successful future land use planning, redevelopment, and regulation of existing land uses. In terms of land use policy development, there is often a disconnect between expert risk analysis and the public risk perception (Cutter, 2001; Frazier et al, 2010; Burby, 1998). In order to address this disconnect, a sustainable approach to hazard research and planning is necessary to balance community growth and their resilience to natural hazards (Frazier et al, 2010). This requires the revision of comprehensive plans and hazard mitigation plans which can often be difficult due to competing interests that do not understand the complexity or necessity of some elements to the plans.

Another step to assess a community's vulnerability and resilience to hazards is through the incorporation of stakeholder interviews in the planning stage. (Godschalk, 2003; Burby, 2006; Frazier et al, 2010). Hazards research shows significant literature supporting the importance of this component in planning for natural hazards and climate change. This can increase community knowledge of the hazard or climate impacts (Moser, 2005). Climate change can increase the hazard risk and can put stress on long-term land-use planning within a community. By involving stakeholders in long-range comprehensive planning, vulnerability assessments, and climate adaptation planning, the local community can better understand the necessity of these elements in their community plans (Godschalk, Brody, Burby, 2003; Moser, 2005; Burby, 2006; Frazier et al, 2010).

Burton et al. (1978) states that the vulnerability of a population to natural hazards is created through the interaction of three elements. These include the physical environment, the human environment, and the adjustments we make to cope with the hazard. Vulnerability is a function of exposure, sensitivity and resilience, also known as adaptive

capacity (Turner et al. 2003; Cutter et al. 2006). The science of vulnerability is an exploration into the physical, social, economic, and political elements by which a community or system is influenced. It also includes how a community can mitigate these impacts and recover if an event were to occur (Wood, Burton, Cutter, 2010). Currently, communities struggle with planning and mitigating for contemporary hazards. Climate change impacts are expected to exacerbate these current vulnerabilities to hazards as many climate change models predict the intensification of hazard events (Frazier et al, 2010). As such, vulnerability is becoming a more prominent theme in the area of global and environmental change (Cutter et al, 2006).

Community vulnerability to flooding is increased when land uses are changed and precipitation increases (Miller, 2000; IPCC, 2012). Climate change has caused the total average precipitation in the United States to increase by greater than 5% over the past century. The amount of precipitation falling in the heaviest 1% of rain events has increased by over 20%. Precipitation trends in the United States indicate an increase in the frequency and intensity of heavy downpours as the climate continues to shift (USGCRP, 2013). With extended rainy periods, soil becomes saturated and additional rain causes run off and overflow of rivers and streams (Watson et al, 2011). This can impact the duration of floods, since they depend on the amount of water and the gradient of the stream. If the topography is flat, the flood duration is often longer (Miller, 2000). Climate events are estimated to increase in frequency and magnitude and populations and exposed societal assets are also increasing. This places more people and property at risk. There are opportunities for communities to reduce their risk to these climate shifts. This includes an adjustment of current activities, transformation or fundamental changes in activities (IPCC, 2012).

Because of contemporary and potential for increased frequency and magnitude to hazard events, there is a critical need for addressing hazard mitigation in community planning. Currently there is generally a lack of public awareness, a tendency to underestimate disaster probabilities, overreliance on technological fixes, and fatalism and defeatism when it comes to discussing preparedness in a community (Tierney et al, 2001). In order to properly define preparedness, we must look at Godschalk et al (1989) and the four stages of disaster response, which include mitigation, preparedness, response, and recovery. According to Godschalk et al (1989), preparedness includes short-term activities once a hazard warning has been issued, such as evacuation. Another aspect of preparedness is the spatial level on which the planning is occurring. Place-specific analysis provides more precise measurements to properly enhance community resilience through more appropriate mitigation and adaptation strategies (Cutter et al, 2008; Tate, 2012; Wood et al, 2010). The response stage includes emergency aid and assistance immediately following a hazard event. Finally, the recovery is the post-disaster stage that includes the rebuilding of damaged structures and working to restore community operations. Mitigation is the only stage that occurs well before the disaster, and where this research will be focused. (Godschalk, Brower, and Beatley, 1989).

In developed countries the loss of life due to natural hazards is decreasing, but property damage is climbing due to increased exposure of societal assets to natural hazards. Hurricanes, floods, earthquakes, and other disasters have caused billions of dollars of damage to communities across the United States. Because more societal assets are being exposed to hazards, the United States Congress has directed FEMA to make natural hazard mitigation its highest priority. This created the shift from responding to and recovering from

disasters to mitigating future events (Godschalk, 2003). When done properly, hazard mitigation planning can play a key role in reducing community vulnerability to natural hazards and can increase their resilience (Schwab, 2010; Frazier et al, 2013; FEMA, 2008). The magnitude of these hazard events depends on the population of the area impacted, the infrastructure exposed to the hazard, and the effectiveness of pre-disaster mitigation (Godschalk, 2003). Protecting infrastructure from damage requires a significant amount of money. FEMA has various grant programs available for states, tribes, and territories to aid in mitigation to reduce disaster losses. Sub grants can then be given to local communities within those states, tribes, and territories. Hazard Mitigation Assistance (HMA) grants provide funding for pre- and post- disaster mitigation to reduce loss of life and property from the impacts of natural hazards (FEMA, 2012).

Another part of that movement towards prioritizing hazard mitigation planning was the Stafford Act of 1988. This act detailed base level requirements for a hazard mitigation plan. FEMA requires a community to have an HMP in order to be eligible for hazard mitigation grants and an increase in post-disaster recovery federal funds. The Disaster Mitigation Act of 2000 established minimum requirements for these plans. Part of these minimum requirements are detailed in FEMA's crosswalk document that compares a local hazard mitigation plan's contents with official requirements in order to determine if the plan is in compliance (Schwab, 2010).

FEMA also has a Flood Mitigation Assistance Program which was created as part of the National Flood Insurance Reform Act of 1994. These grants assist states and communities in reducing the long-term risk of damage from flooding to infrastructure

insured under the National Flood Insurance Program. These grants come in three types: Planning Grants, Project Grants, and Management Cost Grants. Planning Grants are used to prepare flood mitigation plans. Project Grants implement measures to reduce flood losses. Management Cost Grants help administer the flood mitigation assistance program and the included activities (FEMA, 2012). Floodplain management in the United States is "a decision-making process that aims to achieve the wise use of the nation's floodplains" (FEMA, 2012). This includes reducing flood losses and protecting natural resources and the function of floodplains. They use the Flood Hazard Mapping Program to identify flood hazards, assess flood risks, and work with states and communities to provide data for mitigation efforts. Flood Insurance Rate Maps use statistical data from river flow, storms, rainfall, etc., to create flood hazard maps that outline flood risk areas in communities (FEMA, 2012).

FEMA's 2013 Mitigation Ideas document suggests strategies to be incorporated into local comprehensive plans in order to properly address floodplain issues. Below is the list found in the document:

- Determining and enforcing acceptable land uses to alleviate the risk of damage by limiting exposure in flood hazard areas
- Developing a floodplain management plan and updating it regularly
- Mitigating hazards during infrastructure planning. For example, decisions to extend roads or utilities to an area may increase exposure to flood hazards.
- Adopting a post-disaster recovery ordinance based on a plan to regulate repair activity, generally depending on property location
- Passing and enforcing an ordinance that regulates dumping in streams and ditches
- Establishing a "green infrastructure" program to link, manage, and expand existing parks, preserves, greenways, etc.
- Obtaining easements for planned and regulated public use of privately-owned land for temporary water retention and drainage (FEMA, 2013, 22).

Even with all of these guides on how to conduct hazard mitigation, there are still constraints to implementing strategies. One constraint is that hazards often cross political boundaries. Burby (2004) discusses that strategies need to manage watersheds on all levels and not just certain portions, because without continuity there can be serious consequences. Communities mitigating for hazards in a certain part of the watershed can negatively impact communities that are not mitigating. For example, certain areas may be flooded by levees in place up river when a storm event occurs (Burby, 1998). Godschalk (2003) discusses opportunities for mitigation actions, both structural and nonstructural that can aid in reducing long-term risk to human life and property from hazards. Some of these mitigation actions include strengthening infrastructure through building codes, design, and construction practices, building dams, levees, and seawalls, avoiding hazardous areas by redirecting new development to safer areas through land-use plans and regulations, and maintaining natural features that can protect against hazards such as sand dunes, wetlands, forests, and other ecological elements (Godschalk, 2003).

Hazard research, particularly relating to flooding, has been occurring since as early as 1936. For example, White in 1936 discussed how there are significant reductions in property damage from natural hazards when plans are an amalgamation of hazard mitigation and comprehensive planning (White, 1936; Schwab, 2010). However, White states that hazard mitigation plans are often poorly crafted and require much expertise in their construction. This is one reason, White notes, that hazard mitigation is not incorporated very well, or at all, into comprehensive plans. The major problem White observes with these lapses in plans is the federal policies that do not discuss in detail the importance of and proper ways to utilize land-use planning for hazard mitigation (White, 1936). Communities

can also create better hazard mitigation programs within local governments to more appropriately address hazards in community plans (White, 1936). The comprehensive plan holds that legal status and can make decisions regarding capital expenditures and land use (Schwab, 2010). This can also help with plan consistency and reduce the issues with plan outcomes since they will be related (Schwab, 2010). The Disaster Mitigation Act of 2000 could be amended to include a requirement that requires that mitigation regulations be integrated into the local comprehensive or community plans (Burby, 2006). However, an unfunded federal mandate could create problems for local communities lacking the budget flexibility to incorporate this element. These regulations would also be on a national scale and may not be specific enough for local communities and their specific hazards.

Even after decades of research showing the importance of integrating HMPs with comprehensive plans, communities still find it difficult to complete this task. Ten states throughout the United States currently have requirements that local comprehensive plans must address natural hazards in a specific element (Schwab, 2010). California policy and law is also requiring climate change mitigation and adaptation be addressed in their local comprehensive plans and Nevada has requirements for plans to address natural hazards in communities of more than 400,000 people (Schwab, 2010). In Florida, North Carolina, and South Carolina, coastal management elements are required in comprehensive plans and Florida's Growth Management Plan requires that these plans be reviewed and approved by the state Department of Community Affairs (Schwab, 2010).

Burby et al. (2000), looks at the impact that the DMA has on land use planning and the reduction of hazard losses. Burby's research yields a series of principles for managing development to reduce local exposure to hazards, which are as follows:

- Using maps to delineate hazards
- Preparing design guidelines for hazardous areas
- Steering development to hazard-free land
- Reviewing land for potential hazards before allowing subdivision
- Providing incentives for building in appropriate locations
- Purchasing properties in hazard-prone locations
- Using project-specific design to reduce hazard exposure
- Using post-disaster periods as windows of opportunity for mitigation (Burby et al. 2000)

Strategies from the Northridge 1994 earthquake that were examined by Burby et al. (2001), found that there was less damage in Southern California communities that had implemented high-quality safety elements for natural hazards in their comprehensive plan than communities that did not have these elements. Again since hazard mitigation plans hold no legal standing, it is important to have hazard mitigation incorporated into the comprehensive plan through ordinances and land use regulations since these do have legal basis.

One mitigation strategy to reduce flood losses is through engineering and construction modifications (White, 1960). When more infrastructure is built to withstand flooding, there is often an accelerated movement of people and businesses onto the

floodplain (White, 1960). This continues today with dams, reservoirs, and levees. These are engineering methods that have been put in place to reduce risk in these vulnerable areas while still reaping the rewards of continued development (Burby, 1998). However, structural support for buildings in coastal and river hazard zones is not always up to the best standards. Development along coastal and river hazard zones have been in place for a long time and they often have very few recent updates to withstand floods (Burby, 1998). These infrastructure modifications may impact the risk perception of the community because they often view these supports as providing complete protection against hazards, when in reality they can only provide partial protection (Burby, 1998). Prior to Hurricane Katrina, the national development policy focused on making hazardous areas safe by putting up higher levees. Land behind the levees became "targets for catastrophe" since the levees encouraged more development behind them. Those levees then failed during Hurricane Katrina destroying the communities (Burby, 2006). White (1994), states that engineering, flood proofing, improved warnings, emergency disaster assistance, indemnification through an insurance system, changes in land-use, and restoration of once low-lying wetlands, are all ways to reduces flood loss in an area. However, it must be noted that communities need to find the best combinations of all these methods in order to protect their community specifically. What may work for one area may not for another (White, 1994).

Selecting the most adequate mitigation strategies from a variety of alternatives is a complex decision making process (Bose and Bose, 1995). Bose and Bose discuss elements required in this decision-making process. Qualitative methods such as stakeholder interviews (Frazier et al, 2010) and quantitative methods such as Geographic Information Systems (GIS) (Bose and Bose, 1995) to delineate where flooding is possible, can aid in

multi-criteria decision making for hazard mitigation planning (Bose and Bose, 1995). This research will assess plans through qualitative interviews and quantitative GIS analysis.

Chapter Overview

The following paragraph briefly describes the four chapters contained within this thesis. Chapter Two describes the methodology used to complete this research. It explains methods used in site selection, the interview process, the geocoding the mitigation strategies, the flood frequency assessment, and the review of climate change modeling within the literature. Chapter Three gives the results of each method used in the research. It details the results from interviews and shows the results of the mitigation strategy assessment from interviews and climate change data as well as the formulation of additional strategies. Chapter Four is a discussion of the results. Furthermore, this chapter discusses the benefits of this research to society as well as some limitations to the research conducted. Following it are the reference section and appendices for the paper.

CHAPTER 2: Methodology

Selection of Study Site

A contributing factor to my selection of Rapid City as my case study area was my familiarity with the city and region. I became intimately familiar with the community during the summer of 2011 when I lived in Rapid City. The understanding I gained during my residency enabled me to easily navigate community websites and create maps in ArcGIS. Furthermore, my knowledge was helpful when interviewees described details of the city. Another contributing factor to my selection of this community is due to the extensive damage and loss of life brought on by the 1972 flash flood in Rapid City, South Dakota, making this city and region a more than adequate case study. By exploring the conditions before 1972, the improvements made to the community since 1972, and the future potential for flooding, this research will provide insights into the adequacy of flood mitigation strategies within a flood prone community. Rapid City, in Pennington County, is located along Rapid Creek. This creek is prone to flash flood events and provides an excellent case study when examining flood mitigation strategies.

Pennington County completed the most recent version of their Pre-Disaster Mitigation Plan (PDM) in 2013. I obtained a digital copy of the current plan, which allowed me to locate stakeholders that had knowledge of the current mitigation strategies. The other community plans used in this research were taken from Rapid City since the floodplain being explored is within the city limits.

In April of 2012, Rapid City was moved from a Class 8 to a Class 7 in FEMA's Community Rating System (CRS). Rapid City is the only city in South Dakota that is part of this program. They joined the program in 1992 (Community Rating System, 2013). CRS is a voluntary incentive program that recognizes communities that have exceeded the minimum National Flood Insurance Program (NFIP) floodplain management activities. Flood insurance premium rates are discounted based on how the community reduces flood damage to insurable property, strengthens and supports the insurance aspects of NFIP, and encourages a comprehensive approach to floodplain management (FEMA, 2013). The areas they exceeded NFIP standards were elevation certificate, map information service, outreach projects, hazard disclosure, flood protection information, additional flood data, open space preservation, higher regulatory standards, flood data maintenance, stormwater management, repetitive loss category, drainage system maintenance, flood warning program, and dam safety (Kooiker, 2012).

The methods used to conduct this research in Rapid City are as follows.

Mitigation Strategy Assessment

Compilation of flood mitigation strategies in various community plans

Ten community plans were collected from relevant community departments or organizations around Rapid City and were evaluated for inclusion of strategies that pertain to flooding or the floodplain. A word search was performed on each plan that included flood, mitigation and mitigate, storm, and land use. Sections that were noted as having one or more of these words were then closely examined for mention of a specific strategy relating to flooding. Each flood strategy that was found was recorded. Plans without any

flood related strategies were noted as containing no flood strategies. The following section details the plans that were evaluated for flood strategies.

1. *Pennington County Pre-Disaster Mitigation Plan (2013)*

The Pennington County Pre-Disaster Mitigation Plan (PDM) was chosen for assessment based on its relevance to Rapid City and inclusion of mitigation strategies. This plan was prepared in response to the Disaster Mitigation Act of 2000. It was developed by the Pennington County Emergency Management Office and the local Planning (Steering Committee) Team. Current mitigation strategies that related to either Rapid City or Pennington County as a whole with relation to flooding were assessed.

2. *Rapid City 2013 Plan drafts*

Since the 2013 plan is currently being updated, this research assessed the plan drafts that were available. Rapid City's first city plan was adopted in 1949, with the last full update in 1981. There have been elements updated throughout the years since 1981, but the plan has never undergone complete revision until this year, 2013. Therefore, I will be exploring the Plan Rapid City website for updates on the plan or drafts that may arise while I am completing publication efforts for this research. These drafts will serve as the unofficial assessment for the comprehensive plan. Some of these include:

- *Issues and Opportunities for the Plan (Plan Rapid City Update) to address*
- *Draft Future Land Use Maps & Categories*
- *Draft Plan & Policy Framework*
- *2011 Community Survey*
- *Community Profile Document (2013)*

3. *Rapid TRIP 2035 - Long Range Transportation Plan for the Rapid City Area (2010)*

The Rapid TRIP 2035 plan addresses areas in and around Rapid City that are expected to become urbanized by the year 2035. It is a 413 square mile planning area and the plan was developed through an open and collaborative planning process that complied with applicable government legislation and regulations.

4. *Capital Improvement Plan 2013-2018 (2013)*

This document detailed the capital improvement projects in list and map form as of July 2013. It is noted that it should be updated annually or as significant changes occur. The tables list the project names, initial year of construction, estimated project cost, department driving the project, and the components of the project.

5. *Airport Master Plan (2008)*

This master plan contains a long-term vision for the Rapid City Regional Airport and acts as a guide for future Airport development.

6. *2020 Strategic Plan: A Clear Vision for Rapid City's Future (2011)*

This document explores the strategic goals Rapid City would like to see accomplished by the year 2020.

7. *Campus Master Plan (2011)*

This plan explores the execution of the 2020 Strategic Plan by the South Dakota School of Mines and Technology. With their proximity to Rapid Creek, it is important to assess their plan for mitigation strategies.

8. *2008 Land Use Plan*

This plan is the framework for ensuring orderly and efficient growth in Rapid City and is a compilation of sixteen neighborhood plans. It encompasses 413 square miles and the type of development desired by each community.

9. *Rapid City Area Bicycle and Pedestrian Master Plan (2011)*

Since many bike and pedestrian paths are located along or within the floodplain, it was important to include this plan in the assessment. This plan builds on past and on-going efforts by the Rapid City Area Metropolitan Planning Organization and the City of Rapid City to enhance transportation options and improve the quality of life in the Rapid City Area. This will be adopted as part of the Rapid City Comprehensive Plan.

10. *Stormwater Ordinances (2007)*

These ordinances relate to the regulation of construction site runoff to prevent pollution, impairment, and destruction of natural resources.

Locations of Flood Mitigation Strategies

After the flood strategies were obtained from the various community plans, their general location was identified. This was determined through contextual clues to the locations of projects and further research into specific projects. The X and Y coordinates of these locations were then found using Google Maps and recorded in an Excel spreadsheet.

Once the flood mitigation strategies were compiled in an Excel spreadsheet, the file was converted to a .csv file in order for it to be opened in ArcGIS. A feature class was created from the .csv file. This feature was then added to a base map of Rapid City that was added to the map from ArcGIS online to show the mitigation strategies spatial relationship to Rapid Creek, which is where the major flooding occurs in this community. The shapefile of the strategies was further manipulated to create separate shapefiles of specific types of strategies that have been implemented. The symbology was altered in order to use easy to understand symbols that would be creative, and interesting for use in a presentation or poster.

By creating different categories to group mitigation strategies together, structural and non-structural strategies were able to be determined. A table was created to display what types of strategies were found and whether or not they were structural or non-structural. This showed totals of each and determined which type of mitigation effort is most prevalent tin this community based on the strategies that were compiled.

An imagery basemap from November 2013 was added to the strategies shapefiles and flood zones layer to get a better understanding of the infrastructure in place along the creek and in the hazard zones. Four area maps were created to identify areas where future mitigation may be needed or areas where more investigation needs to be done to determine the threats those infrastructure face.

Stakeholder Interviews

Selection of Stakeholder Interview Participants

Stakeholder interaction provides nuance that supports this type of research and has been incorporated in this type of research in the past (Burby, 2006; Moser, 2005; Godschalk, Brody, Burby, 2003). Creswell (2013) has also acknowledged interviews as a useful qualitative method to gain stakeholder knowledge. For this research, in order to identify stakeholder perceptions of current flood mitigation strategies, I conducted interviews. These interviews were with relevant stakeholders that were determined through interactions with local contacts as well as from government websites. Initial contact with a local expert, Dr. Cody Knuteson, who resides in Rapid City and works on drought preparedness through interviews, focus groups, and surveys of relevant parties, also facilitated the formulation of relevant stakeholders contacts. With Dr. Knuteson and Dr. Frazier's expertise in the area of stakeholder interview etiquette, I developed a comprehensive list of stakeholders with knowledge domains relevant to the research being conducted. These stakeholders included professionals at the following agencies: National Weather Service, USGS, faculty at the South Dakota School of Mines and Technology, Emergency Managers, the State

Climatologist, United States Army Corps of Engineers, FEMA, Community Planners, and the National Flood Insurance Program. These agencies were chosen based on their expertise within the area of flood mitigation and their occupation relating to either mitigation strategy formulation or implementation. Local contacts as well as government websites were used to obtain contact information for each stakeholder selected.

Interview Process

In total, 13 stakeholders were interviewed for this research. Initial emails were sent out in May of 2013 to determine which stakeholders would be available for an in person interview when I traveled to the study site. Since I was confined to my travel dates some interviews were conducted over the phone or via email. I was not able to connect with stakeholders from Housing and Urban Development (HUD) and Department of Transportation (DOT), and was unable to find contact information for homeowner associations. I was successful in contacting every other stakeholder group. The phone and in person interviews was each roughly transcribed throughout the conversation. One stakeholder forwarded the questions to a co-worker who had more expertise in the area and I received his answers in written form. Throughout the interview process, stakeholders suggested other relevant professionals that would be useful to interview. This provided additional contacts that were not initially found on the preliminary search.

Prior to conducting stakeholder interviews, the interview questions were sent to the Institutional Review Board (IRB) at the University of Idaho to ensure that the research was being conducted in a manner that the University supported. IRB certified this interview phase of the research as an exempt project. In order to ensure that the stakeholders being

interviewed understood the University's view on the project, I included this statement on each interview form. Figure 2 below shows the interview questions.

Stakeholder Interview

Name:

Organization:

Date:

In-person interview/Phone/Email

"The University of Idaho Institutional Review Board has Certified this project as Exempt."

1. What do you perceive as the most important mitigation strategy currently in place for flood preparedness in Rapid City?
2. In your experience, what are some past successes and/or failures of flood mitigation strategies in Pennington County or Rapid City?
    a. Have these been proactive or reactive strategies?
3. What are other strategies you think the community needs to implement or weaknesses in current strategies that could be improved?
4. Who or what would be the most at risk if another 1972 magnitude flood were to occur in this community?
5. Is there anything you feel I have left out of this interview or anything else you would like to comment on or discuss?
6. Can I give you a call if I need clarification or more information on something we discussed?

Figure 2: Stakeholder Interview Questions

Analysis of Interview Data

I used the Atlas TI software to code the interviews. This software systematically analyzes qualitative data by locating, coding, and annotating text. It can be used to weigh

and evaluate the importance of findings, and visualize relationships between data (Lewins, 2007). Coding in this manner allowed me to find patterns or common phrases related to flood mitigation strategies. In short, Atlas TI provided a method to organize, synthesize and quantify the stakeholder interviews. Each rough interview transcription was entered into the software interface as a word document. All documents were coded by selecting key words from each interview questions and then using those codes to find related phrases in each question. This created a document containing each code and the phrases associated with that code. Common phrase usage was recorded to show repetition between stakeholder perceptions for each question.

Climate Change Projections

Review of climate change and variability predictions and how it impacts this study site

Historical flood events found within the literature were analyzed to determine the flood frequency along Rapid Creek. Climate change projections were then used to estimate if the frequency and magnitude of flooding events was likely to change given future climate scenarios. Due to the regional nature of climate change projections, accurate predictions on a city level were unable to be determined, and state assumptions had to be made.

Regional climate change data was found in the United States Global Change Report that is in draft form for the year 2013 as well as the International Panel on Climate Change 2007 Future Trends Section. Precipitation and temperature distribution was reviewed to determine the levels of drought and increased precipitation that could be anticipated in this state. With regards to flooding, drought is important to assess because drier conditions

make an area more susceptible to flash floods. Without the ability to rapidly absorb precipitation, areas are more likely to experience rain running over the ground instead of absorbing. The projected number of dry days was reviewed to determine if there was a visible increase in precipitation in the area. The USGCRP 2013 looked at conditions in lower emissions as well as higher emissions to see if there would be a difference in projections. The projections are stated for the years 2041-2070.

Additionally, reports put out by the Intergovernmental Panel on Climate Change (IPCC) were reviewed for information pertaining to increases in precipitation, drought conditions, and temperature distributions. The IPCC is the leading international body for the assessment of climate change (IPCC, 2012). Both the USGCRP and IPCC were used to determine climate projections and to show if flooding may be an even larger issue for Rapid City in the future.

Changes to current strategies or additional strategies formed

Mitigation strategies that were found to be missing in PDM based on the answers to the stakeholder interviews were determined through Atlas TI and consistent missing information was noted to determine necessary changes to current strategies or additional strategies needed in the community.

Strategies were formed through an assessment of the maps created during the spatial exploration of strategies and through information obtained from stakeholder interviews. Areas that appeared lacking in mitigation efforts and that may have infrastructure in hazardous areas were noted as locations for further analysis to determine the adequacy of

their strategies. Hazard literature relating to planning and hazard mitigation were identified and used to find adequate strategies.

Climate change data from IPCC and USGCRP was used to determine if the strategies in the plan are adequate given the predicted changes to the environment. Additional strategies were then framed in order to address the potential impacts from climate change to this region and the adequacy of the current mitigation strategies to the local hazard.

CHAPTER 3: Results

This section details the findings in this research. Each research question is noted and the goals associated with that research question were identified. The methods used to achieve that goal are noted and results from those methods are then explicitly detailed. First the spatial distribution of flood events will be discussed, followed by interview coding, then the climate change coding, and finally the additional strategy recommendations are detailed.

Mitigation Strategy Assessment

Question 1: Are current flood strategies consistent with contemporary and potential community risk?

Goals addressed: Conduct an assessment of flood mitigation strategies within local plans

Methods Used: Spatial distribution of flood events in ArcGIS

Twelve community plans were gathered and a word search was performed to determine if there were flood mitigation strategies present within the plan (Table 1). These were then placed into an Excel spreadsheet and their X and Y coordinates were determined through Google Maps (Table 2).

This spreadsheet was then converted to a .csv format in order to bring it into the ArcGIS software. A feature class was created and a shapefile was added to the map document. These strategies were then manipulated in the attribute table to group together similar strategies and more easily display them in separate shapefiles with unique symbology (Figure 3).

Results:

Table 1 shows that of the twelve plans collected and assessed for inclusion of flood mitigation strategies, eight contained these strategies.

Table 1: Community plans and number of strategies per plan

Plan Title	**# of Strategies per plan**
PDM	5
Plan Rapid City Drafts	1
Rapid Trip 2035	3
2008 Rapid City Area Future Land Use Plan	2
SDSMT Campus Master Plan	6
Airport Master Plan	2
Rapid Map Online	40
Capital Improvement Plan	17
2020 Strategic Plan	0
Stormwater Ordinances	0
Bicycle and Pedestrian Master Plan	0
Total	**76**

Seventy-six strategies in total were identified and 51 strategies were able to be identified with an X and Y coordinate. Table 2 shows the list of these strategies.

Table 2: Flood Mitigation Strategies and their X and Y Coordinates

STRATEGY	ADDRESS1	ADDRESS2
RapidTRIP 2035 discourages the development of roadways in or through floodplains	44.084687	-103.243808
Maintain the Rapid Creek greenway corridor for public use, public safety, and flood protection, and discourage encroachment by incompatible uses in the corridor.	44.084549	-103.243915
Sites selected for joint use with Rapid City or Penn Co as athletic playfields or county fairgrounds should retain these uses since they are in the Rapid Creek 100 year floodplain and not suitable as building sites.	44.074853	-103.20012
Demonstrate environmental stewardship by using landscaping consistent with the native landscape of the Black Hills, xeriscaping, reforesting slopes and unstable soils, and employing best practices in stormwater management and floodplain preservation	44.073681	-103.20675
Jackson Blvd Utilities Chapel Ln - Rapid Creek Bridge	44.060329	-103.294877
Creek Drive Bridge Replacement - Check if over Rapid Creek	44.07364	-103.186359
Jackson Blvd Utilities Chapel Ln - Rapid Creek Bridge-Mt View	44.060329	-103.294877
Canyon Lake Dam	44.058032	-103.285843
Sheridan Lake Rd Reconstruction - June Ct to Rapid Creek	44.073928	-103.262197
St Patrick Levee	44.067885	-103.180808
two levees north of omaha between maple ave and Dakota	44.083346	-103.220204
two levees north of omaha between maple ave and Dakota	44.083346	-103.220204
eastern railroad bridge levee	44.064893	-103.196021
Federal Levee Between Canyon Lake & Sheridan Road	44.0749	-103.262129
Pactola Reservoir	44.08105	-103.507031

Greenway ParcelCanyon Lake park	44.0594	-103.2911
Greenway Parcel	44.0578	-103.2837
Greenway Parcel Meadowbrook Golf Course	44.0579	-103.2816
Greenway Parcel Dinosaur Park	44.0771	-103.2474
Greenway Parcel Storybook island	44.0726	-103.2617
Greenway Parcel Jackson Frisbee Golf Course	44.07	-103.2683
Greenway Parcel	44.0746	-103.2588
Greenway Parcel	44.0802	-103.2564
Greenway Parcel	44.0822	-103.2554
Greenway Parcel	44.0836	-103.2551
Greenway Parcel Founders Park	44.0829	-103.246
Greenway Parcel	44.0838	-103.2445
Greenway Parcel	44.0833	-103.2482
Greenway Parcel	44.0842	-103.2492
Greenway Parcel	44.0852	-103.246
Greenway Parcel	44.0873	-103.2364
Greenway Parcel	44.0847	-103.2345
Greenway Parcel	44.0858	-103.2314
Greenway Parcel	44.0851	-103.2268
Greenway Parcel	44.0842	-103.2218
Greenway Parcel	44.0863	-103.2223
Greenway Parcel	44.0861	-103.2207
Greenway Parcel	44.0857	-103.2181
Greenway Parcel	44.083	-103.2174
Greenway Parcel	44.0824	-103.2131
Greenway Parcel	44.0829	-103.2078
Greenway Parcel	44.0845	-103.211
Greenway Parcel	44.0811	-103.2079
Greenway Parcel	44.0799	-103.2067
Greenway Parcel	44.0777	-103.2061
Greenway Parcel	44.0806	-103.2026
Greenway Parcel	44.08	-103.2028
Greenway Parcel	44.0798	-103.2025
Greenway Parcel	44.078	-103.2032
Greenway Parcel	44.0794	-103.2013
Greenway Parcel	44.0786	-103.2013
Greenway Parcel	44.0787	-103.2
Greenway Parcel	44.0736	-103.1987
Greenway Parcel	44.0741	-103.1943
Greenway Parcel	44.072	-103.1934

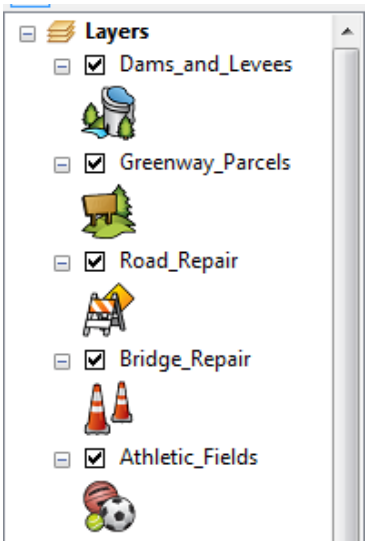

Figure 3: Grouping of mitigation strategies from attribute table

Figure 4 shows the spatial distribution of flood mitigation strategies in Rapid City, South Dakota. Symbology was adjusted in ArcGIS to help visually identify specific types of strategies more easily.

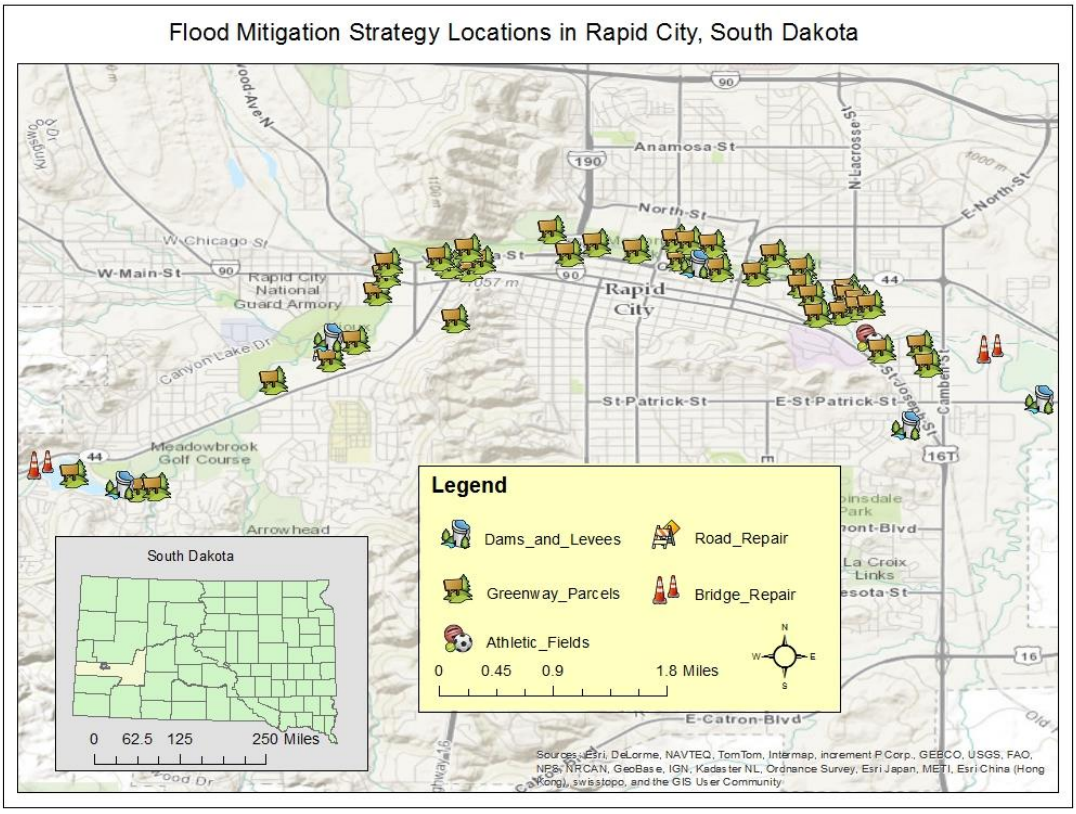

Figure 4: Overview Map 1

Figure 5 shows the flood hazard added to the mitigation strategy elements.

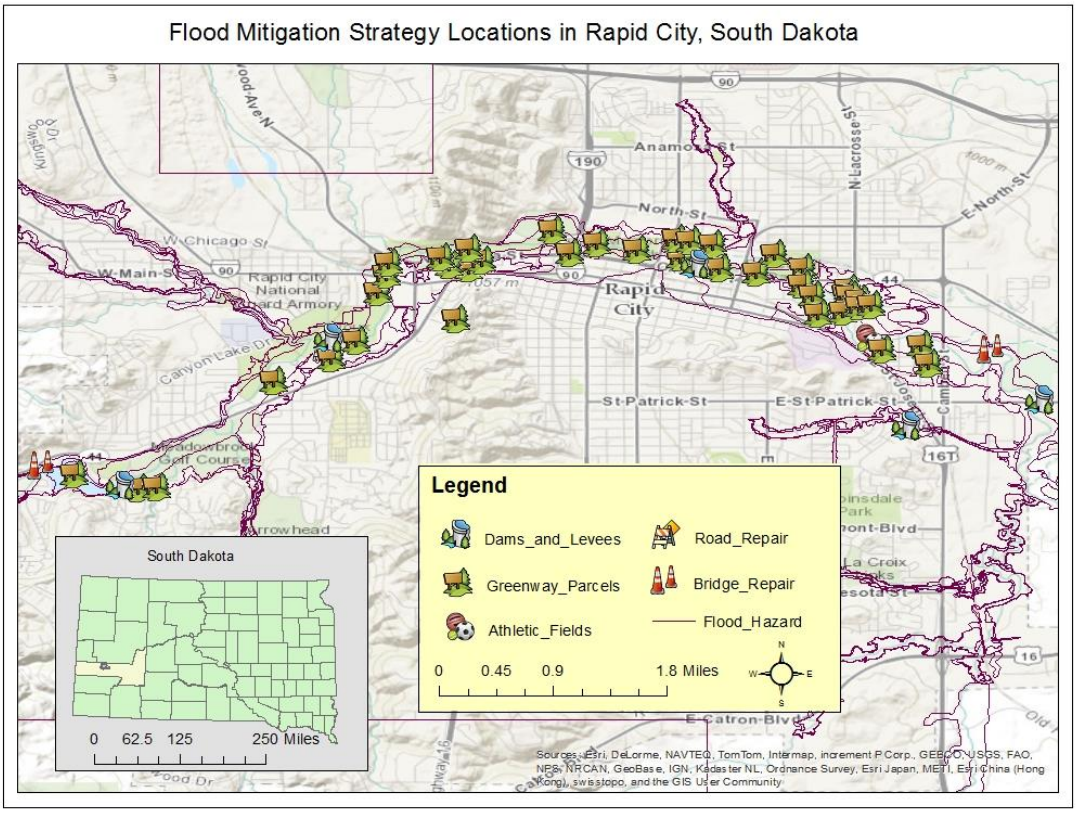

Figure 5: Overview Map 2 with Flood Zones

Greenway parcels designation is the most numerous strategy with 40 found in Rapid City's plans. These parcels were found on Rapid Map, an online map system that the city of Rapid City has created to allow citizens to view and create maps. Unfortunately, this program was not easy to manipulate and layers could not be added to it, so I simply identified the center of each greenway parcel, noted the X and Y coordinate of each center point, and added it to the spreadsheet. The basemap on the map above also shows parkland in green which corresponds to the greenway parcels. This shows that these strategies were in fact implemented.

Figure 6 shows the mitigation strategies, flood zones, and an imagery basemap of Rapid City. This basemap was added to show in more detail the types of infrastructure that may be present within the flood zones. This basemap was found on Arc Online and shows satellite and aerial imagery. It was last updated in November 2013 so all the structures present should be up-to-date with the strategies.

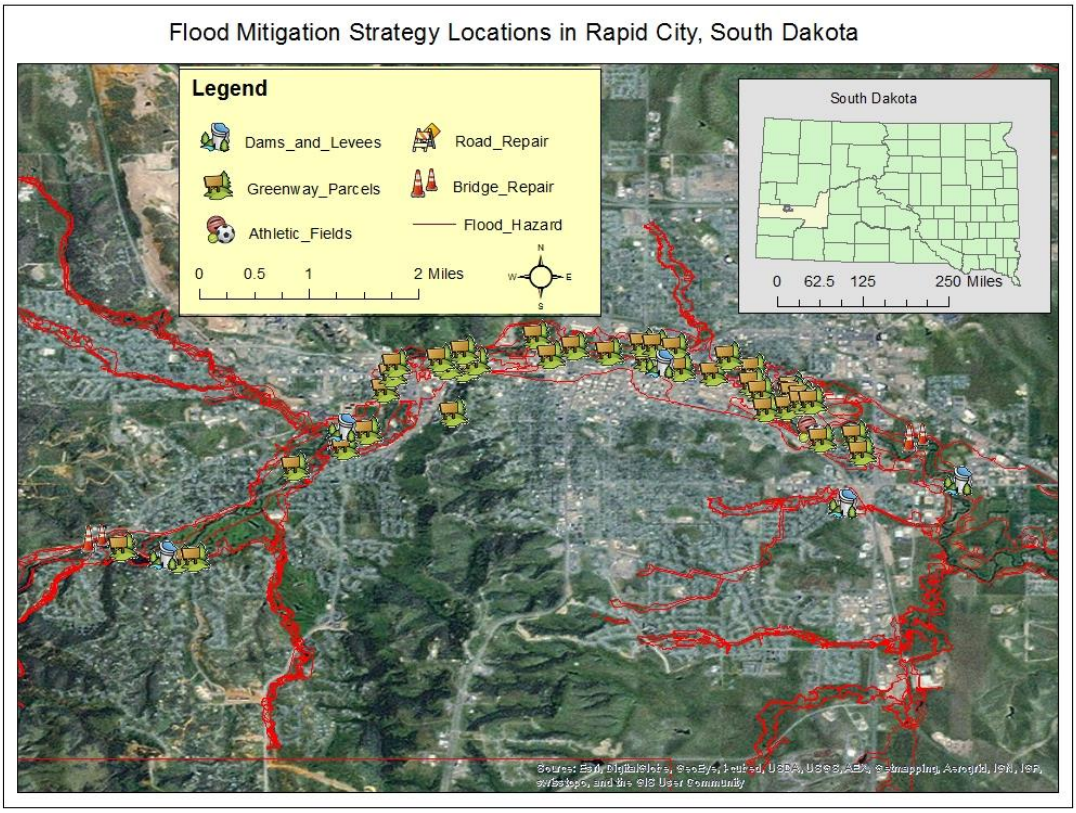

Figure 6: Overview Map 3 with Imagery Basemap

Figure 7 shows the flood mitigation strategies, flood hazard zones and an imagery basemap. The orange arrows represent areas where residential can be found within the flood zones. The purple area is an elementary school is located within the flood zones.

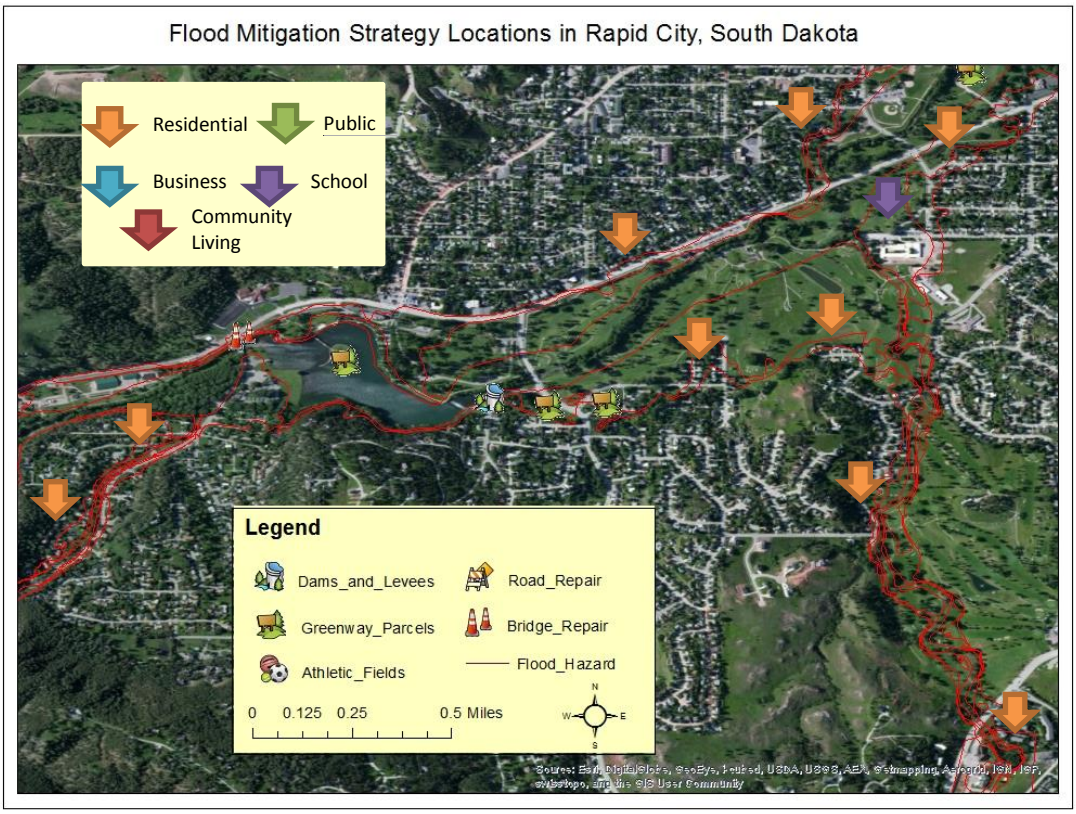

Figure 7: Area Map 1: West Rapid City

Figure 8 shows the flood mitigation strategies and an imagery basemap. The red arrow in this map is a senior living center and is located within the flood zone. The orange arrow is residential, the blue arrows are large shopping centers, the purple arrow is the high school, and the green arrow is the civic center. All of these arrows show infrastructure that is in the flood zones.

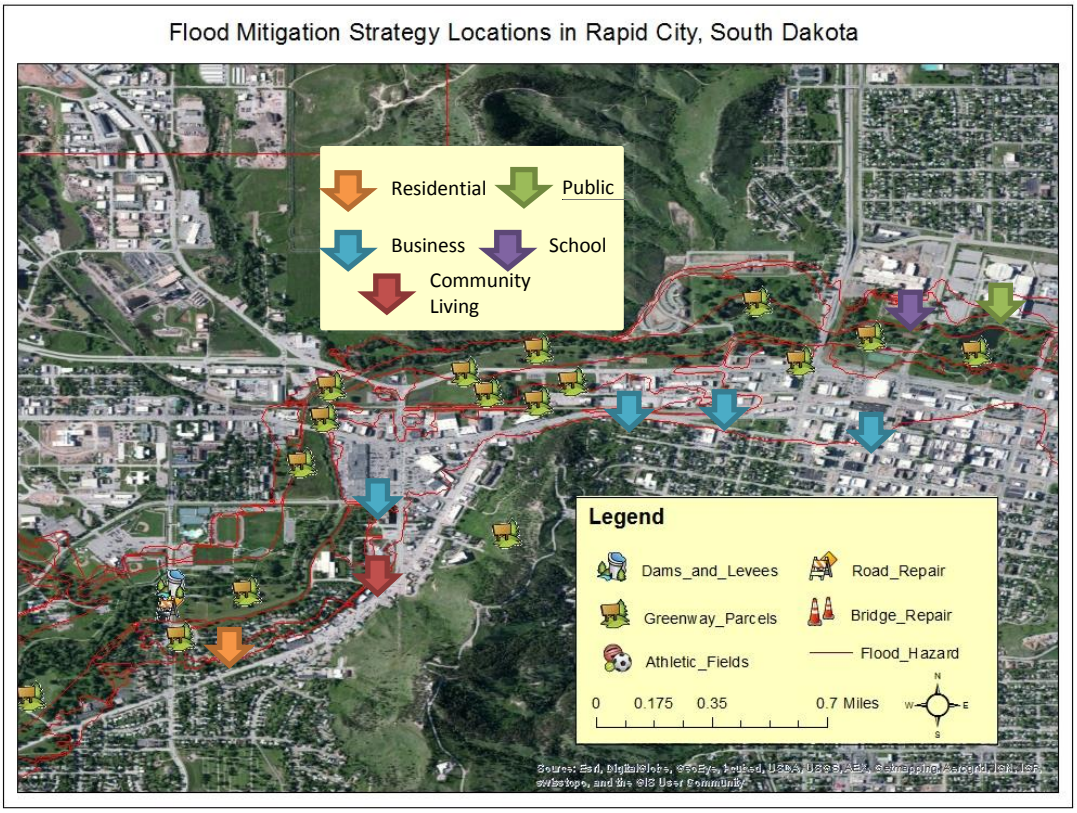

Figure 8: Area Map 2: West Central Rapid City

Figure 9 shows the flood mitigation strategies and an imagery basemap. The orange arrows are residential, the blue are businesses including Dakota Mill and Grain and Dakota Utilities, the green arrows are public spaces such as the fairgrounds, ice arena, and Star of the West Sports Complex, and the purple arrow is the South Dakota School of Mines and Technology. All these arrows are within the flood zones.

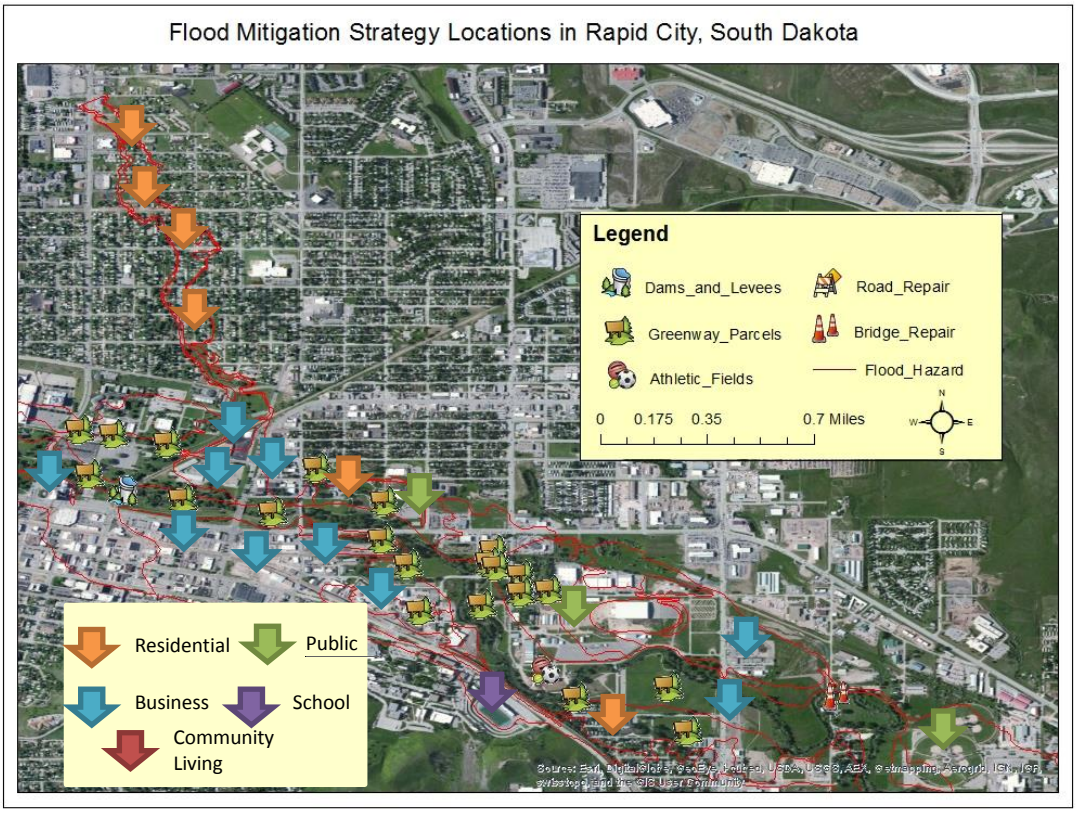

Figure 9: Area Map 3: East Central Rapid City

Figure 10 is the eastern part of Rapid City. This area is close to the edge of the Rapid City boundary. The orange areas are residential areas that are within the flood zones.

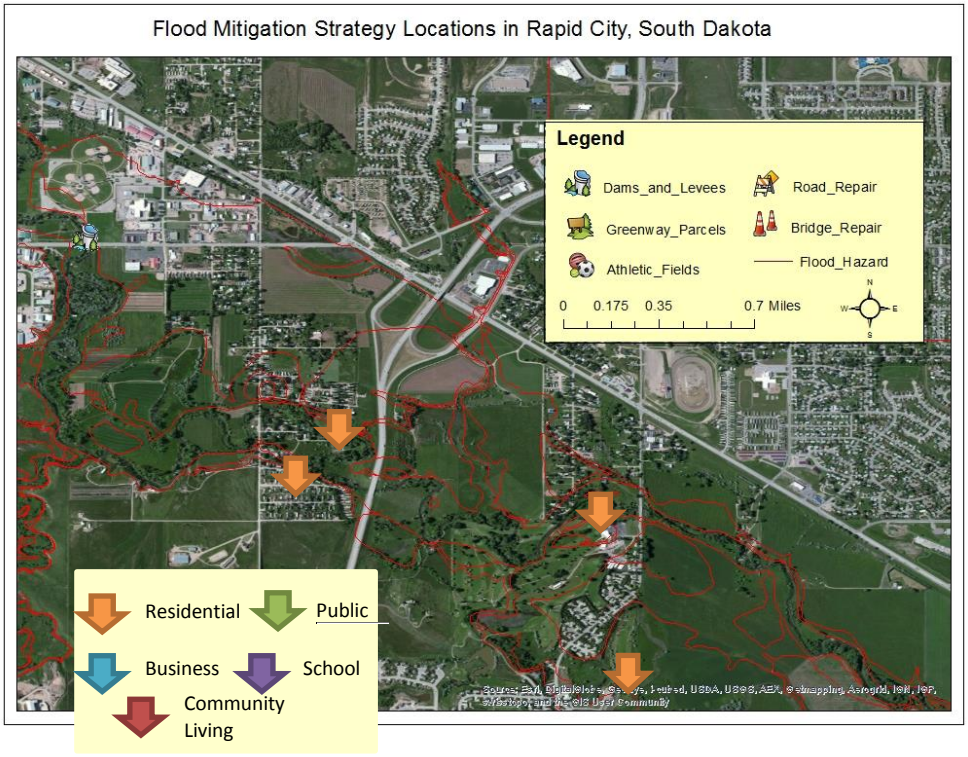

Figure 10: Area Map 4: East Rapid City

Table 3 shows the number of strategies that are structurally based and those that are non-structural or more ecologically based. From the strategies collected in this research, it appears Rapid City has implemented more non-structural mitigation strategies than structural.

Table 3: Non-Structural and Structural Strategy Type

Type of strategy	**Structural**	**Non-Structural**	**# of strategies**
Field		X	1
Greenway		X	40
Bridge repair	X		3
Dams and levees	X		6
Road repair	X		1
Total	10	41	**51**

Stakeholder Interviews

Question 2: What are the stakeholder perceptions of flood mitigation strategies in the community?

Goals addressed: Interview salient stakeholders to help understand the perception of preparedness in current mitigation strategies

Methods Used: Stakeholder interviews, Atlas TI coding software

Results:

Stakeholder interviews were transcribed during the interview process. The interviews were then typed and inputted into the Atlas TI software. Codes were created (Figure 11) for specific parts of each question and these were used for each interview. These codes and the responses can be found in the tables below.

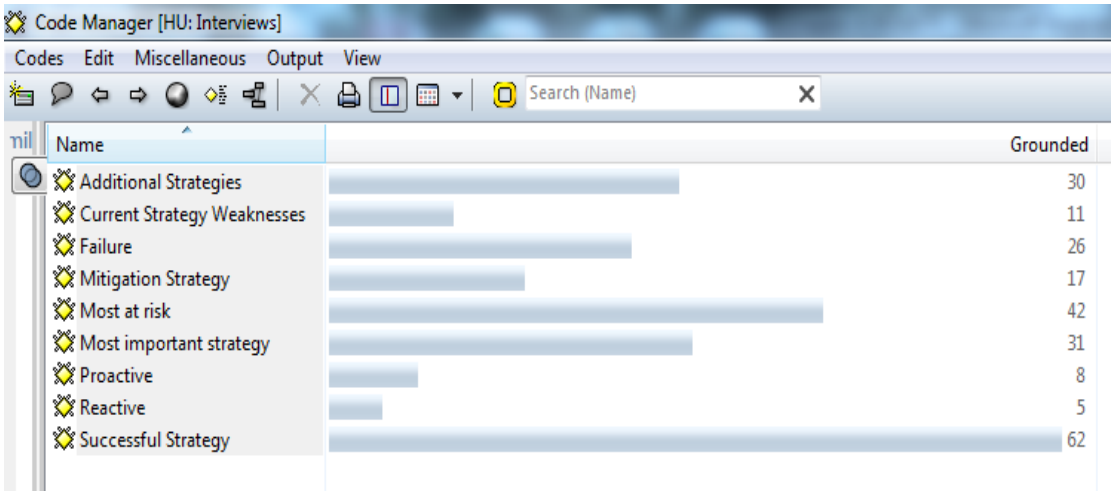

Figure 11: Codes created in Atlas TI to code interview responses

The first interview question asked stakeholders what they viewed as the most important mitigation strategy in Rapid City. There were 30 answers coded throughout the 13 interviews.

Table 4 shows the interview responses regarding the most common important mitigation strategy in Rapid City. The most common response was evacuating the floodplain with 12 coded responses. The greenway was the second most common answer with 5 coded responses and ordinance was third with 4 coded responses.

Table 4: Question 1 coded responses

Question 1	
Most important mitigation strategy	
greenway	5
flood maps	1
evacuate floodplain	12
ordinances	4
construction regulations	1
levee system	2
CRS rating	1
land use development	3
warning system	1
Total	**30**

Question 2 asked about past successful strategies and strategies that were failures. Additionally, the question implored whether stakeholders thought strategies were more proactive or reactive. For past mitigation successes, there were 53 coded responses. For past mitigation failures, there were 17 coded responses and for the proactive versus reactive questions there were 13 responses. These tables can be seen below.

Table 5 shows interview responses to past mitigation strategy successes in Rapid City. The most common response was rain gauges and sensors with 10 coded responses followed by the greenway with 8 coded responses. Additionally, the third and fourth most

common response was better communication capabilities with 7 responses and flood warning system with 6 coded responses.

Table 5: Past mitigation successes coded responses

Question 2	
Past mitigation successes	
Greenway	8
flood warning system	6
rain gauges and sensors	10
better communication capabilities	7
keeping people and development off floodplain	5
40 year anniversary event/education	4
NFIP	3
CRS	3
Regulations	3
levees and dams	2
FIRM maps kept up-to-date	1
paleo flood study	1
Total	**53**

Table 6 shows interview response to past mitigation strategy failures in Rapid City. The most common response was pre-1972 risk perception with 5 coded responses. The second most common response was restroom structure on the floodplain with 3 coded responses. Finally, with 2 coded responses each, a bridge that only allows a 25 year flood underneath and heavy reliance on structural flood control were the third most common responses.

Table 6: Past mitigation failures coded responses

Question 2	
Past mitigation failures	
pre 1972 risk perception	5
no good way to clear floodplain rapidly	1
Rapid City has done a good job, county has not	1
heavy reliance on structural flood control	2
mobile homes near rapid creek	1
restroom structure on floodplain	3
bridge only allows 25 year flood	2
public does not understand 500 year flood	1
pressure of encroachment	1
Total	**17**

Table 7 shows that 8 coded responses were that Rapid City uses proactive mitigation strategies and 5 coded responses were that Rapid City uses reactive mitigation strategies.

Table 7: Proactive or reactive coded responses

Question 2	
Proactive	8
Reactive	5
Total	**13**

Question 3 asked about additional strategies that need to be implemented or weaknesses in current strategies that need to be addressed. For additional strategies, there were 23 coded responses and for weaknesses there were 10 coded response. These responses can be found in the tables below.

Table 8 shows the coded responses to the first part of the third question relating to additional strategies Rapid City needs to implement. The most common coded response was education with 8 coded responses. Second most common response was shut down roads and

bridges in flood event with 4 coded responses. Third most common response was early warning system with 3 coded responses.

Table 8: Additional strategies coded responses

Question 3	
Additional Strategies	
redefine 100 and 500 year floodplain	1
zoning to not allow high density housing in floodplain	1
shut down roads and bridges in flood event	4
everyone adjacent to rapid creek should evacuate	1
Education	8
early warnings	3
extend greenway	1
more levees	1
diversify mitigation efforts	1
new model of extent of flooding	1
markers of high water level around city	1
Total	**23**

Table 9 shows the coded responses for the second part of question 3 relating to the weaknesses in current mitigation strategies. The three most common responses were education is lacking, individual preparedness is weak, and enforcement of floodplain ordinances needs to be better each with 2 coded responses.

Table 9: Weaknesses in strategies coded responses

Question 3	
Weaknesses in strategies	
county not doing well	1
education is lacking	2
more mitigation with more money	1
individual preparedness	2
no climate adaptation working group in Rapid City	1
enforce floodplain ordinances better	2
review emergency preparedness plans	1
Total	**10**

Question 4 asked stakeholders who or what they thought would be most at risk if another 1972 magnitude flood were to occur in Rapid City. There were 34 coded responses for this question. The coded responses to this question can be found in the table below.

Table 10 shows the coded responses to the question of whom or what is most at risk if another large flood were to occur in Rapid City. The most common coded response was businesses/infrastructure that are still in existence on the floodplain with 13 coded responses. Next, with 5 coded responses was people driving during a flood and homes in the floodplain with 4 coded responses.

Table 10: Whom or what is most at risk coded responses

Question 4	
Who or what is most at risk?	
surrounding areas	3
people watching the flood waters rise	2
people driving during a flood	5
businesses/infrastructure on floodplain	13
water treatment plant	1
tourists	2
individuals	2
homes in floodplain	4
street flooding	1
dam failure	1
Total	**34**

Lastly, other mitigation strategies that were noted throughout the interviews that were not specifically related to the answer to any question were coded and put into a table. There were 14 mitigation strategies coded and they can be seen in the tables below.

Table 11shows the coded responses of other mitigation strategies that were found within the interviews that did not relate to a question. The most common coded response was the remembrance events and education that occurs in the community with 6 coded responses.

Table 11: Other mitigation strategies noted in interviews

Other mitigation strategies noted	
property buyouts	1
high density housing away from creek	1
remove people from sleeping on floodplain	1
fast clearing of floodplain	1
weather alert systems	1
no rebuilding on floodplain	1
building restrictions	1
rebuild to regulations	1
remembrance and education	6
Total	**14**

Climate Change Projections

Question 3: What will the climate change impacts be on flooding in this community?

Goals addressed: Explore the extent to which climate change will impact flooding in the community

Methods Used: Review of climate change projections from IPCC and USGCRP and flood frequency on Rapid Creek.

Results:

The frequency of past flooding events was determined through research into the past flood events along Rapid Creek. These were put into a table and divided into ten year increments. Next, climate change projections were explored to determine if the magnitude of flooding is projected to increase in the region.

Figure 12 shows the flood frequency of Rapid Creek. It is broken up into ten year increments to show whether the frequency of flooding is increasing. 2001-2010 has the highest amount of floods with four in that time frame.

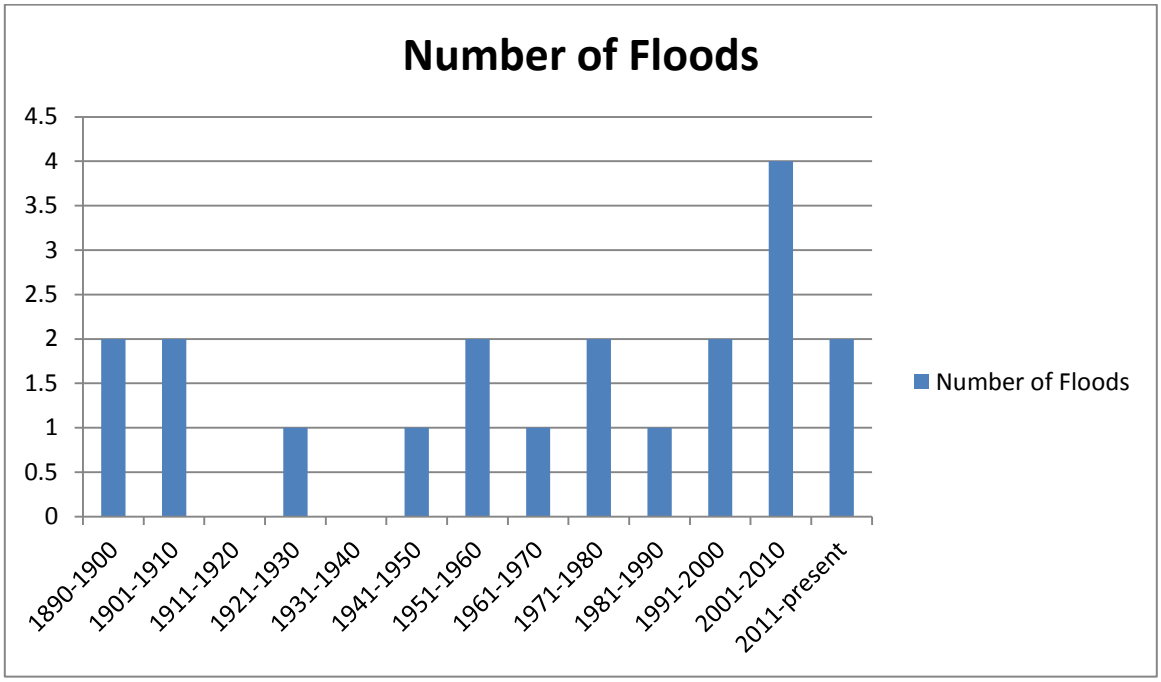

Figure 12: Flood frequency along Rapid Creek in Rapid City

The next figures show information from the USGCRP 2013 draft report on climate projections for the Great Plains region.

Figure 13 above shows the annual temperature and precipitation in the Great Plains region. For South Dakota, and in particular the southwestern corner, the annual precipitation will be 10-17 or 17-24 inches.

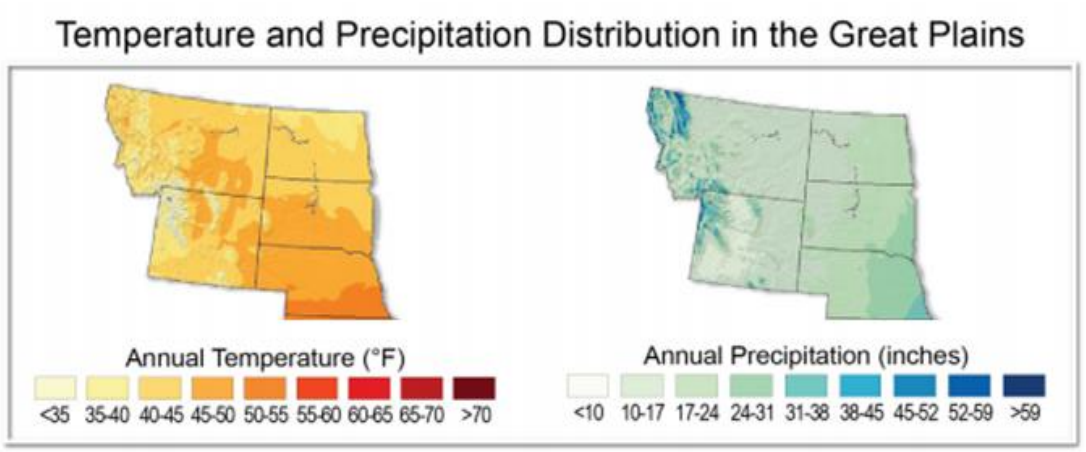

Figure 13: Annual Temperature and Precipitation in the Great Plains (USGCRP, 2013)

Figure 14 shows the change in the number of dry days in the Great Plains region. For the southwestern part of South Dakota, there will be 6 to 8 less dry days which means more wet days throughout the year.

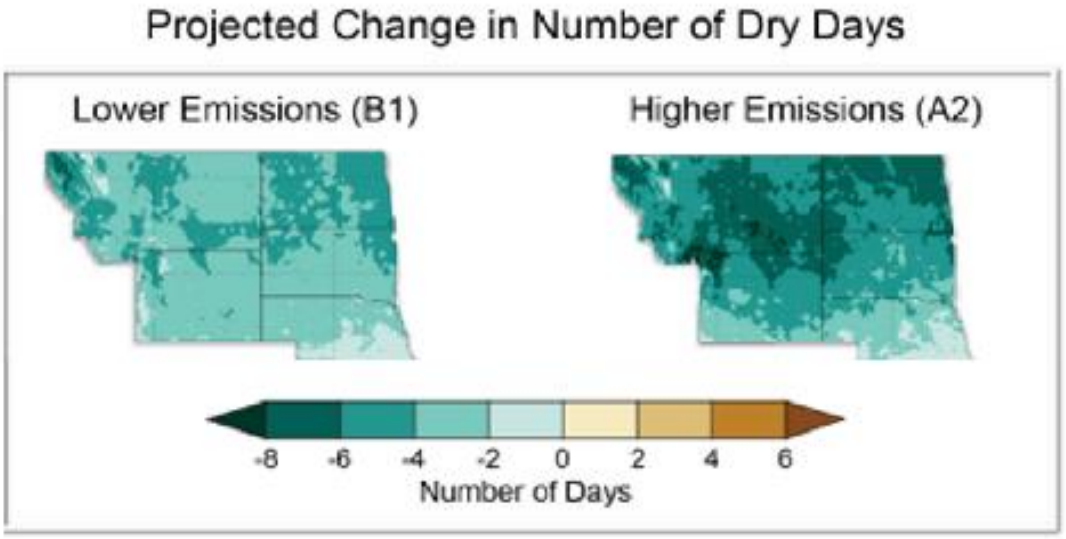

Figure 14: Projected change in number of dry days in the Great Plains region (USGCRP, 2013)

Future predictions in this region show (USGCRP, 2013):

- Number of days with heavy precipitation is expected to increase by mid-century
- Days with little or no precipitation will be less common, up to five fewer days
- Warmer winters mean more rain falling than snow and snow melt beginning sooner
- Trend towards increased precipitation by the end of the century

The following figures and paragraphs will detail information found in the IPCC 2012 report. This information will detail climate projections for North America.

From 1900 to 1994, precipitation in the Great Plains increased by 10-20% as seen in Figure 15. In South Dakota for the time frame of 1900 to 1994, it can be seen that there were increases of 5, 10, and 20%. The area nearest to Rapid City appears to have increases of 10%.

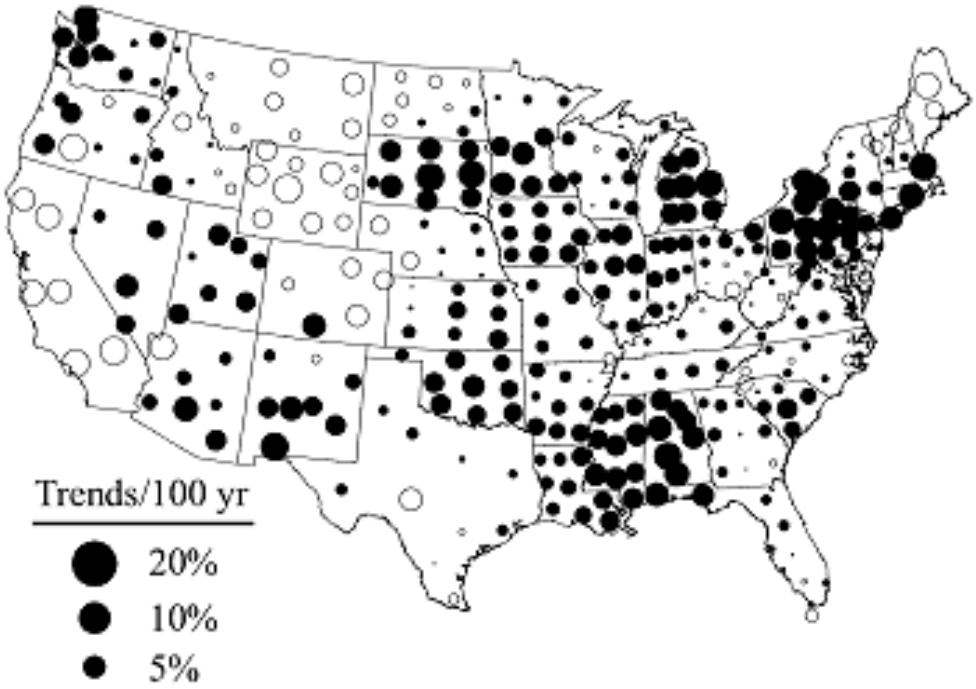

Figure 15: Precipitation trends in the United States (IPCC, 1994)

In the Climate Change 2007 Synthesis Report by IPCC, there was high agreement and much evidence that with the current climate change mitigation policies, emission of greenhouse gases will continue to grow over the next few decades.

Figure 16 shows the global precipitation changes for 2090-2099. It shows increases northern United States near the study area.

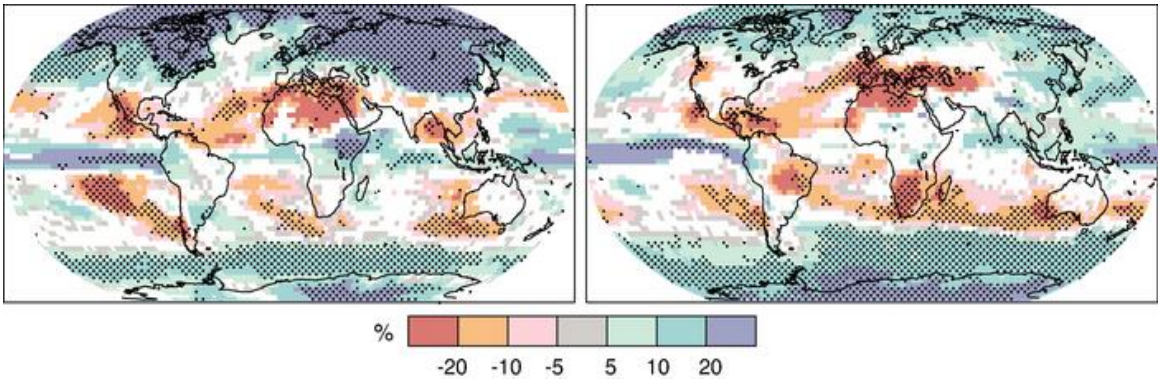

Figure 16: Projected patterns of precipitation changes for the period of 2090-2099 (IPCC, 2012)

Figure 17 shows the projected surface temperature global distribution for the years 2020-2029 and 2090-2099. Changes in precipitation and temperature will impact water runoff and it is projected with high confidence to increase by 10 to 40% by mid-century.

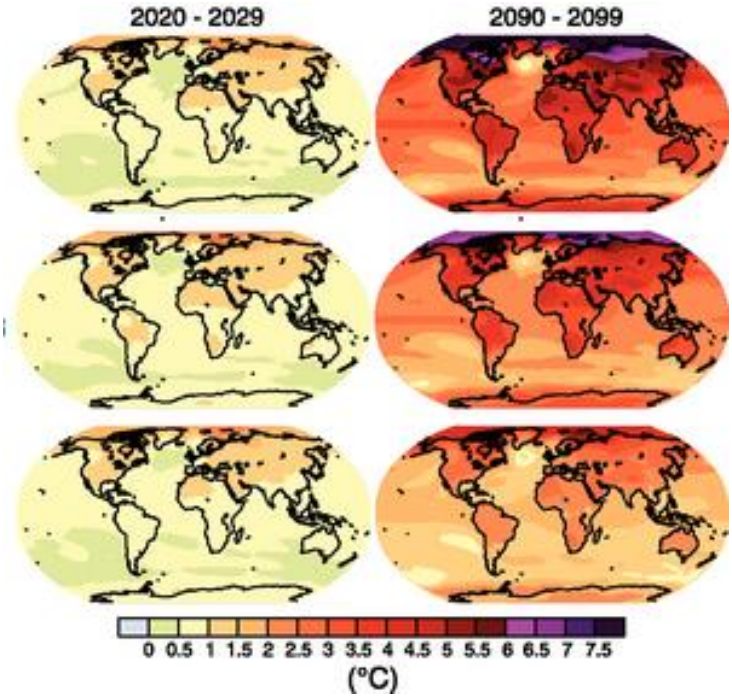

Figure 17: Projected Surface Temperatures changes for the early and late 21st century (IPCC, 2012)

Question 4: What are opportunities and constraints for enhancing current mitigation strategies?

Goals addressed: Determine additional strategies to improve community resiliency

Methods Used: Atlas TI results and GIS mapping results

Results:

Table 12 above shows four recommendations for Rapid City regarding flood mitigation strategies. These were identified from interview assessments and map results.

Table 12: Recommendation of additional strategies for Rapid City

Strategy Number	New Strategy	Atlas TI results	ArcGIS Results
1	Consider relocation of civic center	Stakeholders identified civic center as a hazard in the flood zones.	Civic center located within flood zones on maps
2	Creation of evacuation plans and signs	Stakeholders noted many people died in cars in 1972	Many roads are near or over the creek
3	More education of public	Stakeholders noted ways of improving public education	-
4	Determine if areas in flood zones noted with arrows are being mitigated efficiently	Stakeholders identified locations in the flood hazard zones that are not adequate	Locations noted on GIS maps where further investigation should be conducted

To summarize the results of the research, I found areas of concern that appear to little or no mitigation strategies in place. These include residential areas, businesses, and community centers. Stakeholder perceptions that were coded in Atlas TI showed that most interview participants thought evacuating the flood plain was the most important mitigation strategies in the community. The most common perception of successful strategies was the rain gauges and sensors and the most common perception of failed strategies was the pre-1972 risk perception of the community. Stakeholders found the strategies to be more proactive than reactive. For strategy weaknesses, lack of education, individual preparedness, and enforcement of floodplain ordinances were common perceptions. Stakeholders stated that education was an additional strategy to implement. The final stakeholder perception was that business and infrastructure would be the most at risk if another large flood were to hit this community. The climate change projections show an increase in precipitation and a rise in temperature which causes an earlier snow melt date.

Chapter 4: Discussion

Discussion

The 1972 Rapid Creek flood caused major impacts to the community physically, economically, and socially. The city has implemented numerous mitigation strategies to protect the community from a future flood of this magnitude. This research aimed to spatially explore the relationship of flood mitigation strategies from various community plans to the flood zones and the actual layout of the city. Stakeholder interviews were conducted to determine local experts' perceptions on the adequacy of current mitigation strategies.

This chapter explores in more detail the results of the research. It gives more detailed explanations of what each finding meant and recommendations for the city of Rapid City. Finally, there is a conclusion section that includes benefits of this research to society and the research community and various limitations that were faced when conducting the research.

Spatial distribution of strategies

The symbology was adjusted to more easily display flood strategies. This can be a useful tool for a planner who may be using this map in public meetings or to help push forward a future mitigation strategy. By making the map more visually appealing and easier to understand, users of the map can more easily identify areas where strategies are lacking and if there is the need to consider implementing more strategies in that location.

Research question 1 was assessed through exploring the spatial distribution of flood mitigation strategies in ArcGIS. Greenway parcels being set aside for parkland within the flood zones is an important strategy to address flood risks in the community. Based on a rudimentary review of current climate projections, flooding is predicted to increase in the state of South Dakota. Through a compilation of the community's plans and flood mitigation strategies found in those plans, many different departments are addressing flood risk and implementing projects to reduce that risk in the future.

The maps created containing mitigation strategies, flood zones, and a satellite imagery basemap, show areas that could be lacking in mitigation implementation. There are large schools, shopping centers, numerous neighborhoods, a civic center, and athletic fields in flood hazard zones. It is important for a community to identify these societal assets and this research aimed to present a spatial method to represent areas that need more focus in hazard mitigation. Further analysis would need to be conducted on each hot spot to determine if the surrounding mitigation strategies adequately address their flooding needs.

Based on the spatial relationship of the flood zones to numerous residential communities, Rapid City should ensure that the residents of each hazard area are aware of their flood risk and create some sort of education and outreach program to help residents better individually prepare. Additional research should be conducted to determine if residents in the exposed areas feel informed and prepared for a potential flood event. Three stakeholder interviews also noted that education of the community would be a much needed addition to current mitigation strategies. Rapid City's emergency management website has detailed information on how to prepare for a hazard event. These include creating family

plans, building a disaster kit, and getting involved in the community with training and neighborhood groups. On the first page of the website they have a community alerts feature that keeps the community up-to-date on important information regarding hazards. Future research could be done in each at risk neighborhood to assess their risk perception, preparedness level, and awareness of this website.

It would be helpful for each of the city departments to compile all their hazard mitigation strategies, similar to how this research compiled flood mitigation strategies. Departments could find common mitigation goals or projects and could collaborate to achieve better results. This could increase the funding available for a particular project. This comprehensive list would be helpful to show physical areas that are lacking in strategies or particular hazards that need more attention.

Campus plans discuss the athletic playfields and the county fairgrounds are on the 100 year floodplain and are not suitable for development. However, peak flash flood season is in the time that the county fair would occur as well as most athletic games would occur. There needs to be functional warning equipment at these locations as well as posted placards of what to do in the event of a flash flood.

FEMA's hazard mitigation plan requirement includes a heavy emphasis on flooding. It is important to diversify mitigation efforts to focus on all types of hazards that may impact a community. For instance, winter storm "Atlas" was an official disaster declaration in Rapid City on November 8, 2013. They also experience minor earthquakes, landslides, and hail events. Rapid City could conduct a similar project to this research for each hazard they face.

From this assessment of current flood mitigation strategies, Rapid City has implemented numerous strategies to keep people and infrastructure off of the floodplain. There are still major structures in the flood zones that should be investigated to determine their risk level. If it is found that those structures have adequate mitigation, Rapid City is properly mitigating for the contemporary flood risk. However, they are not addressing the future flood risk with climate change impacts that may increase the frequency and magnitude of flood events in the area.

Stakeholder interviews

Stakeholder interviews were conducted with various members of the Rapid City community that had experience with flooding in the area. These were conducted both over the phone, in person, and one was sent via email. The questions asked were aimed at determining the perceptions of the adequacy of flood mitigation strategies within Rapid City. Atlas TI software was used to analyze the interview transcriptions and made it easier to compare the interviews for common answers to the questions. A few of the answers given to questions relating to weaknesses in strategies were also weaknesses I identified when exploring the mitigation strategies in place. This includes the presence of various infrastructures in the flood zones. Some of these answers that coincided with arrows I placed on the maps I created in GIS were the civic center, a bank, the fairgrounds, and the grain elevator. All of these structures are in the flood zones and could be at risk if a flood were to enter Rapid City at the same magnitude as the 1972 flood. Some stakeholders discussed how evacuation of the floodplain has been an important strategy for increasing resilience to a future flood; however there are some development pressures and structures

that have gone into the floodplain or have remained. Moser (1985) discusses that relocation and permanent evacuation of activities on the floodplain are beneficial to communities. However, this can be costly and communities should explore the economic benefits or costs that could occur by removing these structures (Moser, 1985). Johnson (1976) has conducted research using a cost/benefit analysis of permanent evacuation of the floodplain and federally subsidized flood insurance programs. This type of assessment could be useful to Rapid City to determine if it would be more beneficial for them to change their land uses or to simply allow the flood insurance program to cover any flood damage.

Some stakeholders said that there was an overreliance on structural flood controls such as Pactola Dam and the various levees around the city. Rahn (1991) states that overreliance on flood control structures causes people to have a false sense of security against a flood and may cause flood plain development to increase and regulations to become lax. Many stakeholders discussed how more education and outreach would be helpful to keep the new generations aware of the flood threat and understand that they need to keep development free of the flood zones or protected from flood waters through other mitigation efforts. With the current generation considerably removed from the 1972 flood, education and public awareness need to be constant and increasing as time progresses (Rahn, 1991).

Numerous stakeholders discussed the mitigation strategies that were put into place post- 1972. Among these included rain gauge systems upstream to allow for real time and accurate information on flood stage. One stakeholder suggested a real-time video be put into place on these gauges to allow citizens to understand the water levels and what levels are hazardous. An obelisk could be constructed to show the 1972 level and other smaller

flood levels to easily compare the present level with record levels. This will help with the education of citizens by allowing them to make their own decisions on when to evacuate. It could help to empower citizens to make decisions on what to do during a flood event and when to do it, possibly even before an official warning is sent out.

Another common element I observed when reviewing interview results was that there does not appear to be clear evacuation routes in the area. The emergency management website has information on how families should have routes planned out from their homes to higher grounds and there are orange hang tags that the city may place on their door if there is the threat of a hazard and what level of evacuation they are. However, there are not formalized routes specified. Also, in the event of a flash flood, I wonder how quickly the city could get those hang tags placed on the homes of citizens since flash flood occur in such a short time span. One recommendation I have for Rapid City is to consider marking roads and bridges so that in the case of an emergency, people know where to go and what roads or bridges to avoid. As stated by many stakeholders and literature I have read, many deaths in the 1972 flood were due to people entering their cars and driving to unsafe locations or being spectators, watching the event unfold (Carter et al, 2002). Carter et. al. (2002) reports that when flooding occurs in the Black Hills, damage is widespread along roads and bridges and highways experience closures from excessive water on the surface and mudslides (Carter et al, 2002).

These types of fatalities could be eliminated or reduced if proper signage were placed on roads and bridges that would be a threat during a flash flood in the future. This is an inexpensive strategy that could have wide spread success and support from the community. It is important that these signs are easy to comprehend by motorists. On

expressways, it is important to show which route to take in the event of an evacuation (Liu, 2011). This is especially important for Rapid City since there is a major interstate running through the city that may be occupied by drivers in the event of a flash flood. There could be beacons placed above signs on the shoulder lanes that could be used during an evacuation so that motorists understand that usage is allowed during an evacuation. This could be up all the time with additional signage saying that it is only to be used in emergency situations or the sign could be folded and opened only during emergency events. Flashing signage could also be used in this capacity to give additional information regarding shelter locations, route information, or areas to avoid (Liu, 2011).

During the summer months, Rapid City boasts upwards of 2.7 million tourists. There are about 4.400 guestrooms in the area (Black Hills Visitor, 2013). Hotel occupancy in the Black Hills, and Badlands region saw an increase form 59.9% in 2011 to 64.4% in 2012 (Annual Report, 2012). This poses another problem for the community since most tourists arrive by car, motorcycle, or RV. Campgrounds are the busiest in August for the Sturgis Bike Rally, and also have high visitor rates in September (Meyer, 2010). Both of these times fall within the peak flood season. With most flood events occurring between April and October, the population in the area is increased significantly. Planners and emergency managers need to realize that theses tourists are not aware of their evacuation procedures or routes and they should be clearly marked along the main highway corridors for out of town guests to understand. An accurate and reliable warning system should also be in place in case of a loss of power to the community. A flood event could knock out cable, radio, and cell phone receptions, which are the main sources of warning systems. Generators could be placed in areas where main sources of power exist. Hotels in the area

should be up-to-date on evacuation plans and should have information readily available for guests in the event of a flash flood. Laminated pamphlets could be put in each hotel room or given to visitors that are in the area during the flooding season. This is an inexpensive way to warn visitors and increase their awareness of the potential for a flash flood during their visit.

The Black Hills Visitor website has a comprehensive history of the 1972 flood detailing the events of the day of the flood, information about the museum display about the flood, and links to the library that has information on the flood. However, it does not talk about the potential for a flood like this to happen again. I think they should include a section on this webpage for what to do if you find yourself in the midst of a flood while on vacation. Since visitors to Rapid City come to this site for information about Rapid City, it would be useful to have emergency information or at least a link to the Rapid City Emergency Management site somewhere on the webpage.

The Rapid City Emergency Management website has useful information regarding what to do in a natural disaster and how to prepare whether you live in the area or are visiting on vacation. They also have a community information section that says to make a plan for disasters even when you are on vacation. They have a map visitors can download that has general tips, weather watches and warnings, evacuation tips, information on summer storms, and detailed maps of roads and surrounding cities. I think a link to this website should be included on all tourism related sites. Additionally, the National Weather Service for Rapid City, South Dakota has a website that has links to watches and warnings and other salient information for a flash flood event. I think a link to this website should be also included on all tourist sites.

Based on these interview results, the stakeholders perceive that Rapid City has implemented important and successful mitigation strategies in place, but there are areas that they could improve if give more resources.

Climate Change Implications

The assessment of flooding frequency on Rapid Creek yielded the result that based on the last three time frames, 1991-2000, 2001-2010, and 2011 to the present, they appear to show an increase in flooding frequency. 1991-2000 had two floods, 2001-2010 has four floods, which was the highest in any ten year increment, and 2011 to the present has already had two floods seven years still left to go in this time frame. The frequency in the most recent time frame will most likely be up to the previous frequency or even surpass it.

Research in the Rapid City area has been conducted by the USGS to assess the paleofloods in the area. Paleofloods can be defined as a past or ancient flood that occurred before recorded history or before instrumental recording methods were used (Baker, 2008). The peak flows during the 1972 flood are considered outliers from records dating back to the early 1900s. However, USGS assessed Rapid Creek back 2,000 years using geologic assessment methods and found that floods as large as or larger than the 1972 flood have impacted this area (Harden et. al., 2011).

With predictions stating that there will be an increase in precipitation in the future and the increase of droughts, the conditions assume that there will be increased flooding frequency and magnitude. Based upon the USGS literature, they predict that since paleofloods have been significantly larger than the 1972 flood, there are most likely going to be even bigger floods in the future (Harden et al, 2011).

USGCRP shows increases in precipitation in the Great Plains region which will bring about more flooding events. The number of wet days per year is also projected to increase by six to eight days a year. Rapid City should begin planning for these increases in precipitation and wet days to understand what areas are at risk and where more mitigation strategies should be implemented.

The Intergovernmental Panel on Climate Change (IPCC) discusses how changes in the climate will create issues relating to water. Changes in precipitation could exacerbate current flooding events causing present mitigation techniques to be ineffective. Reports showed that precipitation in South Dakota increased by 10-20% in the time period of 1900 to 1994. Projections show increased precipitation in the northern United States and this could create more flood events in Rapid City.

By looking at two different sources on climate change projections, it shows that they are in agreement on the fact that precipitation is projected to increase for the future in the Great Plains region. It is important for Rapid City to understand this and potentially take action to reduce greenhouse gas emission and maybe create a climate adaptation plan for the city. One stakeholder noted that the state of South Dakota is creating a climate adaptation working group and that Rapid City could benefit from participating or creating a working group for the Rapid City area.

Rapid City already has areas that are of concern for current flood zones and if the precipitation events are increased, it will create a larger flood zone and more infrastructures could be at risk for a flood event. Rapid City should begin reassessing the areas surrounding the flood zones and determine the best way to prepare those areas for the impacts of climate change.

Additional Strategies

Recommendation Strategy 1: Consider relocation of civic center

Relocation of the civic center was identified in both the interviews and on the map as at risk of flooding. It would be a beneficial strategy for Rapid City to consider relocation of this structure in order to reduce the vulnerability of that structure to flooding. Because of the size of the structure, it could be used during a disaster as a shelter location. However, if it received flood damage, it will be deemed unsafe and will not be able to be used for this type of purpose.

Recommendation Strategy 2: Creation of evacuation plans and signs

Evacuation routes are important in flash flood situations because water flows through a city at rapid speeds. Since Rapid Creek runs close to major roads, bridges and the highway, it is important for Rapid City to have an easily understood evacuation route. They have done significant outreach to address this issue through their emergency management website, but with tourists unaware of these websites, it is important to have signage along hazardous roads to allow for quick road closure and alternate route directions.

Recommendation Strategy 3: More education of public

As the time between the present and the Rapid Creek flood of 1972 continues to lengthen, it is important to keep the community aware of the continued risk of another flood of this magnitude. Rapid City has done a good job thus far with the exhibit in the Journey Museum in town, 40 year anniversary commemorative event last year in 2012, signs on the greenway depicting what happened during the flood and information on websites about the

flood. It is important to keep these education outlets open and continuing as time progresses. One way to continue education is to place more flood level signs to show how high the water was in 1972 on the greenway and other places that were inundated.

Stakeholders discussed empowering local citizens to make their own decisions regarding when to evacuate by placing real-time video at major stream gauges that show an obelisk of where the water level presently is, where hazard levels are and where the water level was in 1972. By giving citizens the tools necessary to assess flood levels, it creates a more informed community and gives them the opportunity to make their own decisions regarding whether or not to evacuate.

Recommendation Strategy 4: Determine if areas in flood zones noted with arrows are being mitigated efficiently

It is important for Rapid City to assess further locations noted with arrows on the GIS maps to determine if they have enough mitigation to protect them or should be considered for additional mitigation efforts or relocation out of the flood zones

For example there are many bridges that go over the creek. Stakeholders noted that one bridge is only at the 25 year flood level and would clog and cause major issues if a 500 or even 100 year flood were to come through. It would be important to have the department of transportation take another look at this bridge and determine if they should consider altering it to make it less dangerous in a flood event.

There are many opportunities and constraints to implementing various hazard mitigation strategies. As one stakeholder that was interviewed noted, there are many more

strategies that Rapid City could be implementing if there was more funding available. One way to increase funding available is more collaboration between city departments.

One constraint that could be easily overcome is to have more collaboration between city departments. There is often a tendency for many different departments to be working on similar strategy implementations. A great result of this research was that many different departments in Rapid City are working on mitigation strategies for flooding issues. This shows that flooding is a priority in the community and that they take the community risk seriously. It would be helpful in their next comprehensive plan or post-disaster mitigation plan if they had a resource available for all departments to collaborate on projects. Whether that be with funding, sharing of projects, or just sharing of information regarding current projects. A website could be created for the departments to update with current strategy projects and where they are in the process. For example, the emergency management department has a project relating to transportation, the department of transportation can give input into techniques to use or examples of where they have had success.

By having a location where departments are collaborating on projects, it will create better mitigation efforts and more awareness across the city with regards to what is happening. I think the emergency management department should take the lead on this since they are the main department in charge of emergency situations. There is a shift towards a more inclusive hazard mitigation and comprehensive planning process (Schwab, 2011). It seems that the next step is towards more collaboration between all departments. It is difficult to collaborate on everything going on in each department, but with regards to

mitigation strategy planning and implementation, it could be relatively easy to create a on online location where all departments can input their respective projects and plans.

Conclusion

Rapid City has improved greatly since the devastating flood of 1972. They have evacuated parts of the floodplain, created a greenway park system along the creek to reduce the amount of housing and infrastructure in the flood zone area, and have created levee and bridge systems to mitigate against future floods. While they are very proactive about their mitigation efforts, there are always areas in which to improve, and with the threat of increased frequency and magnitude of flood events with the impacts of climate change, the hazard zones may change. This research was an assessment of current flood mitigation strategies in the city as well as expert stakeholder perceptions on those strategies. The primary recommendation that comes as a result of this research is to further investigate where flood mitigation strategies are lacking and determine if those areas need additional mitigation efforts.

Planners play a key role in hazard mitigation and could use this work to understand the best and most efficient ways to assess community mitigation strategies. By compiling each community plan and assessing them for inclusion of flood strategies, planners and key decision makers can comprehensively understand the mitigation efforts in the community. By interviewing stakeholders that play a role in hazard mitigation planning, planners can understand what each stakeholder thinks the strengths and weaknesses are of the current strategies.

Benefits of research

This research can help the city of Rapid City, South Dakota better plan for and mitigate against the effects of increased flood potential caused by climate change. By spatially exploring community mitigation strategies, interviewing salient stakeholders, and reviewing climate change projections and historical flood records, changes or additions to current flood mitigation strategies can be established to better prepare the city. This is a first step towards improving the community's resilience and helping to create a sustainable city in the face of future flood risk.

Changes to current mitigation strategies can strengthen plans in place and reduce the cost of creating new strategies. By suggesting additional strategies based on stakeholder interviews and plan assessments, a more comprehensive view of the community risk can be seen and better plans created.

With stronger, more clear, flood mitigation strategies, Rapid City can ensure that there is a reduction or elimination of loss of life and a reduction in the damage done to property and infrastructure if another 1972 magnitude or higher flood were to come through this community.

Limitations of research

Due to the distance to the study site, second round interviews as well as focus groups were not completed for this study like initially planned. However, researchers determined that the information gathered in the first round interviews was more than adequate at answering the questions proposed by the interview section of this research.

Rapid City is in the process of updating their comprehensive plan for the first time since 1980. This plan was not completed when this research was conducted and an additional assessment of that new plan would be needed to determine any additional strategies in place. The flood plain maps were also updated in the summer of 2013 and were not easy to locate in a GIS format. I was in contact with a FEMA employee who directed me to a site that contained a flood hazard zone layer that was used to show areas of concern.

Due to the non-spatial nature of some mitigation strategies, many were left out of the maps. Their X and Y coordinates could not be determined from context clues in the strategy or further research into the particular project.

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